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ELEMENTS
OF
MINERALOGY,
CRYSTALLOGRAPHY
AND
BLOWPIPE ANALYSIS,
FROM A PRACTICAL STANDPOINT.
INCLUDING

BY
ALFRED J. MOSES, E.M., Ph.D.,
Adjunct Professor of Mineralogy, Columbia College, School of Mines, New York City.

AND
CHARLES LATHROP PARSONS, B.S.,
Professor of General and Analytical Chemistry, New Hampshire College, Durham, N. H.

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PREFACE.

A KNOWLEDGE of the common minerals is essential to the mining engineer, metallurgist, geologist and chemist, and is of fundamental importance to the student of geology. The study of the inorganic kingdom of nature has, moreover, an educational value that is not always recognized.

Minerals have their own peculiar forms and structure which are none the less interesting and instructive because they are not endowed with vitality, and crystals illustrate better, perhaps, than anything else the absolute constancy and invariability of nature's laws.

In many of our educational institutions, however, mineralogy is made merely an optional study, elected, perhaps, by only a few students or in schools of a more technical character, although frequently a part of the required course, it is crowded into such a brief space of time that often but a faint memory of some striking or beautiful specimens is left upon the student's mind.

When time is limited, descriptions of rare minerals, complex crystals, microscopic structure and all the great mass of detail belonging to the science of mineralogy cumber and obscure those facts which, to the professional man and to the student in a technical or scientific school, are of paramount importance. What is the mineral? What use has it? How do you recognize it? If you can not recognize it, how can you determine it by simple and rapid tests?

The answers to these questions and to others like them we have endeavored to here present in a clear, concise manner, together with that amount of the strictly scientific detail and principles which is essential.
PREFACE.

In connection with any useful study of mineralogy, and preliminary to it, some instruction in crystallography and in blowpipe analysis must always be given. We have, therefore, included these subjects, but have labored to make them as simple as is consistent with accuracy, and have treated them with a direct reference to the work in hand. A knowledge of both is essential to a proper understanding of most minerals and is of the greatest service in their identification. We have also attempted to arrange the typography of the book in such a manner that the important characters may not be lost among less essential details, and so that, by regularity of position, they may be readily found.

If, in the short period too often allotted to the subject in our technical schools and colleges, this book is found to assist to a useful knowledge of mineralogy, we shall be satisfied; but, if in addition it should occasionally serve the professional man as a means of reference to the economic minerals with which he may have to deal, we shall be doubly repaid.
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PART I.

CRYSTALLOGRAPHY.

CHAPTER I.

GENERAL PRINCIPLES.

Substances which are definite chemical compounds or elements, whether natural or manufactured, frequently solidify in forms bounded by plane faces intersecting at salient angles. These forms are called crystals, and the description of these forms constitutes crystallography.

Crystalline Structure, of which distinct crystals are the most prominent evidence, is due to a regular arrangement of the component particles which appear to be similarly grouped along all parallel lines and in all parallel planes, so that the most minute grain receives the same internal structure as the mass.

This structure exists and can be studied in the absence of distinct crystals. For instance, solid masses will often break or cleave in certain directions parallel to planes yielding frequently polyhedral solids absolutely constant in angles, no matter how far the cleaving is continued or how small the resulting solids may be. It is also thoroughly proved that in glass or in other mixtures not definite chemical compounds, such properties as hardness, velocity of transmission of light, heat, or electricity, expansion from heat, elasticity, color, lustre, etc., are, generally speaking, alike in all directions and portions, or if unlike it is without any regularity of difference. In definite chemical solids, however, there is in most cases a marked difference, evidently due to a regular arrangement of the particles in straight lines and planes; for in any given substance the effect of the structure upon transmission of light, heat or electricity, upon hardness, elasticity, etc., is exactly the same in all parallel directions, but is not necessarily or even generally alike in directions not parallel.
CRYSTALLOGraphY.

The same substance may exist with and without crystalline structure. The simplest theory is that in the latter case the solidification was too rapid to permit a regular arrangement of the particles.

LAWS OF CRYSTALS.

The three great laws of crystals are:
1°. The Law of Constancy of Interfacial Angles.
2°. The Law of Symmetry.
3°. The Law of Simple Mathematical Ratio.

1°. The Law of Constancy* of Interfacial Angles.

The corresponding angles between faces of different crystals of the same substance are constant, however much the similar crystal faces may differ in development or the crystals differ in complexity.

Similar faces are not apt to be equally developed in real crystals, though for convenience, as will be explained later, equally developed ideal forms are made use of in study and delineation. In cubic crystal forms, the "cubes" are necessarily composed of six planes parallel to the planes of the mathematical cube; the angles between the planes are all right angles, but the planes may be equal or unequal in size. Similarly, in Fig. 1, the eight planes of the distorted form are each parallel to a plane of the enclosed octahedron, and adjacent planes are at 109° 28' 16'' to each other, just as in the ideal form.

Regularity of structure only requires constancy of direction and is not concerned with quantity. Crystal growth is by layers parallel to definite planes, and for many reasons, such as inequality of supply, the growth of similar planes may be unequal. If, however, the faces must retain parallelism to certain directions, the angles which they make with each other can never vary.

2°. The Law of Symmetry.

Before stating the law certain definitions are needed:

* Slight differences result from slight variations in composition or temperature at time of measurement.

This law is based on the observations of Nicolaus Steno in 1669, Romé de l’Isle in 1783, and proved beyond reasonable doubt by the vast series of accurate measurements now on record.
A solid is *symmetrical to a point* whenever every straight line through the point encounters at equal distances on each side of the point two corresponding points* of the solid.

A solid is *symmetrical to a plane* when every line perpendicular to the plane, and within the solid, connects corresponding points of the solid and is bisected by the plane.

The law may be stated as follows:

*The faces of all crystals are symmetrically grouped with reference to a central point, and usually also with reference to one or more definite planes of symmetry.*† *The degree of symmetry is the same for all complete crystal forms in which a given substance crystallizes.*

3°. **Law of Simple Mathematical Ratio.**

The bounding planes or faces of crystals are most easily considered and described by assuming the existence of "axes," lines passing through the centre of the crystal. Usually three axes, which are prominent lines of symmetry are selected. Their mutual inclinations will be constant in all crystals of the same substance.

The axial intercepts or co-ordinates of the different faces determine in space the position of the faces, and by proper formulas the angular relations between different faces can be deduced from the axial intercepts and *vice versa.*

Since, as stated on p. 2, the growth of similar planes may be unequal, but they must retain parallelism to certain directions, it follows that parallel planes need the same symbol. This is most simply obtained by stating the intercepts as a ratio; for instance, two planes cutting corresponding axes at distances $\frac{3}{2} : 1 : 2$ and at $1 : 2 : 4$ are parallel and are expressed by the same symbol $\frac{3}{2} : 1 : 2$.

The actual intercepts are therefore never considered, but simply the ratio they bear to each other; that is, parallel planes all receive the same symbol because the ratio of the axial intercepts is the same for all of them.

---

* For instance, the centres of similar edges or the intersections of similar lines, or the centres of similar faces or vertices of similar polyhedral angles.

† This law may be said to be based on de l'Isle's law: "Every face has a similar face parallel to it," and on Hally's law: "Similar parts are modified in the same manner, and all are modified at the same time."
The law may be stated as follows:*

In all crystals of the same chemical substance, if any face be taken as a unit and the axial intercepts of all other faces be expressed in terms of the corresponding intercepts of the unit face, the resulting expression will be a very simple one, involving only simple numbers, simple fractions or infinity (parallelism).

For instance, the chosen unit plane of sulphur crystals cuts the axes in distances relatively 0.81309 : 1 : 1.60339 expressed as $a : b : c$, the relative intercepts of another plane may be, for instance, $1.62618 : 1 : 3.71017$, which is then expressed as $2a : b : 3c$; but a plane with intercepts $1.734 : 1 : 6.275$ could not occur on crystals of sulphur because the ratios $\frac{1.734}{0.81309}$ and $\frac{6.275}{1.9039}$ between corresponding terms are not reducible to either simple or infinite values.

THE SIX CRYSTAL GROUPS OR SYSTEMS.

All complete crystals are symmetrical to a central point, and may be classified according to the number and kind of their planes of symmetry.†

Planes of symmetry are of two kinds, principal and secondary.

Principal Planes of Symmetry contain two or more equivalent lines or directions; that is, if the crystal is rotated about an axis normal to the plane of symmetry at its centre until these equivalent lines exchange positions,‡ the appearance of the crystal is in no way changed.

Secondary Planes of Symmetry do not contain any such equivalent lines or directions.

Starting with the lowest grade of symmetry, the groups are:

Triclinic.—Symmetrical only to a central point.

Monoclinic.—With one secondary plane of symmetry.

Orthorhombic.—With three secondary planes of symmetry.

Hexagonal.—With one principal plane of symmetry, and six secondary planes at 30° to each other and at right angles to the principal plane.

---

* This law is based on innumerable measurements. It is practically the equivalent of the law of Malus: "The position of planes may be assigned by numbers which bear some simple ratio to the relative lengths of the crystal axes."
† Partial forms will be considered under each system.
‡ For instance, in Figs. 11 to 14 a plane through any two of the axes is a principal plane of symmetry, and those axes are equivalent lines or directions.
GENERAL PRINCIPLES.

TETRAGONAL.—With one principal plane of symmetry, and four secondary planes at 45° to each other and at right angles to the principal plane.

ISOMETRIC.—With three principal planes of symmetry, at right angles to each other, and six secondary planes which bisect each of the angles between the principal planes.

Selection of Axes in Each System.

The selection is, in part, arbitrary. Examination of the crystal reveals the presence, or absence, of planes of symmetry; from these the position of the essential crystallographic axes result, preference being given:

First, to diametral lines, normal to principal planes of symmetry.

Second, to diametral lines, normal to secondary planes of symmetry.

Third, to diametral lines, arbitrarily chosen, but in a plane of symmetry.

When there is no plane of symmetry at all, the selection is entirely arbitrary, and the axes thus chosen may differ in position from those selected by some other observer. The selection of arbitrary axes, in conformity with some standard record, is easily accomplished by checking the position of recorded dihedral angles, etc.

As axes are always important diametral lines, they commonly terminate in important similar points, such as centres of edges or of faces, or the vertices of polyhedral angles.

In crystal models and in natural crystals, not too unequally developed, the axes can frequently be located by noting how many mathematically similar parts there are which can serve for terminations of axes: For instance, each axis requires an exactly similar opposite pair, and the pairs for interchangeable axes must again be exactly similar, while the pairs for dissimilar axes are necessarily dissimilar.

Interchangeable or Equivalent Axes.

As stated on page 4, “principal planes of symmetry contain two or more equivalent lines or directions,” that is, lines which bear exactly similar relations to the shape of the crystal, and are necessarily surrounded by the same number of planes placed in the same way. It is evident that such lines are exactly equivalent, or inter-
changeable as to shape and structure, because, around them the planes of the crystals are similarly grouped, with perfect equality in number and in angular position. For many reasons, the equality rarely extends to size.

**Forms.**

In each system a certain limited number of typical forms can occur. The term "form" has a limited technical meaning in crystallography, and is not necessarily a polyhedron, but frequently is only a pair of parallel planes. All planes of a form can be represented by the same symbol, because all cut the axes at the same relative distances; but the form does not necessarily include all the faces which possess this symbol. The term "form" is understood to imply that assemblage of planes possessing a common symbol, which is made necessary by the symmetry of the system to which the form belongs.

To illustrate: In the triclinic system, eight different planes may be represented by one symbol, such as $2a:b:c$, but the symmetry simply requires that each plane be accompanied by an opposite parallel plane. Hence two such planes constitute a "form."

**Half and Quarter Forms.**

In certain compounds, only complete forms occur; in others, however, crystal faces occur which correspond in position and in symbol to faces of complete forms, but, there has been an apparent regular suppression of one-half or three-quarters of the faces required by the symmetry of the system.

Hemihedral or tetartoehedral forms are due to differences in structure, and are only mathematically related to the corresponding complete forms. Substances on which they are developed always show other proofs of hemihedral and tetartoehedral structure.

In this book, important half and quarter forms will be described as if produced by the suppression of faces of the whole form with the same symbol. The more complete discussion would involve apparent complete forms really hemihedral, and apparent hemi-forms really tetartoehedral.

**Ideal Forms.**

From longer continued or more rapid growth in one direction than another, or from other causes, corresponding faces frequently
GENERAL PRINCIPLES.

vary in size on the same crystal. It is, however, more convenient to consider the mathematical cube or the prism, the right section of which is a regular hexagon, than the actual forms which occur. The ideal form may be said to be enclosed in the actual form, and, angle for angle, they will absolutely agree, and if each plane of the actual is moved in parallel to itself it will encounter and coincide with a plane of the ideal. In ideal forms, interchangeable axes are equal in length, while dissimilar axes are irrational multiples of each other, and never equal or even simply related.

Symbols.

The symbol of any crystallographic plane is usually some expression of the relation which exists between the co-ordinates of the plane. That is, the plane intersects the different axes at certain finite (or infinite when parallel) distances from the centre of the crystal, these distances, or some ratio derived from them, constitute the symbol of the plane.

The Symbols of Weiss

Some plane of the crystal, as A, B, C, Fig. 2, is chosen as a unit, or fundamental plane, its co-ordinates taken always in the fixed order corresponding to the directions O A, O B, and O C, are called respectively, a, b, and c, and the symbol of this unit plane is written $a:b:c$. Another plane, as R N M with co-ordinates O R, O N, and O M, is described by stating its co-ordinates as multiples of those of the unit plane. If $O R = \frac{1}{2} O A$, $O N = 2 O B$, and $O M = 1\frac{1}{2} O C$, the relation would be $\frac{1}{2} a : 2b : 1\frac{1}{2} c$, or reducing until one term is unity, $\frac{1}{2} a : b : \frac{1}{2} c$, or $a : 4b : 3c$, or, more generally, $a : nb : mc$, in which $m$ and $n$, called parameters, are, by Law 3, necessarily simple numbers, simple fractions, or infinite.

The Naumann and Dana Symbols.

These are simply contractions of the corresponding Weiss symbols.

The only changing components of the Weiss symbols are the parameters $(m, n, \text{ and } \infty)$, hence the fixed components $a : b : c$, may be omitted and understood, provided the parameters are written in a fixed order. In both Naumann and Dana, the coefficient (parameter) of the vertical axis is written first, the other parameter last.
Dana connects these with a hyphen, Naumann with a capital letter, P (pyramid), or O (octahedron). A Weiss symbol, $3a : b : 4c$, would be in Dana, $4 \cdot 3$, and in Naumann $4P3$, the $-$ being the sign of the short coordinate $a$ of the unit form.

The Miller Symbols.

Because all parallel planes cut the axes in the same relative distances, we can consider the unit plane to be moved into new positions, parallel to the first, without changing its symbol, and the co-ordinates of any other plane, $h k l$, Fig. 3, then become fractional parts of the unit co-ordinates; for instance, $O h = \frac{1}{2} O A$, $O k = \frac{1}{4} O B$, and $O l = \frac{1}{6} O C$.

If the plane $ABC$ is moved still further out, for instance six times as far, these values would become,

$$O h = \frac{1}{5} O A = \frac{1}{3} O A, \quad O k = \frac{1}{2} O B = \frac{1}{5} O B, \quad O l = \frac{1}{1} O C.$$

That is, whatever the fractions are, we may divide each by the least common multiple of the numerators—as, for instance, $\frac{3}{5}, \frac{3}{5}, \frac{5}{5}$ so divided yields $\frac{1}{5}, \frac{3}{5}, \frac{5}{5}$, which is simply to assume the unit plane moved six times as far from the centre, but parallel to its original position.

In Miller's Notation we assume the unit plane moved to such a position that the intercepts of any other plane, $h k l$, are fractional parts of the unit intercepts, with a constant unit numerator, as above explained, and we write as symbol of the plane the denominators in constant order. For instance, the plane $h k l$ would be $(9, 8, 12)$, and these numbers, 9, 8, 12, are called the indices of the plane.

When the symbol is enclosed in brackets, e.g., $\{ 4 3 2 \}$, it is understood to typify the form, but when in parentheses it signifies the individual face $(432)$.

Weiss parameters and Miller indices are essentially reciprocals of each other. For instance, a plane with indices $(4 3 2)$ means $\frac{1}{4} a : \frac{1}{3} b : \frac{1}{2} c$, and making $a$, for instance, unity, we have $a : \frac{3}{4} b : 2c$ as the Weiss symbol. Conversely, a plane with a symbol $5a : b : \frac{3}{2} c$ is first reduced to $a : \frac{1}{5} b : \frac{3}{2} c$; then, taking reciprocals, $(1 5 3)$ is the Miller symbol.
The Axes of the Six Systems.

The "axes," or axial cross, represents the relative axis length of some assumed unit and ideal form. Except in the isometric minerals, each mineral has its own characteristic axial cross.

**Isometric.**—Fig. 4 represents three interchangeable equal axes ($a$) at right angles to each other and each normal to a principal plane of symmetry.

**Tetragonal.**—Two equal and interchangeable axes ($a$) at $90^\circ$ to each other and one unequal, dissimilar axis, $c$, at right angles to the others. The axes $a$ lie in the principal plane of symmetry and $c$ is normal to this plane and conventionally is placed vertically.

Fig. 5 represents in projection the axes of the mineral ZIRCON, in which the planes of the common pyramid selected as a unit occur at such angles as to cut two axes at equal distances, $a$, from the centre, and the third axis at a distance, $c$, which is $0.64373 \times a$.

**Orthorhombic.**—Three unequal, not interchangeable axes at $90^\circ$ to each other. Each is normal to a secondary plane of symmetry.

Fig. 6 represents, in projection, the axes of the mineral BARITE, in which the planes of the chosen unit pyramid cut the three axes at relative distances, $\delta$, $a = 0.815 \times \delta$, and $c = 1.313 \times \delta$. 

---

**Figure 4**
- A diagram showing three equal axes ($a$) at right angles to each other.

**Figure 5**
- A diagram showing two equal axes ($a$) and one unequal axis ($c$) at right angles.

**Figure 6**
- A diagram showing three axes ($a$, $\delta$, $c$) with relative distances indicated.

---

**Figure 7**
- A diagram showing an isometric axial system.

**Figure 8**
- A diagram showing a tetragonal axial system.

**Figure 9**
- A diagram showing an orthorhombic axial system.
CRYSTALLOGRAPHY.

c is conventionally placed vertically, and \( \delta \) horizontally from left to right.

MONOCLINIC.—Three unequal, not interchangeable axes, two of which, \( a \) and \( c \), lie in the plane of symmetry at an angle \( \beta \) to each other. The third \( \delta \) is normal to the plane of symmetry, and therefore at 90° to both \( a \) and \( c \).

Conventionally, \( \delta \) is placed horizontally from right to left, \( c \) is placed vertically, and \( a \) sloping down from back to front.

Fig. 7 represents in projection the axes of pyroxene, in which the planes of the chosen unit occur at such angles that \( \beta = 74^\circ \), \( \gamma' = 90^\circ \), and the axes are cut at distances relatively \( \frac{a}{c} = 1.092 \times \frac{c}{c} \) and \( c = 3.89 \times \frac{c}{c} \).

TRICLINIC.—Three unequal, not interchangeable, axes at oblique angles, \( a, \beta \) and \( \gamma \), to each other.

Any one of the axes may be selected as \( \xi \), the vertical; the shorter of the others, \( \alpha \), will take the position of \( a \) of the monoclinic, and the third, \( \delta \), will go where it must.

Fig. 8 represents in projection, the axes of olivine, in which the planes of the chosen unit occur at such angles that \( \beta = 94^\circ \), \( \gamma = 116^\circ \), \( \gamma' = 58^\circ \), and the axes are cut at distances relatively \( \frac{a}{c} = 1.54 \times \frac{b}{c} \) and \( c = 5.57 \times \frac{c}{c} \).

HEXAGONAL.—Three equal and interchangeable axes, \( a_1, a_2, a_3 \), at 60° to each other and in the principal plane of symmetry, and one unequal, dissimilar axis, \( c \), normal to the principal plane of symmetry, and hence at 90° to the others.

The axis \( c \) is conventionally placed vertically, the axis \( a_1 \), horizontally from left to right.

Fig. 9 represents in projection, the axes of the mineral apatite, in which the planes of the selected unit form cut two of the axes \( a \) at equal distances, are parallel to the third and cut the axis \( c \) at a distance \( 7.246 \times a \).

All crystal planes in systems with three axes may be conventionally classified as:

PINACOIDAL.—Parallel to two axes.

PRISMATIC or DOME-LIKE.—Parallel to one axis.

PYRAMIDAL.—Intersecting all axes.

The various forms in the different systems will be composed always of faces of one type, with equivalent symbols, so that the symbol of any face may typify the others. The number of faces in a form will be determined by the symmetry of the system.
CHAPTER II.

ISOMETRIC SYSTEM.

This system must include all forms which can be referred to three equivalent interchangeable axes at right angles to each other, hence equal in length in the ideal forms. Complete forms have three principal planes of symmetry parallel to the faces of the cube and six secondary planes of symmetry through diagonally opposite edges of the cube. Fig. 10 shows the relative position of the three principal planes and one of the secondary planes.

All forms in this system may be classified as composed of:

I.—Pinacoidal Planes (parallel to two axes):
Hexahedron.

III.—Prismatic or Dome-Like Planes (parallel to one axis):
Rhombic Dodecahedron.
Tetrahexahedron.

II.—Pyramidal Planes (intersecting all axes):
Octahedron.
Trigonal Trisoctahedron.
Tetragonal Trisoctahedron.
Hexoctahedron.

The axes being interchangeable or equivalent, a unit's length on any one will be a unit's length on the others. In the various notations a unit plane will be expressed as follows:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a : a : a)</td>
<td>(O)</td>
<td>1</td>
<td>(1 1 1)</td>
</tr>
</tbody>
</table>

Any other plane will be expressed in terms of the unit symbol as follows:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
</tr>
</thead>
<tbody>
<tr>
<td>(a : na : m)</td>
<td>(mOn)</td>
<td>(m = n)</td>
</tr>
</tbody>
</table>
in which \( m \) and \( n \) are simple values greater than unity and \( m \) is never less than \( n \).

Miller's symbol will be \((hk\ell)\), in which \( h \) is greater than \( k \), which, in turn, is greater than \( l \), and in value \( h \), \( k \) and \( l \) will be essentially the reciprocals of the Weiss parameters taken in the same order.

I. Forms Composed of Pinacoidal Planes.

**Hexahedron or Cube.**—Composed of six faces, each parallel to two axes, all diedral and plane angles being right angles. The commonest of all crystal forms. In the ideal form the faces are squares.

In this \( m \) and \( n \) are both infinite, and as the reciprocal of \( \frac{\infty}{\infty} \) is \( \frac{1}{\infty} \) or 0, we have, by substitution in the general symbols

\[
\text{WEISS: Naumann: Dana:}^* \quad \text{Miller:}
\]

\[
a : \infty a : \infty \quad \approx O \approx \quad i - i \quad \{100\}
\]

II. Forms Composed of Prismatic or Dome-like Planes.

**Rhomobic Dodecahedron.**

Composed of twelve faces each parallel to one axis and cutting the others at equal distances. In the ideal form each face is a rhombus.

In the general symbol the larger parameter is then infinite and the smaller \( n \) is unity, that is:

\[
\text{WEISS: Naumann: Dana: Miller:}
\]

\[
a : a : \approx a \quad \approx O \quad i \quad \{110\}
\]

All interfacial angles are either 120° (adjacent faces) or 90° (alternate faces). The plane angles between edges are equal to the interfacial angles of the octahedron, i.e., 109° 28' 16' and 70° 31' 44'.'

**Tetrahexahedron.**

Composed of twenty-four faces each parallel to one axis and

---

* Dana uses \( i \) or \( \infty \) as sign of infinity.
cutting the other two unequally in distances bearing a simple ratio to each other. In the ideal forms the faces are equal isosceles triangles.

In this form one parameter will be unity, one a finite number greater than unity, one will be infinite, that is in general:

\[
\begin{align*}
\text{Weiss} & : \text{Naumann} & : \text{Dana} & : \text{Miller} \\
& : \propto & : \propto 0 n & : i - n & : \{ h k 0 \}
\end{align*}
\]

The value of \( n \) may always be calculated after measuring either \( C \) or \( A \), Fig. 13, by the following equations, \( n = \tan(135^\circ - \frac{1}{2} \cdot C) \) or \( n = \tan \frac{\pi}{3} \cdot \cos \frac{\pi}{3} \cdot A \times 1.4142 \).

For \( n = 2 \), \( A = C = 143^\circ 8' \); for \( n = 3 \), \( A = 154^\circ 9', C = 126^\circ 52' \).

**Pentagonal Dodecahedron or Hemi Tetrahexahedron.**

Composed of twelve faces each cutting the axes as in the whole form. In the ideal forms the faces will be pentagons.

The symbols will be those of the preceding form with a slight change\(^*\) to indicate that the forms are hemihedral:

\[
\begin{align*}
\text{Weiss} & : \text{Naumann} & : \text{Dana} & : \text{Miller} \\
\frac{1}{2} \cdot \{ a : na : \propto a \} & : \propto 0 n & \frac{i - n}{2} & : \pi \{ h k 0 \}
\end{align*}
\]

The planes of Fig. 16 correspond to the white faces of Fig. 15, and those of Fig. 17 to the striated faces.

\(^*\) The brackets [ ] indicate what is called a parallel form and the \( \pi \) has the same meaning; in distinction the parentheses ( ) or the letter * indicates an inclined hemihedral form.
The value of $n$ may be found by the equation $n = \tan \frac{1}{2} A'$.

III. Forms Composed of Pyramidal Planes.

Octahedron.

Composed of eight faces each cutting the three axes at equal distances. In the ideal form the faces are equilateral triangles.

All parameters being unity we have:

\[
\begin{align*}
\text{Weiss} & : \text{Naumann} & \text{Dana} & : \text{Miller} \\
1 : a : a & 0 & 1 & \langle 1 1 1 \rangle
\end{align*}
\]

The angles are $109^\circ 28' 16''$ between adjacent faces and $70^\circ 31' 44''$ between alternate faces.

The alternate edges are at right angles and the adjacent edges at $60^\circ$.

Tetrahedron or Hemi Octahedron.

Composed of four faces each cutting the axis as in the whole form.

The symbols are:

\[
\begin{align*}
\text{Weiss} & : \text{Naumann} & \text{Dana} & : \text{Miller} \\
\frac{1}{2} (a : a : a) & 0 & \frac{1}{2} & \langle 1 1 1 \rangle
\end{align*}
\]

All interfacial angles are $70^\circ 31' 44''$ and all plane angles between edges are $60^\circ$.

The planes of Fig. 20 correspond to the white faces of Fig. 19 and those of Fig. 21 to the striated faces.

Trigonal Trisoctahedron.

Composed of twenty-four faces, each cutting two axes at equal
Isometric System.

Distances, the third axis at some longer distance a simple multiple of the others. In the ideal forms the faces are isosceles triangles.

The general symbols are therefore:

\( a : a : ma \)  \( mO \)  \( m \)  \( \{ hhi \} \)

The value of \( m \) may be calculated by the following equations:

\( m = \tan \frac{1}{2} B \times 0.7071 \), or when \( A \), Fig. 22, is measured, \( \cos \frac{1}{2} A \times 1.1546 = \cos \rho \) and \( m = \tan(144^\circ 44' - \rho) \).

For \( m = 2 \), \( A = 152^\circ 44' \), \( B = 141^\circ 33' \). For \( m = 3 \), \( A = 143^\circ 8' \), \( B = 153^\circ 28\frac{1}{2}' \).

Hemi Trigonal Trisoctahedron.

Composed of twelve faces, each cutting the axes as in the whole form. In the ideal form the faces are trapeziums.

The symbols are therefore:

\( \frac{1}{2} (a : a : ma) \)  \( mO \)  \( m \)  \( \{ hhi \} \)

The planes of Fig. 25 correspond to the white faces of Fig. 24 and those of Fig. 26 to the striated faces.

The value of \( m \) may be calculated either by the equation invol-
ving A under the whole form, or, when B' is known, by the equations \( \cos e = \cos \frac{1}{2} B' \times 1.1546, m = \tan (35^\circ 16' + e) \times .7071. \)

For \( m = 2, B' = 90'; \) for \( m = 3, B' = 99^\circ 5'. \)

**Tetragonal Trisoctahedron or Icositetrahedron.**

Composed of twenty-four faces, each cutting two axes equally and the third in some shorter distance bearing a simple ratio to the others. In the ideal form the faces are trapeziums.

The general symbols are therefore:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( a : ma : ma )</td>
<td>( mOm )</td>
<td>( m-m )</td>
<td>( { hkk } )</td>
</tr>
</tbody>
</table>

**FIG. 27.**

\[ 2 \cdot 2. \{ 211 \} \]

**FIG. 28.**

\[ 3 \cdot 3. \{ 311 \} \]

The value of \( m \) may be calculated by the following equations:

\[ \cot \frac{1}{2} B = \cos e, \] \( m = \tan e \) or if \( A \) is measured \( \cot \frac{1}{2} A \times .5773 = \cos \rho. \)

For \( m = 2, A = 146^\circ 27'; \) \( B = 131^\circ 59'. \) For \( m = 3, A = 129^\circ 31'; \) \( B = 144^\circ 44'. \)

**Hemi Tetragonal Trisoctahedron.**

Composed of twelve faces each cutting the axes as in the whole form. In the ideal form the faces are isosceles triangles.

**FIG. 29.**

**FIG. 30.**

**FIG. 31.**

The symbols are therefore:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{1}{2}(a : ma : ma) )</td>
<td>( mOm )</td>
<td>( m-m )</td>
<td>( { hkk } )</td>
</tr>
</tbody>
</table>
The planes of Fig. 30 correspond to the white face of Fig. 29 and those of Fig. 31 to the striated faces.

The values of \( m \) may be calculated either by the equations involving \( A \) given under the whole form, or, when \( B' \) is measured, by the equations \( m = \tan \frac{A}{3} B' \times 1.4142 \).

For \( m = 2, B' = 109^\circ 28' \). For \( m = 3, B' = 124^\circ 7' \).

**Hexoctahedron.**

Composed of forty-eight faces each cutting the three axes in three different, but simply proportionate, distances. In the ideal forms the faces are scalene triangles.

\[
\begin{align*}
\text{Fig. 32.} & \\
3 - \frac{A}{3} \{ 321 \} \\
\text{Fig. 33.} & \\
4 - 2 \{ 421 \}
\end{align*}
\]

The general symbols are therefore:

\[
\begin{align*}
\text{WEISS.} & : \text{Naumann.} \quad m : n \quad m : n \\
& \text{Dana.} \\
& \text{Miller.} \quad \{ k \ell \}
\end{align*}
\]

The values of \( m \) and \( n \) can be calculated whenever any two of \( A, B, C \), Fig. 33, are known by the following equations:

\[
m = \tan \frac{A}{3} B \sin v, \quad n = \tan v
\]

\( v \) may be found by either:

\[
\cos v = \frac{\cos \frac{A}{3} B + \cos \frac{A}{3} A \times 1.4142}{\sin \frac{A}{3} B} \quad \text{or} \quad \cos (\frac{135^\circ}{3} - v) = \frac{\cos \frac{A}{3} C}{\sin \frac{A}{3} B}
\]

For \( m - n = 3 - \frac{A}{3} \), \( A = 158^\circ 13' \); \( B = 145^\circ \); \( C = 158^\circ 13' \).

For \( m - n = 4 - 2 \), \( A = 162^\circ 15' \); \( B = 154^\circ 47' \); \( C = 144^\circ 3' \).

**Hextetrahedron, or Hemi Hexoctahedron Inclined.**

Composed of twenty-four faces each cutting the three axes as in the whole form. In the ideal form the faces are scalene triangles.
The general symbols are:

\[
\begin{align*}
\text{WEISS.} & \quad \frac{1}{3}(a : na : ma) \\
\text{NAUMANN.} & \quad \frac{mOn}{2} \\
\text{DANA.} & \quad \frac{m-n}{2} \\
\text{MILLER.} & \quad \{hkl\}
\end{align*}
\]

The planes in Fig. 35 correspond to the white faces of Fig. 34 and those of Fig. 36 to the striated faces.

The angles A and C, Fig. 35, are as in the whole form, and \( m \) and \( n \) may be calculated from them as before.

For \( m-n = 3 - \frac{1}{3} \), \( B' = 110^\circ 55^\prime \). For \( 4 - 2 \), \( B' = 124^\circ 51^\prime \).

DIPLOID OR HEMI HEXOCTAHEDRON PARALLEL.

Composed of twenty-four faces each cutting the three axes as in the whole form. In the ideal form the faces are trapeziums.

The general symbols are:

\[
\begin{align*}
\text{WEISS.} & \quad \frac{1}{3}[a : na : ma] \\
\text{NAUMANN.} & \quad \left[ \frac{mOn}{2} \right] \\
\text{DANA.} & \quad \left[ \frac{m-n}{2} \right] \\
\text{MILLER.} & \quad \{hkl\}
\end{align*}
\]

The planes in Fig. 38 correspond to the white faces of Fig. 37 and those of Fig. 39 to the striated faces.

The values of \( m \) and \( n \) may be calculated (Fig. 39) by the following:
ISOMETRIC SYSTEM.

\[
\frac{\cos \frac{1}{3} A'}{\sin \frac{1}{3} B'} = \cos \theta, \quad n = \tan \theta, \quad m = \frac{n \cos \frac{1}{3} A'}{\cos \frac{1}{3} B'}.
\]

For \( m - n = 3 - \frac{1}{3} \), \( A' = 115^\circ 23' \); \( C' = 141^\circ 47' \).
For \( m - n = 4 - 2 \), \( A' = 128^\circ 15' \); \( C' = 131^\circ 48\frac{1}{2}' \).

TETARTOHEDRAL OR QUARTER FORMS.

The only new geometric shape equivalent to the suppression of three-quarters of the faces of any complete isometric form is the TETARTO HEXOCTAHEDRON or TETARTOID, a twelve faced form with pentagonal faces. Fig. 40 shows such a form.
CHAPTER III.

TETRAGONAL SYSTEM.

This system must include all crystal forms referable to two equivalent interchangeable axes at right angles to each other and one axis normal to the interchangeable axes but not equivalent. In the ideal forms the interchangeable axes will be of equal length, the third axis will be of a length which is not a simple multiple or aliquot part of the others.

Fig. 41.

Complete forms have one principal and four secondary planes of symmetry, the latter being normal to the principal plane and at 45° to each other as shown in Fig. 41. The interchangeable axes $a$ and $c$ are chosen arbitrarily, normal to alternate secondary planes of symmetry, the principal axis $c$ is normal to the principal plane of symmetry and is always assumed to be in vertical position.

SERIES.

All forms referable to such axes are tetragonal forms. The irrational quotient of $\frac{c}{a}$ may however have many values making possible with each value a new lot of geometric forms.

A series is a group of such forms, all of which can be referred to some one value of $\frac{c}{a}$. That is the planes of these forms will occur only in positions corresponding either to a constant value for $\frac{c}{a}$ or to values so related that any one value is either a simple or infinite multiple or aliquot part of any other value.

A given substance crystallizes only in forms of one series.

For example, calculation of the relative distances at which the common forms of the mineral zircon cut the axes will yield the ratios $1 : 1 : 0.64$; $1 : 1 : \infty$; $1 : 1 : 1.92$; $1 : \infty : \infty$; $1 : 3 : 1.92$; $1 : \infty : 1$; $1 : 1 : 1.28$. If now we call the first form our unit form and denote it by $a : a : c$ the second in comparison is $a : \infty : c$, the
TETRAGONAL SYSTEM.

third is \( a : a : 3c \), the fourth is \( \infty a : \infty c \), the fifth is \( a : 3a : 3c \),
the sixth \( a : \infty a : c \), the seventh is \( a : a : 2c \).

The parameters (coefficients) are all either unity or infinity or 2 or 3 in the known planes of this common mineral.

We may classify all tetragonal forms as composed of

I.—PINACOIDAL PLANES (parallel to two axes):

Basal Pinacoid.
Prism of Second Order.

II.—PRISMATIC OR DOME-LIKE PLANES (parallel to one axis):

Prism of First Order.
Ditetragonal Prism.
Pyramid of Second Order.

III.—PYRAMIDAL PLANES (intersecting all axes):

Pyramid of First Order.
Ditetragonal Pyramid.

A unit plane in any series may be denoted as follows:

<table>
<thead>
<tr>
<th>WEISS.</th>
<th>NAUMANN.</th>
<th>ADA.</th>
<th>MILLER.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a : a : c )</td>
<td>( P )</td>
<td>1</td>
<td>( { 111 } )</td>
</tr>
</tbody>
</table>

Any other plane in that series will be expressed in terms of the unit symbol as follows:

<table>
<thead>
<tr>
<th>WEISS.</th>
<th>NAUMANN.</th>
<th>ADA.</th>
<th>MILLER.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a : na : mc )</td>
<td>( mpn )</td>
<td>( m - n )</td>
<td>( { hkl } )</td>
</tr>
</tbody>
</table>

in which \( m \), the coefficient of \( c \), may be greater or less than unity, but \( n \) is never less than unity. In Miller's symbol \( h > k \).

I. Forms* Composed of Pinacoidal Planes.

Basal Pinacoid.

Is always composed of two planes parallel to the basal axes.

The general symbols are, therefore:

<table>
<thead>
<tr>
<th>WEISS.</th>
<th>NAUMANN.</th>
<th>ADA.</th>
<th>MILLER.</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \infty a : \infty a : c )</td>
<td>( OP )</td>
<td>0</td>
<td>( { 001 } )</td>
</tr>
</tbody>
</table>

* The basal pinacoid or the prisms of the first or second order and the ditetra-
CRYSTALLOGraphy.

TETRAGONAL PRISM OF SECOND ORDER.
Composed of four planes parallel to the vertical axis and to one basal axis.
The general symbols are, therefore:

\[
\begin{align*}
\text{WEISS.} & : \infty a : \infty c & \approx P \approx & i \cdot i \{ 100 \} \\
\text{NAUMANN.} & \quad \text{DANA.} & \quad \text{MILLER.}
\end{align*}
\]

The interfacial angles are 90°.

II. FORMS COMPOSED OF PRISMATIC OR DOME-LIKE PLANES.

TETRAGONAL PRISM OF FIRST ORDER.
Composed of four planes parallel to the vertical axis and cutting the basal axis at equal distances from the centre.
The symbols are, therefore:

\[
\begin{align*}
\text{WEISS.} & : a : \infty c & \approx P & i \{ 110 \} \\
\text{NAUMANN.} & \quad \text{DANA.} & \quad \text{MILLER.}
\end{align*}
\]

The interfacial angles are 90°.

DITETRAGONAL PRISM.
Composed of eight planes parallel to the vertical axis and cutting the two basal axes in distances unequal but simply proportionate.
The general symbols are, therefore:

\[
\begin{align*}
\text{WEISS.} & : a : a : \infty c & \approx P h & i \cdot n \{ h k 0 \} \\
\text{NAUMANN.} & \quad \text{DANA.} & \quad \text{MILLER.}
\end{align*}
\]

\[
\begin{align*}
i \cdot 2, \{ 210 \}.
\end{align*}
\]

\[n\] may be determined by the equations:

\[n = \tan \frac{1}{2} X, \text{ or } n = \tan (135^\circ - \frac{1}{2} Y)\]

PRISM OF THIRD ORDER OR HEMI-DITETRAGONAL PRISM.
Composed of four planes parallel to the vertical axis and cutting the basal axes as in the whole form.

gonal prism cannot occur without other planes, although they are "forms" in the sense that they comprise all the faces required by the symmetry of the system.
The symbols are, therefore:

\[
\begin{align*}
\text{WEISS} & : \frac{1}{2}[a : na : zoc] \\
\text{NAUMANN} & : \left[ \frac{\infty Pn}{2} \right] \\
\text{DANA} & : \left[ \frac{i-n}{2} \right] \\
\text{MILLER} & : \{ lko \}
\end{align*}
\]

The planes of Fig. 47 correspond to the white faces of Fig. 46, and those of Fig. 48 to the striated faces.

All forms thus far described are unchanged by variations in the relative lengths of \(c\) and \(a\); that is, they are exactly alike in all series, as may be understood by examination of their symbols. The remaining forms of the system vary in shape and angle with the variation of \(\frac{c}{a}\), and it is, therefore, proposed to represent forms constructed on the axis lengths of:

\[
\begin{align*}
\text{Zircon} & : \frac{c}{a} = 0.6404 \\
\text{Apophyllite} & : \frac{c}{a} = 1.2515 \\
\text{Octahedrite} & : \frac{c}{a} = 1.7771
\end{align*}
\]

The forms described, however, will not necessarily be forms which have been observed.

**Tetragonal Pyramid of the Second Order.**

Composed of eight faces, each parallel to one basal axis, and cutting the other basal axis and the vertical axis at either unit
distances or simple multiples of these. In ideal forms the faces are isosceles triangles.

The symbols are therefore:

**Weiss.**
\[ a : \infty a : mc \]

**Naumann.**
\[ mP\infty \]

**Dana.**
\[ m - i \]

**Miller.**
\[ \{ h0l \} \]

The value of \( mc \) may be determined by the following equations, Fig. 49:

\[
\cos \frac{1}{2} Y \times 1.4142 = \sin a, \quad \tan \frac{1}{2}Z = \tan a, \quad mc = \tan a.
\]

**III. Forms Composed of Pyramidal Planes.**

**Tetragonal Pyramid of First Order.**

Composed of eight faces, each cutting the basal axes at equal distances, and the vertical axis at some distance not a simple multiple of the basal intercepts. In the ideal form the faces will be isosceles triangles.
TETRAGONAL SYSTEM.

There may be a series of such forms with each substance differing in the value \( \frac{c}{a} \), but the different values will be simple multiples of each other.

**Fig. 55.**

**Fig. 56.**

**Fig. 57.**

Zircon

\[ \{ 111 \} \]

\[ \{ 221 \} \]

\[ \{ 331 \} \]

Aepthyllite.

1. \{ 111 \}

3. \{ 113 \}

5. \{ 115 \}

Octahedrite.

1. \{ 111 \}

3. \{ 223 \}

5. \{ 335 \}

The general symbols will be:

- **Weiss.**
- \( a : r : mc \)
- **Naumann.**
- \( mP \)
- **Dana.**
- \( m \)
- **Miller.**
- \( l \), \( h l l \)

The value of \( mc \) may be determined by the following equations:

\[ mc = \tan \frac{1}{2}Z \times 3.7071 \text{ or } \sin a = \cot \frac{1}{2}X, mc = \tan a \]

TETRAGONAL SPHENOID OR HEMI-PYRAMID OF FIRST ORDER.

Composed of four faces, each cutting the axes as in the whole form. In the ideal form the faces are isosceles triangles.

**Fig. 58.**

**Fig. 59.**

**Fig. 60.**

The symbols are therefore:
The planes of Fig. 59 correspond to the white faces of Fig. 58, and those of Fig. 60 to the striated faces.

**DITETRAGONAL PYRAMID.**

Composed of sixteen faces, each cutting the two basal axes at unequal but simply commensurate distances, and the vertical axis at a distance not simply proportionate to the other distances. In the ideal forms the faces are scalene triangles.

The symbols are therefore:

\[
\begin{align*}
\text{Weiss.} & : \quad mPn \\
\text{Naumann.} & : \quad mPn \\
\text{Dana.} & : \quad m-n \\
\text{Miller.} & : \quad hkl
\end{align*}
\]

The values of \(m\) and \(n\) may be determined from any two diedral angles. For \(X\) and \(Y\) equations are

\[
n = 1 + \frac{\cos \frac{1}{2} Y \times 1.4142}{\cos \frac{1}{2} X}, \quad n \cot \frac{1}{2} X = \sin \alpha, \quad \tan \alpha = mc.
\]

**Pyramid of Third Order or Hemi-Ditetragonal Pyramid.**

Fig. 63.

Composed of eight planes, each cutting the axes as in the whole form. In form similar to the other two eight-faced pyramids but differing in relation of faces to the axes as shown in basal section Fig. 63.
TETRAGONAL SYSTEM.

The symbols are therefore:

\[
\begin{align*}
\text{Weiss.} & : \quad \frac{1}{2} [a : n a : m c] \\
\text{Naumann.} & : \quad \left[ \frac{m P t n}{2} \right] \\
\text{Dana.} & : \quad \left[ \frac{m - n}{2} \right] \\
\text{Miller.} & : \quad \langle h k l \rangle
\end{align*}
\]

The planes of Fig. 65 correspond to the white faces of Fig. 64, and those of Fig. 66 to the striated faces.

TETRAGONAL SCALENOHEDRON OR HEMI-DITETRAGONAL PYRAMID.

Composed of eight faces, each cutting the axes as in the whole form. In the ideal form the faces are scalene triangles.

The symbols are, therefore:

\[
\begin{align*}
\text{Weiss.} & : \quad \frac{1}{2} (a : n a : m c) \\
\text{Naumann.} & : \quad \frac{m P t n}{2} \\
\text{Dana.} & : \quad \frac{m - n}{2} \\
\text{Miller.} & : \quad \langle h k l \rangle
\end{align*}
\]

The planes of Fig. 68 correspond to the white faces of Fig. 67 and those of Fig. 69 to the striated faces.
**CRYSTALLOGRAPHY.**

**TETRAGONAL TRAPEZOHEDRON OR HEMI-DITETRAGONAL PYRAMID.**

Composed of eight faces, each cutting the axes as in the whole form. In the ideal form the faces are trapeziums.

![Fig. 70](image1)

![Fig. 71](image2)

![Fig. 72](image3)

The symbols are, therefore:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \frac{1}{2} (a : ma : mc) )</td>
<td>( \frac{mPn}{2} )</td>
<td>( \frac{m-n}{2} )</td>
<td>( \tau { hkl } )</td>
</tr>
</tbody>
</table>

The planes of Fig. 71 correspond to the white faces of Fig. 70, and those of Fig. 72 to the striated faces.
CHAPTER IV.

ORTHORHOMBIC SYSTEM.

This system must include all forms which are referable only to three axes, at right angles to each other, and not interchangeable. In ideal forms the axes will necessarily be of unequal lengths, which will never be simply proportionate.

Complete forms have three secondary planes of symmetry at right angles to each other (see Fig. 73), and the axes are normal to these planes and equally important.

CONVENTIONAL POSITION FOR AXES AND SELECTION OF UNIT PLANE.

Any one of the axes may be chosen as the vertical, c; this would be decided usually by occurring planes or by cleavages. The other two axes will then be horizontal. A pyramidal plane, if possible, will then be chosen as a unit plane, and its co-ordinates will yield the unit ratio, \(a : b : c\).

The horizontal axis with the longer unit intercept is placed to run from left to right, and is called the macro or \(b\) axis; the shorter axis runs from front to back and is called the brachy or \(a\) axis.

SERIES.

All forms referable to three dissimilar axes at right angles to each other are orthorhombic forms. There are, however, as many series of such forms possible as there are irrational values for \(\frac{a}{b}\) and \(\frac{c}{b}\). Or, more exactly, all planes belonging to the same series lie at such angles to the axes, that when the values \(\frac{a'}{b'}\) and \(\frac{c'}{b'}\)
of any plane are divided by the corresponding quantities \( \frac{a}{b} \) and \( \frac{c}{b} \) of the unit plane; the quotients are simple numbers, simple fractions, or infinite.

A given mineral can crystallize only in planes belonging to one series.

We may classify all orthorhombic forms as composed of:

I.—**Pinacoidal Planes** (parallel to two axes):

- Basal Pinacoid,
- Macro Pinacoid,
- Brachy Pinacoid.

II.—**Prismatic or Dome-like Planes** (parallel to one axis):

- Unit Prism.
- Macro Prism.
- Brachy Prism.
- Macro Dome.
- Brachy Dome.

III.—**Pyramidal Planes** (intersecting all axes):

- Unit Pyramid.
- Macro Pyramid.
- Brachy Pyramid.

A unit plane *in any series* may be denoted as follows:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( a : b : c )</td>
<td>( P )</td>
<td>( t )</td>
<td>( (111) )</td>
</tr>
</tbody>
</table>

Any other plane *in that series* will be expressed in terms of the unit symbol as follows:*  

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>( a : mb : mc )</td>
<td>( mP \bar{n} )</td>
<td>( m - \bar{n} )</td>
<td>( (hkl) )</td>
</tr>
</tbody>
</table>

* It is customary to assume \( m \) as varying only from 1 to \( \infty \), never less than 1; that is, the very possible value, \( \frac{a}{b} : \frac{b}{2c} \), is represented by \( a : 2b : 4c \), *i.e.*, \( m \) is made greater than 1 by transferring it from \( a \) to \( b \) with an appropriate value.
ORTHORHOMBIC SYSTEM.

I. Forms Composed of Pinacoidal Planes.

**Basal Pinacoid.**

Fig. 74.

Composed of two planes parallel to the basal axes. The symbols are, therefore:

WEISS, NAUMANN, DANA, MILLER.

\[ \infty \hat{a} : \infty \hat{b} : \hat{c} \quad \hat{c} \parallel \hat{a} \quad \{ \mathbf{001} \} \]

**Macro Pinacoid.**

Composed of two planes parallel to the macro and vertical axes. The symbols are, therefore:

WEISS, NAUMANN, DANA, MILLER.

\[ \hat{a} : \infty \hat{b} : \infty \hat{c} \quad \infty \parallel \hat{a} \quad \{ \mathbf{100} \} \]

**Brachy Pinacoid.**

Fig. 76.

Composed of two planes parallel to the brachy and vertical axes. The symbols are, therefore:

WEISS, NAUMANN, DANA, MILLER.

\[ \infty \hat{a} : \hat{b} : \infty \hat{c} \quad \infty \parallel \hat{b} \quad \{ \mathbf{010} \} \]

Fig. 77 shows the three pinacoids combined.

The pinacoids are the same in symbol and position whatever the relative values of \( \hat{a} \), \( \hat{b} \) and \( \hat{c} \), that is in all orthorhombic crystals.

\[ \mathbf{0} \parallel \hat{a} \quad \mathbf{100} \parallel \hat{b} \quad \mathbf{i} \parallel \hat{c} \quad \{ \mathbf{010} \} \]
The remaining forms of the system vary in shape and angle for each mineral, or series. To illustrate this, the figures following are drawn on the axes of the three common minerals, sulphur, topaz and barite, in which the unit-forms cut the axes \( a : b : c \) as follows:

- Sulphur, \( 0.81309 : 1 : 1.90339 \).
- Topaz, \( 0.528542 : 1 : 0.476976 \).
- Barite, \( 0.81520 : 1 : 1.31339 \).

Occurring forms of these minerals are selected, though frequently the forms occur only as small modifying faces on some other form.

II. Prismatic or Dome-Like Planes.

**Prisms.**—Composed of four planes, Fig. 78, each parallel to the vertical axis and cutting the basal axes in distances not simply proportionate.

The relation between these distances, \( i.e., \frac{a'}{b'} \), must always be compared with the corresponding relation \( \frac{a}{b} \) of the selected unit plane. If the value of \( \frac{a'}{b'} \) is the same as \( \frac{a}{b} \) of the unit form the prism is called a *unit prism*; if the value is *less* the prism is called a *macro prism* and the fact is expressed by writing the denominator as \( n \, b' \); if the value is *greater*, the prism is called a *brachy prism* and the fact expressed by writing the numerator as \( n \, a \).

The general symbols are therefore:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Prism, ( a : b : c )</td>
<td>( \approx P )</td>
<td>( \perp )</td>
<td>( { 110 } )</td>
</tr>
<tr>
<td>Macro Prism, ( a : b' : c )</td>
<td>( \approx Pt )</td>
<td>( i \perp )</td>
<td>( { hko } )</td>
</tr>
<tr>
<td>Brachy Prism, ( n , a : b : c )</td>
<td>( \approx Pt )</td>
<td>( i \perp )</td>
<td>( { kho } )</td>
</tr>
</tbody>
</table>

![Fig. 79.](image)

Horizontal section of three prisms or pyramids which are relatively unit, macro and brachy.
ORTHORHOMBIC SYSTEM.

Fig. 8a.

Topaz.

\( \{110\} \) and \( \{001\} \)

Fig. 8b.

Topaz.

\( \{110\} \), \( \{120\} \), and \( \{111\} \)

Barite.

\( \{110\} \) and \( \{001\} \)

The value of \( na \) can be determined by the following equation:

\[
\cot \frac{1}{2} \alpha = na.
\]

If \( n \) is greater than unity the symbol is written \( na : b : \infty : \infty \); if \( n \) is less than unity the symbol is reduced to \( a : \infty : b : \infty \).

Domes.

Composed of four planes parallel to one basal axis but cutting the other basal axis and the vertical axis in distances not simply proportionate.

MACRO DOME.

Fig. 8c.

Faces parallel to \( \hat{b} \) the macro axis.
The general symbols are therefore:

\( \text{Weiss, Naumann, Dana, Miller,} \)

\( a : \infty \hat{b} : mc \quad mP \quad m - l \quad \langle h0l \rangle \)

The value of \( mc \) may be determined by the equation (Fig. 8c):

\[
\tan \frac{1}{2} \alpha = \frac{mc}{a}.
\]
CRYSTALLOGRAPHY.

BRACHY DOME.

Fig. 84.

Faces parallel to \( a \) the brachy axis. The general symbols are therefore:

\[ \text{Weiss. Naumann. Dana. Miller.} \]
\[ \approx a : b : mc \quad mP \approx m \quad \{\text{okl}\} \]

The value of \( mc \) may be determined by the equation

\[ \tan \frac{1}{2} B = mc. \]

Fig. 85 shows in combination a macro dome, brachy dome and the basal pinacoid of barite.

Fig. 86 shows in combination a brachy dome two pyramids and the basal pinacoid of sulphur.

Fig. 85.

Fig. 86.

Barite \( \frac{1}{2} 1 \), \( \{102\} ; 1 1 1 \); \( \{101\} \); and \( \{001\} \)

Sulphur \( 1 \), \( \{011\} ; 1, \{111\} \)
\( \frac{1}{2} \{113\} \) and \( \{001\} \)

PYRAMIDS.

Composed of eight planes each of which cut the three axes in the same relative distances; these intercepts are never simple multiples of each other but are necessarily simple multiples of the corresponding intercepts of the selected unit pyramid. In the ideal forms the faces are equal scalene triangles.

As with prisms we divide the possible pyramids which can occur in any one series into three groups dependent on the comparison between the ratios \( \frac{a'}{b'} \) of the given pyramid and \( \frac{a}{b} \) of the unit form.
ORTHORHOMBIC SYSTEM.

See Fig. 79. Unit pyramids in which the value of \( \frac{a'}{b'} \) is the same as \( \frac{a}{b} \) in the unit form. Macro pyramids in which the value is less than in the unit, the fact being expressed by writing the denominator as \( n b \). Brachy pyramids in which the value is greater than in the unit, the facts being expressed by writing the numerator as \( n a \).

The symbols are therefore:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit series Pyramid,</td>
<td>( a : b : nc )</td>
<td>( mP )</td>
<td>( m )</td>
</tr>
<tr>
<td>Macro Pyramid,</td>
<td>( a : nb : nc )</td>
<td>( mPn )</td>
<td>( m - n )</td>
</tr>
<tr>
<td>Brachy Pyramid,</td>
<td>( na : b : nc )</td>
<td>( mPn )</td>
<td>( m - n )</td>
</tr>
</tbody>
</table>

Fig. 87 shows two pyramids of sulphur both of the unit series.

Fig. 88 shows a brachy pyramid of topaz, and figure 89 a macro pyramid, each combined with the basal pinacoid.

![Fig. 87](image)

![Fig. 88](image)

![Fig. 89](image)

The values of \( na \) and \( mc \) may be determined by the following equations (see Fig. 87):

\[
\cos \alpha = \frac{\cos \frac{1}{2} X}{\sin \frac{1}{2} Z}, \quad \sin \alpha = \frac{\cos \frac{1}{2} Y}{\sin \frac{1}{2} Z}, \quad na = \cot \alpha
\]

\[
\cos \gamma = \frac{\cos \frac{1}{2} Z}{\sin \frac{1}{2} Y}, \quad \sin \gamma = \frac{\cos \frac{1}{2} X}{\sin \frac{1}{2} Y}, \quad mc = \tan \gamma
\]

\[
\cos \beta = \frac{\cos \frac{1}{2} Z}{\sin \frac{1}{2} X}, \quad \sin \beta = \frac{\cos \frac{1}{2} Y}{\sin \frac{1}{2} X}, \quad \frac{mc}{na} = \tan \beta.
\]
Orthorhombic Sphenoid or Hemi Orthorhombic Pyramid.

Composed of four planes, each cutting the axes as in the whole form.
In the ideal form the faces are scalene triangles.
The sphenoid may correspond to unit, macro, or brachy pyramid and its symbols will be, for instance, for the macro:

\[
\begin{align*}
\text{Weiss:} & \quad \frac{mPn}{2} \\
\text{Naumann:} & \quad \frac{m-n}{2} \\
\text{Dana:} & \quad \pi \{ hkl \}
\end{align*}
\]

Fig. 91 corresponds to the white faces of Fig. 90 and Fig. 92 to the striated faces.
CHAPTER V.

MONOCLINIC SYSTEM.

This system must include all forms referable only to three axes, one fixed at right angles to the only plane of symmetry, and the other two chosen arbitrarily but in the plane of symmetry and oblique to each other (see Fig. 93). The axes are not interchangeable.

Complete forms in this system possess only one plane of symmetry.

Conventional Position of Axes.

The plane of symmetry is placed vertically, (see Fig. 93) with the fixed or ortho axis \( b \) at right angles to it running from right to left. Then either of the arbitrary axes is made the vertical, \( c \), and the other becomes the clino, \( a \), and is held so that it inclines downward from back to front. The acute angle between the vertical and clino axes is called \( \beta \).

Series.

As in the orthorhombic and tetragonal systems there are possible in this system many different series of forms. A series will include all forms which have the same value for \( \beta \) and in which the axial intercepts yield either constant values for \( \frac{a}{b} \) and \( \frac{c}{b} \) or simple or infinite multiples of these values. A given mineral can crystallize only in forms belonging to one series.

Some form in each series, preferably a pyramidal form, will be selected as the unit of the series and its intercepts \( a : b : c \) and the angle \( \beta \) will be determined. Then all other forms in the series can be expressed in simple symbols in terms of the unit as before described.

We may classify all monoclinic forms as composed of:

Pinacoidal Planes (parallel to two axes):

- Basal Pinacoid.
- Ortho Pinacoid.
- Clino Pinacoid.
PRISMATIC OR DOME-LIKE PLANES (parallel to one axis):
   Unit Prism.
   Ortho Prism.
   Clino Prism.
   Clino Dome.
   Positive* Hemi Ortho Dome.
   Negative Hemi Ortho Dome.

PYRAMIDAL PLANES (intersecting all axes):
   Positive Hemi Unit Pyramid.
   Negative Hemi Unit Pyramid.
   Positive Hemi Ortho Pyramid.
   Negative Hemi Ortho Pyramid.
   Positive Hemi Clino Pyramid.
   Negative Hemi Clino Pyramid.

A unit plane in any series will be denoted by

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$a : b : c$</td>
<td>$P$</td>
<td>$1$</td>
<td>${ \text{I} }$</td>
</tr>
</tbody>
</table>

Any other plane in that series will be expressed in terms of the unit symbol as follows:†

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$a : nb : mc$</td>
<td>$mP\overline{n}$</td>
<td>$m - \bar{n}$</td>
<td>${ \text{lkl} }$</td>
</tr>
</tbody>
</table>

I. Forms Composed of Pinacoidal Planes.

**Basal Pinacoid.**
Composed of two planes parallel to the basal axes.

The symbols are therefore:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>$\infty a : \infty b : c$</td>
<td>$oP$</td>
<td>$0$</td>
<td>${ 001 }$</td>
</tr>
</tbody>
</table>

* Each of these so-called hemi forms is a crystallographically complete and independent form and is in no sense hemihedral. The names are unfortunate and lead to misconception.

† As in the Orthorhombic System it is customary to assume $n$ varying only from 1 to $\infty$ and to represent a plane with the symbol $a : \frac{1}{2} b : 3c$ by the symbol $2a : 3b : 6c$, that is $n$ is transferred from $b$ to $a$. 
MONOCLINIC SYSTEM.

ORTHOD Pinacoid.

Composed of two planes parallel to the ortho and vertical axes.

The symbols are therefore:

WEISS. NAUMANN. DANA. MILLER.
\( \hat{a} \parallel b \parallel c \parallel P \parallel i-i \parallel \{100\} \)

CLINO Pinacoid.

Composed of two planes parallel to the clino and vertical axes.

The symbols are therefore:

WEISS. NAUMANN. DANA. MILLER.
\( \parallel \hat{a} \parallel b \parallel c \parallel P \parallel i-i \parallel \{010\} \)

Fig. 97 shows the three pinacoids of pyroxene combined with unit prism and negative hemi unit pyramid.

Pyroxene.

\[ a_{001}, i-i, \{010\}, i-i, \{100\}, i, \{110\}, I, \{111\} \]

In this system only the ortho and clino pinacoids are constant in position in different series. The basal pinacoid and the remaining forms differ in different series. For illustration, forms constructed on the axes of the common minerals, pyroxene, gypsum and orthoclase are used. In these the constants are:

<table>
<thead>
<tr>
<th>Mineral</th>
<th>( \hat{a} )</th>
<th>( \hat{b} )</th>
<th>( c )</th>
<th>( \overline{\beta} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pyroxene</td>
<td>1.09213</td>
<td>1</td>
<td>0.58932</td>
<td>74° 10' 9''</td>
</tr>
<tr>
<td>Gypsum</td>
<td>0.68994</td>
<td>1</td>
<td>0.41241</td>
<td>80° 42' 10''</td>
</tr>
<tr>
<td>Orthoclase</td>
<td>0.65851</td>
<td>1</td>
<td>0.55538</td>
<td>63° 36' 46''</td>
</tr>
</tbody>
</table>

Occurring forms of these minerals are selected as types, although frequently the forms occur only in combination.
II. Prismatic or Dome-Like Planes.

Prisms.—Composed of four planes each parallel to the vertical and cutting the basal axes in distances not simply proportionate.

As in the orthorhombic forms the relation between these distances, i.e., \( \frac{a'}{b'} \) is always compared with the corresponding relation \( \frac{a}{b} \) of the selected unit plane and according to the result we have the following forms and symbols:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Unit Prisms, ( a : b \propto c )</td>
<td>( \propto P )</td>
<td>( I )</td>
<td>( { 1 \bar{1} 0 } )</td>
</tr>
<tr>
<td>Ortho Prisms, ( a' : b' \propto c )</td>
<td>( \propto P_i )</td>
<td>( \bar{1} \bar{1} 0 )</td>
<td>( { 1 \bar{1} 0 } )</td>
</tr>
<tr>
<td>Clino Prisms, ( a : b \propto c )</td>
<td>( \propto P_i )</td>
<td>( \bar{1} \bar{1} 0 )</td>
<td>( { 1 \bar{1} 0 } )</td>
</tr>
</tbody>
</table>

Fig. 98.

The relation of basal sections of three prisms or pyramids, unit, clino, and ortho relatively, is shown in Fig. 98.

The unit prisms of pyroxene, orthoclase and gypsum are shown in the combination in Figs. 99, 100, and 101 respectively, that of Pyroxene is also shown in Fig. 97.

Fig. 99.  Fig. 100.  Fig. 101.

\( L \{ 110 \} \) \( L \{ 110 \} \) \( L \{ 110 \} \) with \( a \).
\( \{ 001 \} \) \( \{ 001 \} \) \( \{ 011 \} \) \( \{ 011 \} \) \( \{ 011 \} \)
\( 2-i \{ 201 \} \) \( 2-i \{ 201 \} \) and \( i-i \{ 010 \} \) \( \) \( \) and \( i-i \{ 010 \} \)

The ratio between \( a \) and \( b \) cannot be determined from the pris-

\+ See page 32.
MONOCLINIC SYSTEM.

matic angle alone; if, however, the angle $B$ of the unit prism is known, the value of $n$ for any other prism may be determined by measuring its angle $B'$ and using the equation: 

$$n = \frac{\tan \frac{1}{2} B'}{\tan \frac{1}{2} B}$$

If the angle $A$ between the basal pinacoid and unit prism is known and the prism angle $B$, the ratio between the axes and also the angle $\beta$ may be determined by the equations:

$$\cos \delta = \frac{\cos \frac{1}{2} B}{\sin A}; \quad \frac{a}{b} = \cot \delta; \quad \cos \beta = \frac{\cos A}{\sin \frac{1}{2} B}$$

In clino and ortho prisms the values of $n$ may be determined when the angle $\beta$ is known:

$$n = a \tan \frac{1}{2} B \sin \beta; \quad \frac{n}{a} = \cot \frac{1}{2} B \sin \beta$$

Clino Domes.

Composed of four planes parallel to the clino axis and cutting the vertical and ortho axes in distances not simply proportionate.

The general symbols are, therefore:

\[
\begin{array}{cccc}
\text{WEISS.} & \text{NAUMANN.} & \text{DANA.} & \text{MILLER.} \\
\in \hat{a} : \hat{b} : m & & mP \in \in & \{ \text{hol} \}
\end{array}
\]

In any clino dome $mc = \frac{\cot \frac{1}{2} B'}{\sin \beta}$, or if the angle $B$ of the unit dome is known, $m = \frac{\tan \frac{1}{2} B}{\tan \frac{1}{2} B'}$.

Ortho Domes.*

Positive Hemi Ortho Dome.

Composed of two planes lying in the angle $\beta$, parallel to the ortho axis and cutting the clino and vertical axes in distances not simply proportionate.

The general symbols are, therefore:

\[
\begin{array}{cccc}
\text{WEISS.} & \text{NAUMANN.} & \text{DANA.} & \text{MILLER.} \\
\in \hat{a} : \in \hat{b} : m & + & mP \in \in & \{ \text{hol} \}
\end{array}
\]

* For explanation of these so-called hemi forms, see under Pyramids, p. 43.
NEGATIVE HEMI ORTHO DOME.

Composed of two planes laying in the obtuse angles (opposite $\beta$) and cutting the axes as in the negative form.

The symbols are, therefore:

\[
\begin{align*}
\text{Weiss:} & \quad \hat{a} : \infty \hat{b} : m & \text{Naumann:} & \quad mP\infty & \text{Dana:} & \quad m - \hat{t} & \text{Miller:} & \quad \{1\overline{1}0\} \\
\end{align*}
\]

Fig. 103 shows a combination of positive and negative hemi ortho domes.

Figs. 104 and 105 show positive hemi ortho domes of gypsum and orthoclase respectively combined with other forms.

III. Forms Composed of Pyramidal Planes.

The symbols of pyramids and of domes parallel to the ortho

axis correspond to twice the number of planes made necessary by
the symmetry of the system. The symbol of a pyramid, for instance, corresponds to eight planes, but the occurrence of any plane— for instance, plane 1, Fig. 106—with a given pyramid symbol requires the simultaneous occurrence of, first, a diagonally opposite plane, 2, because all complete crystal forms must be symmetrical with respect to the centre; second, each of these diagonally opposite planes needs another plane, 3 and 4 respectively, symmetrically placed on the other side of the vertical plane of symmetry, and these four planes (Fig. 107) are all that are required.

The eight planes, therefore, constitute two distinct forms with the same axial intercepts. In a combination of the ideal forms the four faces which compose the plus or positive form and lie in the acute octants will be smaller than the other four which lie in the obtuse octants and make up the negative form.

The possible pyramids which can occur in any one series are named by a comparison between the ratio \( \frac{a'}{d'} \) of the given pyramid and \( \frac{a}{d} \) of the chosen unit form. In unit pyramids the ratio is that of the unit form. In ortho pyramids the value of \( \frac{a'}{d'} \) is less than \( \frac{a}{d} \) in the unit; this is expressed by writing the denominator as \( n'b \).

In clino pyramids the value of \( \frac{a'}{d'} \) is greater than \( \frac{a}{d} \) in the unit, and this is expressed by writing the numerator \( n'a \).

The symbols are, therefore:

<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Positive Unit Series Pyramid, ( \rightarrow a : \bar{b} : me )</td>
<td>( + mP )</td>
<td>+ m</td>
<td>( { hkl } )</td>
</tr>
<tr>
<td>Negative Unit Series Pyramid, ( \rightarrow a : \bar{b} : me )</td>
<td>( - mP )</td>
<td>- m</td>
<td>( { hkl } )</td>
</tr>
<tr>
<td>Positive Ortho Pyramid, ( \rightarrow a : nb : mc )</td>
<td>( + mPn )</td>
<td>+ m ( \cdot n )</td>
<td>( { hkl } )</td>
</tr>
<tr>
<td>Negative Ortho Pyramid, ( \rightarrow a : nb : mc )</td>
<td>( - mPn )</td>
<td>- m ( \cdot n )</td>
<td>( { hkl } )</td>
</tr>
<tr>
<td>Positive Clino Pyramid, ( \rightarrow na : \bar{b} : mc )</td>
<td>( + mPa )</td>
<td>+ m ( \cdot n )</td>
<td>( { hkl } )</td>
</tr>
<tr>
<td>Negative Clino Pyramid, ( \rightarrow na : \bar{b} : mc )</td>
<td>( - mPa )</td>
<td>- m ( \cdot n )</td>
<td>( { hkl } )</td>
</tr>
</tbody>
</table>

The negative unit pyramid of gypsum is shown in Figs. 100 and 104, and the negative unit of pyroxene in Fig. 97.

Fig. 108 shows a positive and a negative hemi pyramid of pyroxene, both of the unit series, but of different symbols.
Direct calculations from pyramid angles are difficult; if, however, the angles that a given plane makes with the pinacoids can be measured, the relative values of the axial intercepts can be easily obtained.

Denote angle of pyramidal plane with $OP$ by C.

\[
\cos \rho = \frac{\cos B}{\sin A}, \text{ and } mc = \cot \rho, \\
\cos \delta = \frac{\cos B}{\sin C}, \text{ and } na = \cot \delta. 
\]

* In case of macro pyramids $n$ will be fractional.
CHAPTER VI.

TRICLINIC SYSTEM.

This system must include all crystallographic forms which can only be referred to three axes obliquely inclined to each other and not interchangeable. In ideal forms the axes will be of unequal length, which will never be simply proportionate.

There are no planes of symmetry in this system, but the forms are symmetrical to a central point. That is, the occurrence of any plane only makes necessary the occurrence of an opposite parallel plane to satisfy the degree of symmetry of the system. Each "form," according to the definition of the term, is, therefore, only a pair of parallel planes.

Position of Axes.

As there are no planes of symmetry, the position of the three axes is entirely arbitrary and governed by convenience. For instance, the selection of three pairs of pinacoidal planes will settle the direction of the axes.

One of the three chosen axes is placed in a vertical position, and is called the vertical axis, \( c \). Of the others, the one with the shorter unit length takes the position of the clino axis in the monoclinic system and is called the brachy axis, \( a \); the other takes its position according to its angles with \( a \) and \( c \), and is called the macro axis \( \hat{b} \).

The oblique angles between the axes are conventionally designated by Greek letters as follows:

\[
a \wedge \hat{b} \text{ by } \gamma; \ a \wedge c \text{ by } \beta; \ \hat{b} \wedge c \text{ by } \hat{a}.
\]

Unit Form and Series.

There are, in triclinic crystals, five constants in each series, namely, \( a, \beta, \gamma, \frac{a}{\beta} \) and \( \frac{c}{\beta} \), and all forms in any series, must be referable to three axes inclined at certain constant values for \( a, \beta, \gamma \), and furthermore, their axial intercepts must yield either constant
values for $\frac{a}{b}$ and $\frac{c}{b}$, or yield simple or infinite multiples of these values.

Any plane cutting the three axes may be assumed as a plane of the unit pyramid and from it the values $\frac{a}{b}$ and $\frac{c}{b}$ may be obtained.

We may classify all triclinic forms* as composed of:

**Pentacoidal Planes** (parallel to two axes).
- Basal Pinacoid.
- Macro Pinacoid.
- Brachy Pinacoid.

**Prismatic or Dome-like Planes** (parallel to one axis).
- Unit Prism.
- Macro Prism.
- Brachy Prism.
- Macro Dome.
- Brachy Dome.

Each of above consists of two independent hemi forms.

**Pyramidal Plane** (intersecting all axes).
- Unit Pyramids.
- Macro Pyramids.
- Brachy Pyramids.

Each of these consists of four independent tetra pyramids.

A unit plane in any series will be denoted by:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a:b:c$</td>
<td>$P$</td>
<td>1</td>
<td>${111}$</td>
</tr>
</tbody>
</table>

Any other plane in that series will be denoted by:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>$a:nb:mc$</td>
<td>$mPn$</td>
<td>$n-h$</td>
<td>${hkl}$</td>
</tr>
</tbody>
</table>

The constants of certain triclinic minerals are:

<table>
<thead>
<tr>
<th>Albit</th>
<th>$a$</th>
<th>$b$</th>
<th>$c$</th>
<th>$\alpha$</th>
<th>$\beta$</th>
<th>$\gamma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.63347:1:0.55771</td>
<td>94° 3'</td>
<td>116° 28'</td>
<td>88° 58'</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.4921:1:0.4797</td>
<td>82° 54' 13&quot;</td>
<td>94° 51' 43&quot;</td>
<td>131° 23' 19&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>0.36562:1:0.55687</td>
<td>82° 21' 43&quot;</td>
<td>73° 10' 34&quot;</td>
<td>77° 37' 15&quot;</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

* As the "forms" are only pairs of parallel planes, while the same symbol yields eight planes in the case of pyramids, and four in the case of domes and prisms, it follows that the eight planes constitute four distinct forms, and the four planes two distinct forms, though, in each case, with the same axial intercepts.
TRICLINIC SYSTEM.

The forms illustrated are occurring forms of these minerals, often, however, only known in complex combinations, and not in the simpler forms as drawn.

I. Forms Composed of Pinacoidal Planes.

BASAL PINACOID.

Compound of two planes parallel to the basal axes. The symbols are, therefore:

\[ \begin{align*}
\text{Weiss} & : \infty : \infty : c & \text{Naumann} & : \infty : \infty : c & \text{Dana} & : \infty : \infty : c & \text{Miller} & : \infty : \infty : c \\
\{ 001 \} & & \{ 001 \} & & \{ 001 \} & & \{ 001 \} &
\end{align*} \]

MACRO PINACOID.

Composed of two planes parallel to the macro and vertical axes. The symbols are, therefore:

\[ \begin{align*}
\text{Weiss} & : \infty : \infty : c & \text{Naumann} & : \infty : \infty : c & \text{Dana} & : \infty : \infty : c & \text{Miller} & : \infty : \infty : c \\
\{ 00\} & & \{ 100\} & & \{ 100\} & & \{ 100\} &
\end{align*} \]

BRACHY PINACOID.

Composed of two planes parallel to the brachy and vertical axes. The symbols are therefore:

\[ \begin{align*}
\text{Weiss} & : \infty : \infty : c & \text{Naumann} & : \infty : \infty : c & \text{Dana} & : \infty : \infty : c & \text{Miller} & : \infty : \infty : c \\
\{ 010\} & & \{ 010\} & & \{ 010\} & & \{ 010\} &
\end{align*} \]

Fig. 112 shows the combination of the pinacoids of axinite.

The axial angles may be obtained from the three pinacoids by the equation:

\[ \begin{align*}
\cos \alpha &= \frac{\cos A + \cos B \cos C}{\sin B \sin C} ; \\
\cos \beta &= \frac{\cos B + \cos C \cos A}{\sin C \sin A} ; \\
\cos \gamma &= \frac{\cos C + \cos A \cos B}{\sin A \sin B} .
\end{align*} \]
II. Forms Composed of Prismatic or Domelike Planes.

**Prisms.**

Each prism symbol corresponds to four planes, cutting the basal axes at distances not simply proportionate and parallel to the vertical axis. Each prism is, however, simply two diagonally opposite planes. For convenience, the two prisms with the same axial intercepts are called hemi prisms, and the symbols made to differ by accents.*

Macro and brachy prisms bear the same relations to the unit prism that they do in the orthorhombic system.

The symbols are, therefore:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>Right Hemi Unit Prism, $a:b:∞$</td>
<td>$P'$</td>
<td>$I$</td>
<td>${1\text{1}0}$</td>
</tr>
<tr>
<td>Left Hemi Unit Prism, $a:b':∞$</td>
<td>$P'$</td>
<td>$I$</td>
<td>${1\text{1}0}$</td>
</tr>
<tr>
<td>Right Hemi Macro Prism, $a:nb:∞$</td>
<td>$P'n$</td>
<td>$i-n'$</td>
<td>$hko$</td>
</tr>
<tr>
<td>Left Hemi Macro Prism, $a:nb':∞$</td>
<td>$P'n'$</td>
<td>$i-n'$</td>
<td>$hko$</td>
</tr>
<tr>
<td>Right Hemi Brachy Prism, $na:b:∞$</td>
<td>$P'n$</td>
<td>$i-n'$</td>
<td>$hko$</td>
</tr>
<tr>
<td>Left Hemi Brachy Prism, $na:b':∞$</td>
<td>$P'n'$</td>
<td>$i-n'$</td>
<td>$hko$</td>
</tr>
</tbody>
</table>

In Fig. 113 $I_2$, $I_1$; in Fig. 114 $I_1$, $I_2$; and in Fig. 115 the right and left hemi unit prisms of albite and of chalcanthite are shown in Figs. 113 and 114 respectively.

Fig. 115 shows the right hemi prism and three pinacoids of axinite.

* In the Weiss symbols, for all forms, the eye of the observer is vertically over the form; in the Naumann, it is in front. In each case, one half of the crystal is seen and recorded—Weiss recording the upper half, Naumann the front half.
TRICLINIC SYSTEM.

Domes.

As with prisms each symbol corresponds to two forms called hemi domes.

The planes are parallel to one basal axis and cut the other basal axis and the vertical axis in distances not simply proportionate.

As in the orthorhombic system the domes are named after the axis to which they are parallel.

The names and symbols are:

Upper front Hemi Macro Dome, \( a : \approx b : m e \ m'P \parallel m - l \prime \) \( \{ h o l \} \)
Lower front Hemi Macro Dome, \( a' : \approx b : m e \ m, P \parallel m - l, \) \( \{ h o l \} \)
Right upper Hemi Brachy Dome, \( a : b : m e \ m, P \parallel m - l \) \( \{ o k l \} \)
Left upper Hemi Brachy Dome, \( a : b : m e \ m, P \parallel m - l \prime \) \( \{ o k l \} \)

Fig. 116 shows an upper front hemi macro dome of albite with the three pinacoids.

In any macro dome,

\[ a : m e = \sin Y \sin \alpha : \sin Z \sin \gamma. \]

Fig. 117 shows a right upper hemi brachy dome of chalcantite combined with three pinacoids.

In any brachy dome,

\[ b : m e = \sin X \sin \beta : \sin Z \sin \gamma. \]

III. Forms Composed of Pyramidal Planes.

The oblique axes divide space into four pairs of dissimilar octants, the opposite octants being similar. Any pyramidal plane will necessarily be accompanied by an opposite parallel plane and these two planes will constitute the form.

Planes may occur in the other six octants with precisely equal intercepts but each pair is independent of the others.

For convenience each pair of planes, although strictly an independent form, is called a tetra-pyramid.

As in the orthorhombic system, see p. 35, the pyramids of any
series are compared as to the values of \( \frac{a}{b} \) and called unit pyramids, macro pyramids and brachy pyramids.

The symbols of the pyramids of the unit series are:

- **Upper Right Tetra Pyramid**, \( a : b : b' : mc \) \( mP' \) \( m' \) \( \{ hkl \} \)
- **Upper Left Tetra Pyramid**, \( a : b' : b : mc \) \( m'P \) \( 'm \) \( \{ hkl \} \)
- **Lower Right Tetra Pyramid**, \( a' : b' : b : mc \) \( mP \) \( m \) \( \{ hkl \} \)
- **Lower Left Tetra Pyramid**, \( a' : b' : b : mc \) \( mP \) \( m \) \( \{ hkl \} \)

![Fig. 118. Albite.](image)

![Fig. 119. Chalcanthite.](image)

Figs. 118 and 119 show the four tetra unit pyramids of albite and chalcanthite respectively.*

The symbols of the tetra macro and tetra brachy pyramids are strictly analogous modifications of the general symbols:

- **Macro**, \( a : nb : mc \) \( mPn \) \( m - n \) \( \{ hkl \} \)
- **Brachy**, \( na : b : mc \) \( mPn \) \( m - n \) \( \{ hkl \} \)

![Fig. 120.](image)

Fig. 120 shows a right upper tetra pyramid of albite combined with three pinacoids. From such a combination the relation of the axes may be calculated by the following formulas:

\[
\begin{align*}
\sin X : \sin Y & : \sin \rho : \sin \mu, \\
\sin Y : \sin Z & : \sin \tau : \sin \pi, \\
\sin Z : \sin X & : \sin \nu : \sin \delta.
\end{align*}
\]

\[
\begin{align*}
\sin \tau : \sin \delta &= a : b, \\
\sin \rho : \sin \pi &= b : c, \\
\sin \nu : \sin \mu &= c : a.
\end{align*}
\]

* These have never been found so combined.
CHAPTER VII.

HEXAGONAL SYSTEM.*

This system must include all forms referable to four axes, one vertical and at right angles to the others, three horizontal and interchangeable, and at sixty degrees to each other. In the ideal forms the interchangeable axes will be equal.

Complete forms will possess seven planes of symmetry, one principal and six secondary, the latter at right angles to the former and at thirty degrees to each other. See Fig. 121.

The alternate secondary planes are equivalent or interchangeable; that is the original aspect of the crystal is reproduced by a revolution of sixty degrees about their common intersection.

AXES.

The principal axis, \( c \), normal to the principal plane of symmetry is the vertical axis, and the three horizontal axes, \( a \), are lines in the principal plane normal to either set of alternate secondary planes of symmetry. One horizontal axis is taken parallel to the observer and the extremities of the horizontal axes are alternately considered positive and negative.

CONSTANTS OF SERIES.

There will be a series of forms for each value of \( \frac{c}{a} \) and every series will be composed of forms such that if any one be taken as the unit and the value of \( \frac{c}{a} \) calculated, all other forms possible on

---

* Dana makes two divisions of this system.

Hexagonal.—Symmetry by sixes, cleavage and physical characters holohedral, hemis forms vertically direct.

Rhombohedral.—Symmetry by threes, cleavage and physical characters hemihedral, forms hemihedral and vertically alternate.
crystals of the substance will either yield this same value for \( \frac{c}{d} \), a simple multiple of it, or infinity.

The symbols for a unit form in any series are:

<table>
<thead>
<tr>
<th>WEISS</th>
<th>NAUMANN</th>
<th>DANA</th>
<th>MILLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>( a : \omega a : a : \epsilon )</td>
<td>( P )</td>
<td>( 1 )</td>
<td>( { 10 \overline{1} } )</td>
</tr>
</tbody>
</table>

The symbols for any other plane in that series are:

<table>
<thead>
<tr>
<th>WEISS</th>
<th>NAUMANN</th>
<th>DANA</th>
<th>MILLER</th>
</tr>
</thead>
<tbody>
<tr>
<td>( na : \rho a : a : me )</td>
<td>( n\rho a )</td>
<td>( m - n )</td>
<td>( { hkl } )</td>
</tr>
</tbody>
</table>

When \( n \) is known, \( \rho \) may be calculated; for it has been proved* that \( \rho = \frac{n}{n - 1} \).

The maximum value for \( n \) is \( n = \rho \); for any larger value would give a crystal with re-entrant angles, but \( n = \rho \) means \( n = \frac{n}{n - 1} \); i.e., \( n - 1 = 1 \), or \( n = 2 \).

In Miller's symbols the algebraic sum of \( hkl \), the indices of the basal axes, is always zero.

The forms of the Hexagonal System may most easily be classified as:

I. PINACOIDS (faces parallel to basal axes).
   Basal Pinacoid.

II. PRISMS (faces parallel to vertical axis).
    Unit or first order Prism.
    Second order or Diagonal Prism.
    Dihexagonal Prism.

III. PYRAMIDS (faces intersecting vertical axis).
    Unit or first order Pyramid.
    Second order or Diagonal Pyramid.
    Dihexagonal Pyramid.

**HEMIHEDRAL AND TETARTOHEDRAL FORMS.**

The so-called partial forms—hemihedral, tetartohedral and hemimorphic—are of great importance and considerable complexity in this system. The relations between these forms and the whole forms are most easily understood by:

* *Klein Einleitung in die Kristallographie* (1876), p. 319.
HEXAGONAL SYSTEM.

First.—Considering the possible methods of selection of one-half and one-quarter of the occurring planes on the most general form, the dihexagonal pyramid.

Second.—Assuming all complete forms* to be special cases of the most general form, then all the faces of the general form are marked out on the form under consideration, and the corresponding planes are suppressed or retained.

The form resulting from a hemihedral selection will often be composed of all the faces of the whole form, and the form resulting from a tetartohedral selection will often be composed of one-half of the faces of the whole form. This tends to explain why, in crystals having a hemihedral structure, the evident hemihedral forms are often accompanied by apparent whole forms, really hemihedral.

I. Hemihedral Structure.

There are three possible methods of selection of one-half the planes of a dihexagonal pyramid: the trapezohedral, Fig. 122, the pyramidal, Fig. 123, and the rhombohedral, Fig. 124.

![Diagrams](Image)

If each form is regarded as a special case of the dihexagonal pyramid, and these methods of selection applied, only five new geometric forms result; in all other cases the holohedral is reproduced. For example, the prism of the second order is reproduced by the trapezohedral, pyramidal and rhombohedral methods.

The five geometrically new forms are:

* For instance, the Prism of the second Order is a dihexagonal pyramid, in which \[ n = \infty \] and \[ n = 2 \].
II. Tetartohedral and Hemimorphic Structure.

Tetartohedism and hemimorphism may be regarded as the simultaneous suppression of sets of planes of the whole form by two different methods or kinds of hemihedrism.

I. Rhombohedral Tetartohedism (Fig. 125).
Simultaneous suppression by Rhombohedral (Fig. 124) and Pyramidal (Fig. 123) methods.

II. Trapezohedral Tetartohedism (Fig. 126).
Simultaneous suppression by Rhombohedral (Fig. 124) and Trapezohedral (Fig. 122) methods.

III. Hemimorphism (Fig. 127).
Simultaneous suppression by Trapezohedral (Fig. 122) and Pyramidal (Fig. 123) methods.

This method is brought out clearly by Williams* in the following way: Starting at a, and numbering the planes of the dihexagonal pyramid consecutively from left to right, and cancelling suppressed planes by line / for one method and \ for the other, we would have the following results:

**Rhombohedral Tetartohedism.**

Planes above, 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12
Planes below, 1. 2. 3. 4. 5. 6. 7. 8. 9. 10. 11. 12
Leaving above, 1. 5. 9 (Fig. 125).
Leaving below, 3. 7. 11.

---

* Elements of Crystallography, p. 132. 2d Ed.
HEXAGONAL SYSTEM.

TRAPEZOHEDRAL TETARTOHEDRISM.

Planes above, 1. \( \mathbf{\alpha}_1 \), \( \mathbf{\alpha}_2 \), \( \mathbf{\alpha}_3 \), \( \mathbf{\alpha}_4 \), \( \mathbf{\alpha}_5 \), \( \mathbf{\alpha}_6 \), \( \mathbf{\alpha}_7 \), \( \mathbf{\alpha}_8 \), \( \mathbf{\alpha}_9 \), \( \mathbf{\alpha}_{10} \), \( \mathbf{\alpha}_{11} \), \( \mathbf{\alpha}_{12} \).

Planes below, \( \mathbf{\lambda}_1 \), \( \mathbf{\lambda}_2 \), \( \mathbf{\lambda}_3 \), \( \mathbf{\lambda}_4 \), \( \mathbf{\lambda}_5 \), \( \mathbf{\lambda}_6 \), \( \mathbf{\lambda}_7 \), \( \mathbf{\lambda}_8 \), \( \mathbf{\lambda}_9 \), \( \mathbf{\lambda}_{10} \), \( \mathbf{\lambda}_{11} \).

Leaving above, 1. 5. 9 \( \{ \) Fig. 126.
Leaving below, 4. 8. 12 \( \} \)

HEMMORPHISM.

Planes above, 1. \( \mathbf{\alpha}_1 \), \( \mathbf{\alpha}_3 \), \( \mathbf{\alpha}_5 \), \( \mathbf{\alpha}_7 \), \( \mathbf{\alpha}_9 \), \( \mathbf{\alpha}_{11} \).
Planes below, \( \mathbf{\lambda}_1 \), \( \mathbf{\lambda}_3 \), \( \mathbf{\lambda}_5 \), \( \mathbf{\lambda}_7 \), \( \mathbf{\lambda}_9 \), \( \mathbf{\lambda}_{11} \).

This combination evidently would result in the suppression of all the lower planes and the retention of half the upper planes. Fig. 127.

The geometrically new shapes resulting from Rhombohedral or Trapezohedral Tetartohedrism are six in number.

- Whole Form.
  - Dihexagonal Pyramid.
  - Second Order Pyramid.
  - Dihexagonal Prism.
  - Second Order Prism.

- Trapezohedral.
  - Trigonal Trapezohedron.
  - Trigonal Pyramid.
  - Trigonal Prism.

- Rhombohedral.
  - Rhombohedron of 3d Order.
  - Rhombohedron of 2d Order.

These will each be discussed in order following the corresponding whole forms.

I. Pinacoids.

BASAL PINACOID.

Composed of two planes parallel to the basal axes.

The symbols are therefore:

\[
\text{WEISS, NAUMANN, DANA, MILLER.} \\
\infty a : \infty a : \infty a : c \quad O \quad P \quad O \quad \{ \ 0001 \}
\]

II. Prisms.

HEXAGONAL PRISM OF FIRST ORDER.

Composed of six planes each parallel to the vertical axis and one basal axis and cutting the other two basal axes at equal distances.

The symbols are therefore:

\[
\text{WEISS, NAUMANN, DANA, MILLER.} \\
\infty a : \infty a : a : \infty c \quad \infty P \quad I \quad \{ \ 1010 \}
\]

\[\text{FIG. 128.}\]

\[\text{FIG. 129.}\]
CRYSTALLOGraphy.

HeXagonal PrIsm of Second Order.
Composed of six planes each parallel to the vertical axis and cutting one basal axis at a certain distance and the other two at twice that distance.
The symbols are therefore:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>(2a:2a:a: \propto c)</td>
<td>(\propto P_2)</td>
<td>(i-2)</td>
<td>({11\overline{2}0})</td>
</tr>
</tbody>
</table>

Fig. 130. Fig. 131.

\(i-2 \{11\overline{2}0\}\)

Basal Section.

Fig. 131 shows the relation of the first and second order forms in basal section. The equilateral and isosceles triangles show easily the relative values of the distances 1 and 2 at which the second order forms cut the axes.

TrIgonal PrIsm; Tetartohedral PrIsm of Second Order.
Composed of three planes each cutting the axes as in the whole form.

Fig. 132. Fig. 133.

The symbols are therefore:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>(\frac{1}{2} 2a:2a:a: \propto c)</td>
<td>(\propto P_2)</td>
<td>(i-2)</td>
<td>({11\overline{2}0})</td>
</tr>
</tbody>
</table>

\(4\)

HEXAGONAL SYSTEM.

If the second order prism, Fig. 132, is considered to be a special case of dihexagonal pyramid and striated to correspond to Fig. 126, the form resulting from the selection of the white faces will be that shown in Fig. 133.

DIHEXAGONAL PRISM.

Composed of twelve planes each parallel to the vertical axes and cutting all three basal axes at unequal distances which are simple multiples of each other.

The symbols are therefore:

\[
\text{WEISS.} \quad \text{NAUMANN.} \quad \text{DANA.} \quad \text{MILLER.}
\]

\[
na : \frac{n}{n-1} a : a : \infty c \quad \infty Pn \quad i - n \quad \{hklO\}
\]

The value of \( n \) may be calculated by the following equations:

\[
\tan \frac{1}{2} X \times .577 = \frac{n}{2-n} \quad \text{or} \quad \tan \frac{1}{2} Y \times 1.732 = \frac{n+1}{n-1}.
\]

HEXAGONAL PRISM OF THIRD ORDER; HEMI DIHEXAGONAL PRISM.

Composed of six planes each parallel to the vertical axis and cutting all three basal axes at unequal distances which are simple multiples of each other.

The symbols are therefore:

\[
\text{WEISS.} \quad \text{NAUMANN.} \quad \text{DANA.} \quad \text{MILLER.}
\]

\[
\frac{1}{3} na : \frac{n}{n-1} a : a : \infty c \quad \frac{\infty Pn}{2} \quad \left[\frac{i-n}{2}\right] \quad n \{hklO\}
\]

Fig. 136 corresponds to the white faces of Fig. 135.
DITRIGONAL PRISM; TETARTOHEDRAL DIHEXAGONAL PRISM.
Composed of six planes cutting the axis as in the whole form.
The symbols are therefore:

\[
\frac{1}{4} \left( \frac{n-1}{n} a : a : \infty c \right) \quad \frac{2 \pi a}{4} \quad \frac{i - n}{4} \quad \pi t \quad h \tilde{h} l o
\]

In Fig. 137 (striated like Fig. 126) the white planes correspond to the planes of Fig. 138.

As the remaining forms differ in different series, forms of apatite \( c = 0.734 \); calcite \( c = 0.854 \) and quartz \( c = 1.099 \) will be used as types, although some of them are only known in combinations.

III. Pyramids.
HEXAGONAL PYRAMID OF FIRST ORDER.
Composed of twelve planes each parallel to one basal axis, cutting the other two basal axes at equal distances, and cutting the vertical axis at some distance not simply proportionate to the intercepts on the basal axes. In ideal forms the faces are isosceles triangles.
The symbols are therefore:

\[
\text{WEISS.} \quad \text{NAUMANN.} \quad \text{DANA.} \quad \text{MILLER.}
\]

\[
a : \infty a : a : mc \quad mP \quad m \quad \{ holi \}
\]

The value of \( mc \) may be found by the following equations:

\[
\tan \frac{1}{2} Z \times 0.866 = mc \quad \text{or} \quad \sin a = \cot \frac{1}{2} X \times 1.732; \quad \tan a = mc.
\]

Rhombohedron of First Order; Hemi Hexagonal Pyramid of First Order.

Composed of six planes each cutting the axes as in the whole form. In the ideal form the faces are rhombs.

![Figures 141, 142, 143](image)

Calcite \( \{ 10\overline{1}1 \} \) Calcite \( -1 \{ 0\overline{1}\overline{1} \} \)

The symbols are therefore:

\[
\text{WEISS.} \quad \text{NAUMANN.} \quad \text{DANA.} \quad \text{MILLER.}
\]

\[
\frac{1}{2} (a : \infty a : a : mc) \quad mP \quad m \quad \{ Ohli \}
\]

In Fig. 141 the white faces correspond to the faces of Fig. 142, and the striated faces to those of Fig. 143.

![Figures 144, 145](image)

Calcite \( \frac{1}{2} \{ 01\overline{1}2 \} \) Calcite \( 2 \{ 02\overline{1}1 \} \)
The values of $mc$ may be calculated by the following equations, Fig. 144:

\[ \sin \alpha = \cos \frac{1}{2}X \times 1.155; \tan \alpha \times .866 = mc. \]

**Hexagonal Pyramid of the Second Order.**

Composed of twelve planes, each cutting one basal axis at a certain distance, the other basal axes at twice that distance, and the vertical axis at some distance not simply proportionate to the others. In the ideal form the faces are isosceles triangles.

The symbols are therefore:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>$2a : 2a : a : mc$</td>
<td>$mP^2$</td>
<td>$m - 2$</td>
<td>${ hh3hi }$</td>
</tr>
</tbody>
</table>

The values of $mc$ may be calculated, Fig. 146, by the equations:

\[ 2 \cos \frac{1}{2}X = \sin \frac{1}{2}Z; \tan \frac{1}{2}Z = mc. \]

**Rhombohedron of Second Order; Tetartohedral Pyramid of Second Order.**

Composed of six planes, each cutting the axes as in the whole form. The faces in the ideal form are rhombs.

The general symbols are therefore:

<table>
<thead>
<tr>
<th>Weiss</th>
<th>Naumann</th>
<th>Dana</th>
<th>Miller</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\frac{1}{4}(2a : 2a : a : mc)$</td>
<td>$mP^2$</td>
<td>$m - 2$</td>
<td>$\pi { hh2hi }$</td>
</tr>
</tbody>
</table>

The white faces of Fig. 147, which is striated like Fig. 125, correspond to the faces of Fig. 148.
HEXAGONAL SYSTEM.

TRIGONAL PYRAMID; TETARTOHEDRAL PYRAMID OF SECOND ORDER.
Composed of six faces, each cutting the axes, as in the whole form. The faces in the ideal form are isosceles triangles, and a horizontal section is an equilateral triangle.

The general symbols are therefore:

\[
\begin{align*}
\text{Weiss} & : \frac{1}{3} (2a : 2a : a : mc) & mP & \frac{m-2}{4} & \{ \text{Miller} \} & \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \} \\
\text{Naumann} & : mP & \frac{m-2}{4} & \{ \text{Miller} \} & \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \} & \{ \text{Weiss} \} \\
\text{Dana} & : mP & \frac{m-2}{4} & \{ \text{Miller} \} & \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \} & \{ \text{Weiss} \} \\
\text{Miller} & : \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \} & \{ \text{Weiss} \} & \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \}
\end{align*}
\]

In Fig. 149, which is striated like Fig. 125, the white faces correspond to Fig. 150.

DIOCTAHEDRAL PYRAMID.
Composed of twenty-four planes, each of which cut the three basal axes at unequal distances, simple multiples of each other; and cut the vertical axis at some distance not simply related to the others. In the ideal form the faces are scalene triangles.

The general symbols are therefore:

\[
\begin{align*}
\text{Weiss} & : \frac{m}{n} & a : a : mc & mP & m-n & \{ hh2hi \} \\
\text{Naumann} & : mP & m-n & \{ hh2hi \} & \{ \text{Weiss} \} & \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \} \\
\text{Dana} & : mP & m-n & \{ hh2hi \} & \{ \text{Weiss} \} & \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \} \\
\text{Miller} & : \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \} & \{ \text{Weiss} \} & \{ \text{Naumann} \} & \{ \text{Dana} \} & \{ \text{Miller} \}
\end{align*}
\]

The values of \( n \) and of \( mc \) may be found by the following equations. See Fig. 151.

Given \( X \) and \( Z \), \( \cos \nu = \frac{\cos \frac{1}{2}X}{\sin \frac{1}{2}Z} \); \( n = \frac{1}{2} + \tan (\nu - 30^\circ) \times .866 \);
\( mc = \tan \frac{1}{2}Z \sin \nu \).
Given \( Y \) and \( Z \), \( \cos \delta = \frac{\cos \frac{Y}{2}}{\sin \frac{Z}{2}} \); \( n = \frac{1}{2} + \tan (120^\circ - \delta) \times .866 \);
\( mc = \tan \frac{Z}{2} \sin (150^\circ - \delta) \).

The partial forms of the dihexagonal pyramid are:
Hexagonal Trapezohedron, Trapezohedral hemi form.
Hexagonal Pyramid, third order, Pyramidal hemi form.
Hexagonal Scalenohedron, Rhombohedral hemi form.
Trigonal Trapezohedron, Trapezohedral quarter form.
Rhombohedron of third order, Rhombohedral quarter form.
In each of these the planes cut the axes just as described for the whole form.

**Hexagonal Trapezohedron.**

Figure 132.

Composed of twelve faces, which are trapeziums in the ideal form. The adjacent polar angles are equal.

The white planes in Fig. 122 correspond to the planes of Fig. 152.

This form has not yet been observed on minerals.

The general symbols are:

\[
\frac{1}{3} \left( na : \frac{n}{n-1} a : a : mc \right) \quad \text{Naumann} \quad \frac{mPn}{2} \quad m-n \quad \pi \langle hkl \rangle
\]

**Hexagonal Pyramid of Third Order.**

Figure 153.

Composed of twelve planes, which are isosceles triangles in the ideal form. The form differs from the pyramids of first and second order only in the position of its planes with relation to the axes.

The white faces in Fig. 123 correspond to the planes of Fig. 153.

The symbols are:

\[
\frac{1}{3} \left[ na : \frac{n}{n-1} a : a : mc \right] \quad \text{Naumann} \quad mPn \quad \frac{m-n}{2} \quad \pi \langle hkl \rangle
\]
HEXAGONAL SYSTEM.

HEXAGONAL SCALENOHEDRON.

Composed of twelve faces. In the ideal form the faces are scalene triangles. The adjacent polar edges are necessarily unequal. The symbols* are:

\[
\begin{align*}
\text{WEISS.} & : \frac{n^2 a}{n-1} : a : \alpha : n \alpha \\
\text{NAUMANN.} & : \frac{m^2 n}{2} : m - n \\
\text{DANA.} & : \frac{m^2 n}{2} \\
\text{MILLER.} & : s \lVert hkl \parallel \gamma
\end{align*}
\]

The white faces of Fig. 124 correspond to the planes of Fig. 154, the positive scalenohedron.

If the inscribed rhombohedron is known, the value of \( n \) in the abbreviated formula \( m' R^r \) may be determined by the equations in which \( Z' = \text{basal angle of the rhombohedron} \):

\[\tan \frac{1}{2} Z \cot \frac{1}{2} Z' = n.\]

TRIGONAL TRAPEZOHEDRON.

Composed of six faces, which in ideal form are trapeziums.

A form analogous to the hexagonal trapezohedron, with the planes above between those below, but not half way between, as in the rhombohedron.

The symbols are:

\* Abbreviated symbols for scalenohedra are derived from what is known as the "rhombohedron of the middle edges." A series of scalenohedra may have the same lateral edges and varying vertical lengths; that is, may have the same rhombohedron of the middle edges; hence, if we denote the rhombohedron of the middle edges by \( m' R \), the various scalenohedra may be designated by \( m' R^r \), in which \( n' \) is the number by which the semi-vertical axis of the rhombohedron is to be multiplied. It has been proved that the relation between \( m Pn \) of the dihexagonal pyramid and \( m' R^r \) of the scalenohedron is as follows:

\[\frac{n'(2 - n)}{n} = \frac{m}{m'} \quad \text{for} \quad \frac{n'}{m'} = n',\]

or for the reverse transformation:

\[m'n' = m \quad \text{and} \quad \frac{2n'}{1 + n'} = n.\]
In Fig. 126 the white faces correspond to Fig. 155.

Rhombohedron of Third Order.

Fig. 156.

Composed of six faces. In ideal form the faces are rhombs and the form differs from the rhombohedrons of first and second order only in the position of the faces with relation to the axes.

The symbols are:

\[
\frac{1}{4} \left( \frac{na}{n-1} : a : a : mc \right) \quad \frac{mPn}{4} \quad \frac{m-n}{4} \quad \pi \\langle hkl \rangle
\]

The white faces in Fig. 125 correspond to the faces of Fig. 156.
CHAPTER VIII.
MEASUREMENT OF CRYSTAL ANGLES.

The instruments used in determining the angles between crystal planes are called goniometers.

HAND GONIOMETERS.

When the crystal faces are large enough and smooth enough to permit close contact between the arms of the instrument and the planes of the crystal, a simple instrument like that shown in Fig. 157 will yield measurements which are accurate within one degree, and this is usually close enough for the identification of planes of known minerals.

The hand-goniometer consists essentially of two crossed and pivoted arms and a graduated arc. Two strips of cardboard or tin and a protractor will do for rough work. Fig. 157 shows the best type of hand-goniometers in which the light metal arms can be moved backward and forward upon the pivot and with the pivot can be lifted free from the arc and replaced at will.

The arms are first lifted from the arc and slid upon the pivot until the pointed ends are of convenient, but not necessarily equal, length to be applied to the crystal. These ends are then so placed that each is perpendicular to the edge of intersection of the two crystal faces, and in such close contact that no light passes between the arms and the faces. When satisfactory adjustment has been secured the arms are clamped and replaced on the arc, as in the figure, and the angle is read. In the figure the angle is 56 degrees.

Several measurements should be made and the average taken. After each reading the arms should be unclamped and the new measurement made as if it was a different angle.
REFLECTION GONIOMETERS.

The angles between smooth bright faces can be measured to half minutes or even closer by measuring the rotation necessary to obtain successive images of a given object in the two crystal faces.

The principle of construction in all reflection goniometers may be understood by the following figure.

Let ABCD represent a crystal mounted upon an axis, which is normal to the paper at A; that is, the axis of rotation and the edge at A between the planes AB and AC are supposed to be so adjusted as to coincide.

The image of the object L would be reflected from the face AB to the eye at E.

Now, assuming the eye and the object at L to be fixed in position, it is evident that if the crystal is revolved about A until the plane AC is in the position AC', a second image of L will reach E.

The angle of rotation CAB is evidently the supplement of the desired crystal angle, CAB.

Similarly a measurement of any other angle at D, B or C may be obtained by adjusting so that the corresponding edge coincides with the axis of rotation.

The axis of rotation may be horizontal, as in the Wollaston and Mitscherlich instruments, or vertical as in the Babinet and Fuess instruments. The more elaborate instruments (Fuess No. 2 for instance) use two telescopes, the centers of both being in the same plane perpendicular to the axis of rotation. One of these, the signal telescope, has behind the lens a diaphragm in which is cut a signal of some definite shape, usually that shown at L, Fig. 158. A brilliant light back of this diaphragm sends a ray of light of this shape to the crystal faces from which it is reflected to and seen through the other telescope. By means of tangent screws the crystal is rotated until the image or signal is bisected by the cross hairs in the eye telescope.

Such an instrument requires a darkened room in which to
work. The Wollaston goniometer however, especially as improved by Mallard, may be used in ordinary light, and is easily manipulated.

The Mallard-Wollaston as made by Picart, of Paris, is represented in Figs. 159 and 160. No telescopes are used, but in place of the signal telescope a separate collimator lens is employed.

The apparatus therefore consists of two parts, the goniometer proper and the collimator, which when in use are placed with their axes approximately in the same plane at right angles to each other, as shown in Fig. 159.

The goniometer is the ordinary Wollaston type with a horizontal axis.

The edge of the angle to be measured is first made parallel to the axis of rotation as follows: The crystal is fastened with wax to the circular disk and approximately adjusted; then by turning the screws and which rotate two arcs of circles, perpendicular to each other but both centered at A; the crystal is tipped as desired, until, by trial, the signals from both faces successively coincide with the signal in the mirror.* The edge of the crystal and the axis of rotation are then made to coincide by turning the screws.

* The mirror can be inclined 40°-50° to the horizon. To adjust the mirror strictly parallel to the axis of rotation place at the extremity of the axis of the goniometer a plate with parallel faces, such as a cleavage fragment of felspar or calcite. The mirror is adjusted when both of the images given by the two faces of the plate can be brought.
\( u \) and \( u' \), which slide the parts holding the crystal, in two directions perpendicular to the axis of rotation without affecting the parallelism of the edge and axis. When properly centered the crystal edge will not appear to move during the rotation of the crystal.

The crystal, after adjustment as described, is revolved until the eye, held near the crystal, sees in coincidence two images of a given object, one in the face of the crystal the other in the blackened mirror, \( M \). The graduated circle is then read and the crystal again rotated until the second face gives the coincident signals when a second reading is made. The difference between these readings is the supplement of the required angle.

The collimator, also shown in Fig. 159, consists of a cylinder, \( C \), about four inches in diameter, blackened on the inside and supported by two grooved uprights, \( Q Q \), between which it can slide and to which it can be fixed by clamp screws.

The cylinder is closed by the large lens, \( L \), so that the rear end is exactly in the focal plane of this lens, and is closed with the exception of a central orifice. In front of this orifice in a conveniently arranged groove, slides a metallic plate, \( R R \), represented in detail Fig. 160. It carries slits of various forms, \( f, f', f'' \), which can be successively placed at the centre of the orifice. When one of these slits is placed in this position a little ratchet and pawl holds it there.

The slit is illuminated by a gas jet, \( G \), Fig. 159.

![Diagram](image)

Below the signal slits, \( f, f' \), are very fine slits, \( f_i f_i' \) called cross hair slits, and the closest results are obtained when the image of the cross hair slit, seen in the mirror, bisects the image of the signal slit, seen in the face of the crystal.

---

by rotation of the axis of the goniometer, into superposition with the image reflected from the mirror.

To move the mirror parallel to itself there are three movements of translation perpendicular to each other, and of which one is in the direction of the axis of the goniometer.
CHAPTER IX.

CLINOGRAPHIC PROJECTION OF CRYSTAL FIGURES.

The figures in this book are drawn according to the most frequently employed method in which the points of the crystal are projected upon a vertical plane by parallel rays oblique to the plane of projection.* The eye is conceived to be at an infinite distance but a little to the right and above the centre of the crystal.

Denoting the angular revolution to the right by $\delta$ and the elevation by $\varepsilon$, it is usual to assume such angles that $\cot \delta = r$ and $\cot \varepsilon = rs$ are simple numbers for isometric axes, and most frequently $r = 3$ and $s = 2$ for which $\delta = 18^\circ 26'$ and $\varepsilon = 9^\circ 28'$.

Isometric Axial Cross.

For $r = 3$ and $s = 2$ the method of construction is as follows: A horizontal line $ss'$, Fig 161, is bisected at $O$ and trisected at $t$ and $t'$ by perpendiculars. Distances $s'e = \frac{1}{3} ss'$ and $sg = \frac{1}{3} ss'$

![Fig. 161.](image)

are laid off as indicated. The point, $e$, determines the line, $eO$, and $AA'$, the projection of the front horizontal axis is the portion of

---

* This method of projection is described in many text-books, notably C. F. Naumann, Lehrbuch der Kristallographie, 1832; J. D. Dana, System of Mineralogy, 3rd ed., p. 662, etc.
this line which is included between the perpendiculars at \( t \) and \( t' \). The point \( g \) determines the radius \( Og \), which is the length of half the projection of the vertical axis \( CC' \). For the projection of the third axis draw \( A'f \) parallel to \( ss' \), draw \( fO \), and from the intersection \( v \) draw \( vB \) parallel to \( ss' \). \( BB' \) completes the desired projection of axial cross.

Isometric Simple Forms.

The vertices of all solid angles in isometric forms are either points on the axis which are known, or points on the so-called octahedral or rhombic interaxes, which are easily found. If the solid angles are found the edges are obtained by connecting these points.

The projection of the octahedron is obtained by connecting the extremities of the axial cross by straight lines.

The projection of the rhombic interaxes is obtained by connecting the centres of the opposite edges of the octahedron, Fig. 162.

The octahedral interaxes are obtained by connecting the centres of opposite faces of the octahedron. The centre of any triangle is at the intersection of lines from vertices to centres of opposite sides.

In any form, \( m - n \), the lengths of the interaxes are obtained by increasing the normal lengths from centre to extremity as obtained in Figs. 162 and 163 by the proportion obtained by the following formulas:

\[
\text{Octahedral extension} = \frac{2mn}{mn + (m + n)}.
\]

\[
\text{Rhombic extension} = \frac{n - 1}{n + 1}.
\]
For instance, the vertices of the solid angles of the hexoctahedron \( 3 - \frac{3}{2} \), shown in Fig. 32, are all points on axes or interaxes. Substituting in the formulas the values \( m = 3 \) and \( n = \frac{3}{2} \) we have:

\[
\text{Octahedral interaxes extension} = \frac{2 \times 3 \times \frac{3}{2} - (3 + \frac{3}{2})}{3 \times \frac{3}{2} + (3 + \frac{3}{2})} = \frac{1}{2}.
\]

\[
\text{Rhombic interaxes extension} = \frac{\frac{3}{2} - 1}{\frac{3}{2} + 1} = \frac{1}{2}.
\]

That is, each rhombic interaxis will be made \( \frac{1}{2} \) longer and each octahedral interaxis \( \frac{1}{2} \) longer, as illustrated in Fig. 164, in which the octahedral axes normally terminating at the points O, have been extended \( \frac{1}{2} \), and the rhombic axes normally terminating at the points R, have been extended \( \frac{1}{2} \), and the resulting points connected by lines forming the figure.

For inclined hemihedral forms:

\[
\text{Octahedral interaxes extension} = \frac{2 \cdot mn - (m - n)}{mn + (m - n)}.
\]

For parallel hemihedral forms the octahedral interaxes are as in the whole form; other points are most easily obtained by the method explained in the next paragraph.

Directions of Intersection in General.

In the isometric and all other systems, the projected intersections of any planes may be most simply found by the following method.

After obtaining the axial cross of the crystal, every plane on the crystal is assumed to be moved parallel to itself until it cuts the vertical axis \( c \) at unity; the new planes all pass through the extremity of \( c \) and that point is therefore on all lines of intersection.

Another point of each line or direction of intersection will be the intersection of the traces of the two planes on the plane of the basal axes. If the symbol of each plane is reduced until \( c = 1 \), the values of the intercepts on \( a \) and \( b \) result, and the traces of the planes are thus found and the desired points are the intersections of these traces.
Let a', b', c', in Fig. 165, be the axial cross of any crystal. Required the directions of intersection of a pyramidal plane $2a : b : 3c$ with three other planes, viz.: a pyramidal plane $a : 2b : c$, a prismatic plane $a : b : \infty e$ and a pinacoidal plane $\propto a : b : \infty e$, all these being planes of the upper front octant.

Dividing each term in each symbol by the coefficient of $e$, we have the symbols of parallel planes which cut $e$ at unity. The plane $2a : b : 3c$ is parallel to a plane $\frac{2}{3}a : \frac{1}{3}b : e$, the trace of which therefore, passes through $d$ and $e$. The plane $a : 2b : c$ has a trace which passes through $a$ and $f$, and as $d$ and $a$ intersect at $g$, it follows that $g$ is the direction of intersection of these two planes in projection.

Similarly the plane $a : b : \infty e$ is parallel to a plane $oa : ob : e$, the trace of which passes through the centre but parallel to a line from $a$ to $b$, that is its trace is oh which cuts $d$ and $e$ as a direction of intersection.

Finally the plane $\propto a : b : \infty e$ is parallel to a plane $ao : ob : e$, the trace of which must pass through $a$ and $o$, and as $d$ and $a$ intersect at $d$ the line $dc$ represents the direction of intersection.

Also in the same way the following directions are found:

- $k c$, the intersection of $a : 2b : c$ with $a : b : \infty e$.
- $a c$, the intersection of $a : 2b : c$ with $oa : b : \infty e$.
- $o c$, the intersection of $a : b : \infty e$ with $oa : b : \infty e$.

Fig. 166 shows the resultant drawing. In this a free hand sketch in as nearly as possible the conventional position is first made and then the directions corrected by paralleling the lines obtained in Fig. 165.
Tetragonal Axial Cross.

The value of \( c \left( \frac{c}{a} \right) \) is laid off proportionately on the vertical axis of the isometric axial cross. For instance, in zircon crystals, \( c = 0.64 \), the lines \( OC, OC' \) Fig. 161, are reduced to \( \frac{AA}{100} \) of present length.

Orthorhombic Axial Cross.*

The isometric cross, Fig. 161, is considered to be the projection of lines each equal in length to the desired macro axis \( \delta \), and the vertical and brachy axes are laid off as proportionate lengths of \( CC' \) and \( AA' \) respectively. For instance:

The ratio for barite is \( a : b : c = \frac{0.815}{1} : 1.313 \). The proportionate lengths \( 0.815 \) and \( 1.313 \) are measured and laid off on \( AA' \) and \( CC' \) as \( Oa \) and \( Oc \) respectively. \( Oc \) is half the projection of the desired vertical axis, and \( Oa \) is half the desired brachy axis.

---

*By taking \( OC \) a length equal some convenient scale, for instance, a unit’s length of the diagonal scale, Fig. 169, all measurements may be made upon it or any desired ratio may be maintained by proportionate dividers. In this case \( Oc = 1.313 \) and \( Os = 0.815 \) would be measured on the scale; then as \( Os \) is equal to \( OC \times 0.815 \), if \( C \) and \( A \) are connected and \( s a \) drawn parallel to \( CA, Oa \) will equal \( OA \times 0.815 \); that is, \( sa' \) will be the projection of the desired brachy axis.
MONOCLINIC AXIAL CROSS.\footnote{The sines and cosines, as well as other measurements, may be obtained directly by use of Fig. 169.}

As before, the isometric cross is considered to be the projection

A unit's length of the diagonal scale is the radius of the quadrant. The perpendicular and horizontal lines from any degree of the quadrant are in length respectively the natural sine and cosine of the angle corresponding to the degree, multiplied by a unit's length on the diagonal scale.

All measurements, whether axial lengths or sines and cosines of special angles, are measured on the scale or quadrant and laid off from the centre O on CC' (Fig. 161), and when needed, the same proportions of other lines are obtained by the application of the fact that "in any triangle a line parallel to the base divides the sides proportionately."

Fig. 169 is given here a convenient size for actual drawings. OC, in Fig. 161, is one-third of the unit length on this scale.

In the case of pyroxenes the sine and cosine of 74° to' are measured on the quadrant and laid off on CC', Fig. 168, as Om and OI respectively. A and C' are connected, mp is drawn parallel to AC' and the parallelogram pOlt completed to secure the point t and the line tO.

The distances 1.093 and 0.389 are measured on the diagonal scale and laid off on CC' as Ov and Oc respectively. C' and t are connected and vs is drawn parallel to C't; a a' is the projection of the desired clinax axis and Oc is half the projection of the desired vertical axis.

of lines equal to the desired axis $b$, and the vertical axis is laid off as a proportionate length on $CC'$, but $AA'$ being the projection of a line at 90° to $CC'$, is not the correct direction for the clino axis, which makes some oblique angle $\beta$ with $CC'$. The method can best be understood by an example:

The constants for pyroxene are $a: b: c = 1.092 : 1. : 0.589$ and $\beta = 74° 10'$. Assume the isometric cross, make $Oc$, Fig. 168 = $\frac{5}{8} 9 \times OC$; make $Ol = OC \cos 74° 10'$ and $Op = OA \sin 74° 10'$; complete the parallelogram $pOIt$; make $Oa = 1.092 \times Oc$. Then are $Oa$ and $Oc$ the projections of the desired clino and vertical semi-axes.

**Triclinic Axial Cross.**

As before, the isometric axial cross, Fig. 161, is assumed to be the projection of lines equal to the desired axis, $b$. The construction is best understood by an example.

The constants for axinite are $a: b: c = 0.492 : 1 : 0.479$, $d \wedge c = 82° 34' (100) \wedge (010) = 131° 39'$.

---

* By direct measurements, using Fig. 169, the method for axinite would be:

1. To obtain the macro axis $b'$.—The sine and cosine of $131° 39' (48° 21')$ are measured on the quadrant and laid off on $CC'$ as $Oa$ and $Oc$ respectively. $C$ is connected with $A'$ and $B$, and the points $e$ and $d$ are secured by drawing $s$ a parallel to $CB$ and $k$ a parallel to $CA'$; the point $n$ results from the completion of the parallelogram $sOcn$.

2. The sine and cosine of $82° 34'$ are measured on the quadrant and laid off on $CC'$ as $Oy$ and $Ox$ respectively. $C$ is connected with $y$ and $r$ drawn parallel to $Cy$; the completion of the parallelogram $Oxrb$ secures the extremity $b$ of the projection of the desired macro axis.

To obtain the brachy and vertical axes.—The steps are precisely those for monoclinic crystals. The sine and cosine of $91° 32' (88° 6')$ are measured on the quadrant and laid off on $CC'$ as $Om$ and $Ol$ respectively. $A'$ and $C'$ are connected, $m$ and $p$ drawn parallel to $AC'$, and the parallelogram $pOlt$ completed to secure the point $t$ and the line $10$.

The distances 0.492 and 0.479 are measured on the diagonal scale and laid off on $CC'$ as $Ov$ and $Oc$ respectively. $C'$ and $t$ are connected and $v$ is drawn parallel to $C't$; $v a'$ is the projection of the desired brachy axis and $Oc$ is half the projection of the desired vertical axis.
Vertical Axis.—Make $O_c = OC \times 0.479$.

Macro Axis.—Make $O_e = OB \sin 131^\circ 39'$, and $O_d = OA \cos 131^\circ 39'$; complete the parallelogram $dOen$. Make $O_r = On \sin 82^\circ 54'$ and $O_x = OC \cos 82^\circ 54'$; complete the parallelogram $rOxb$. Then is $Ob$ the projection of one-half the desired axis.

Brachy Axis. — Make $O_l = OC \cos 91^\circ 52'$, and $O_p = OA \sin 91^\circ 52'$. Complete the parallelogram $pOlt$; make $O_a = 0.492 \times Ot$; then is $Oa$ the projection of one-half the desired axis.

The Hexagonal Axial Cross.*

The isometric axial cross, Fig. 161, is assumed, and the construction is as follows:

Make $O_c$ proportionate length of $OC$ for the vertical axis of the given crystal. Make $O_p = OA \times 1.732$; draw $pB$ and $pB'$; bisect $Op$ by a line parallel to $BB'$; then are $OB$, $Oa$ and $Oa$, the projections of desired semi-axes.

* In direct measurement by Fig. 169 make $O_m = 1.732 \times OC$; draw $mp$ parallel to $AC'$, then proceed as above.
PART II.

BLOWPIPE ANALYSIS.

CHAPTER X.

APPARATUS, BLAST, FLAME, ETC.

The Blowpipe.

The "Lingke" or "Freiberg" blowpipe (Fig. 172), consists of:

1. A tapering tube of brass or German silver (B), of a length proportionate to the eyesight of the user. It is conveniently wrapped in baize or cardboard to protect the fingers from the heat.

2. A horn mouthpiece (C) at the larger end of the tube, best of trumpet-shape to fit against the lips.

3. A moisture chamber (A) at the smaller end of the tube.

4. A tapering jet (4) at right angles to the moisture chamber.

5. A tip of platinum, shown below, enlarged; it should be bored from a solid piece, and with an orifice of at least 0.5 millimetres.

Care of Blowpipe.

When not in use, the blowpipe should be so placed that the platinum tip is supported free from contact. If the tip is clogged by smoke or otherwise, it must be burned clean in a smokeless flame—never rubbed or cleaned with metal.

(77)
BLOWPIPE ANALYSIS.

The Blowpipe Lamp.

Any flame may be used for some tests; but, the hottest flame and greatest variations in quantity and quality of flame are obtained from oils rich in carbon, such as refined rape-seed, or olive or lard oil, or from mixtures of turpentine and alcohol.

An oil lamp with two openings, equivalent to the old Berzelius lamp (Fig. 173), is generally used.

The wick should be soft, close-woven, and cylindrical, such as is used for Argand lamps. It should be folded and inserted with the opening toward the lower side of the brass holder.

FILLING AND LIGHTING LAMP.

To fill the lamp, remove the two caps and pour in the oil through the smaller orifice. During work, the smaller cap is hung on the vertical rod; the larger is placed over the smaller orifice loosely, keeping out the dust, but admitting the needed air.

The lamp is lighted by blowing a flame up and across the wick. When well charred, the wick is carefully trimmed parallel to the brass holder.

Use of Gas.

Instead of the oil lamp and Lingke blowpipe, a gas blowpipe (Fig. 174) may be used for most of the operations; or if necessary a Bunsen burner may be converted into a blowpipe lamp by inserting in the main tube, another tube so as to cut off the air supply and insure a yellow flame. By flattening this tube at the upper end the flame may be made very much the shape of the lamp flame.

Charcoal and Plaster Supports.

Charcoal made from soft woods, such as willow or pine, is used to support the substance and receive any coats or sublimates that may form, and, in a measure, is a reducing agent. A convenient size is 4 inches long, 1 inch broad, and ⅛ inch thick.

Plaster tablets are used for the same purpose. These are prepared by making a paste of plaster of Paris and water, just thick enough to run, which is spread out upon a sheet of oiled glass and
smoothened to a uniform thickness (1/8" to 1/4") by another smaller sheet of glass, which may be conveniently handled by gumming a large cork to one side and using it as a plasterer's trowel. While still soft, the paste is cut through with a knife into uniform slabs, 4" by 1 1/2". It is then placed, still upon the glass, in an air-bath and dried, after which the tablets are easily detached.

Miscellaneous Apparatus:

Each student should have at his desk, in addition to blowpipe, blowpipe-lamp, charcoal and plaster:

FORCEPS, with platinum tips for fusion tests.

PLATINUM WIRE AND HOLDER.— Wire of the thickness of about 24 Am. standard wire gauge. The handle for holding this is sometimes only a short piece of small glass tubing, into the end of which the wire is fused. A holder with a receptacle for a stock of wires is more convenient.

REAGENT BOTTLES.—Four 2-oz. wide-mouthed bottles; for boric acid, soda, salt of phosphorus, and bismuth flux will be needed at all times. It is better to have about twelve such bottles in a convenient stand.

ANVIL.—Slab of polished steel, about 1 1/2" by 1 1/2" by 2 1/2".

HAMMER.—Steel, with square face, 3/4" or 1 1/4".

CLOSED TUBES OR MATRASSES.

BAR MAGNET, with chisel edge.

TRAYS, for dirt and for charcoal.

LENS, KNIFE, and WATCH GLASSES.

BLUE AND GREEN GLASSES.

STEEL FORCEPS AND LAMP SCISSORS for trimming wick.

Less essential are:

CUTTING PLIERS, for cutting bits from minerals to be tested.

AGATE MORTAR AND PESTLE.—Can be obtained 1 1/2" in diameter.

CUPEL HOLDER AND CUPELS, for silver determination.

SMALL PORCELAIN DISHES, IVORY SPOON, DROPPING TUBE.

THE BLAST.

The blast is produced by the muscles of the distended cheeks, and not by the lungs.

Sit erect, with the blowpipe held in the right hand, lightly but firmly as a pen is, and with the elbows against the sides. First breathe regularly, while the cheeks are distended and the mouth
closed; then, place the mouthpiece against the lips, continue the breathing through the nose, and allow air to pass into the pipe through the lips. From time to time, as needed, admit air to the mouth from the throat.

A LUMINOUS FLAME, Fig. 175, usually shows four fairly distinct portions:
1. A blue luminous base, \( a b \), of carbon dioxide or partially burned carbon.
2. An interior dark cone, \( c \), of unburned gases, not always visible.
3. A yellow luminous mantle, \( d \), of burning gases and incandescent carbon.

Oxidation and Oxidizing Flame.
The oxidizing flame is non-luminous, for luminosity indicates unconsumed carbon, and hence a more or less strongly reducing action.

To produce such a flame, trim the wick parallel to the holder, free from charred threads and not too high.

Place the tip of the blowpipe almost touching the wick, and extending in \( \frac{3}{4} \) the breadth of the flame (Fig. 176).

Blow parallel to the wick until there is produced a clear blue flame nearly an inch long. This blue flame is itself weakly reducing, but just beyond is an intensely hot, nearly colorless zone, which is strongly oxidizing, and the bead is held in this usually as far from the tip of the blue flame as the bead can be kept fluid. If the substance to be oxidized is supported on charcoal, a weak blast must be used.

HOW TO MAKE A BEAD OF BORAX OR SALT OF PHOSPHORUS.

A loop, something the shape of a shepherd’s crook, is made in platinum wire by bending it around a pencil point, or with the forceps, so that the end meets but does not cross the straight part. This loop is heated and dipped into the flux, and the portion of flux that adheres is fused to a bead, more being added until the bead is of good full shape. When the flux is salt of phosphorus,
the wire should be held over the flame so that the ascending hot gases will help to retain the flux upon the wire.

**Testing Purity of Oxidizing Flame.**

Molybdic acid is dissolved in a borax bead in the oxidizing flame until the bead is dark red when hot. The bead is then made opaque and nearly black by a reducing flame, and again made colorless by the oxidizing flame.

**Testing Heating Power of Oxidizing Flame.**

A fine splinter of calamine can *just* be fused at the tip of a strong blue flame.

**Reduction and the Reducing Flames.**

To blow the yellow reducing flame, Fig. 177, place the tip of the blowpipe one-eighth of an inch above and back of the middle of the flame, blow strongly parallel to the wick, and turn the entire flame in the direction of the blast.

The blast must be continuous; too strong to produce a sooty flame, and not strong enough to oxidize by excess of air.

The blue flame also is reducing because of the carbon monoxide it contains, but the quantity is not large enough to be generally effective.

**Testing Purity of Reducing Flame.**

Manganese dioxide is dissolved in a borax bead in the oxidizing flame until the bead is violet red when cold, and then made colorless in the reducing flame.

**Testing Heating Power of Reducing Flame.**

Cupric oxide or oxide of nickel is dissolved in a borax bead until the bead is opaque, and then reduced on charcoal to a clear bead and a metallic button.
CHAPTER XI.

OPERATIONS OF BLOWPIPE ANALYSIS.

Fusion.

The hottest portion of the flame is just beyond the tip of the blue flame. In some instances, noticeably certain iron ores, substances infusible in the oxidizing flame are fusible in the reducing flame.

The test will be differently made, according to the material.

(a) If metallic or reducible, treat in a shallow hole on charcoal, using a fragment of the substance the size of a pin's head.

(b) If stony or vitreous, treat a small sharp-edged fragment in the platinum forceps, at the tip of the blue flame, directing the flame upon the point.

(c) If in powder, or with a tendency to crumble, grind and mix with water to fine paste, spread thin on coal and dry, and, if coherent, hold in the forceps. If not coherent dip a moistened platinum wire in the powder, and treat the adhering powder in the flame.

There will be noted both the degree of fusibility and manner of fusion.

The degree of fusibility is stated in much the same way as the hardness by comparing it with a scale of fusibility. It is generally, however, sufficient to class a mineral as simply easily fusible, fusible, difficulty fusible, or infusible. For purposes of comparison, the following scale, suggested by v. Kobell, is usually adopted:

1. Stibnite, coarse splinters fuse in a candle flame.
2. Natrolite, fine splinters fuse in a candle flame.
3. Garnet (Almandite), coarse splinters easily fuse before the blowpipe.
4. Actinolite, coarse splinters fuse less readily before the blowpipe.
5. Orthoclase, only fused in fine splinters or on thin edges before the blowpipe.
6. Calamine, finest edge only rounded in hottest part of flame.
7. Quartz, infusible, retaining the edge in all its sharpness.
OPERATIONS OF BLOWPIPE ANALYSIS.

The trial should always be made on the smallest and finest pointed fragments, and the flame directed especially upon the point. It is always well to examine the splinter with a magnifying glass, before and after heating, to aid the eye in determining whether the edges have or have not been rounded by the heat.

The manner of fusion may be such as to result in a glass or slag which is clear and transparent, or white and opaque, or of some color, or filled with bubbles. There may be a frothing or intumescence, or a swelling and puffing out (exfoliation). In certain instances color and form may change without fusion, etc.

Flame Coloration.

During the fusion test the non-luminous veil is sometimes unchanged, but it is often enlarged and colored by some volatilizing constituent. There is frequently a feeble yellowish-red coloration due to water or sodium salts, but this gives place to the color proper.

The flame is best seen in a dark room or against a black background, such as a piece of charcoal, and is often improved by hydrochloric acid and occasionally by other reagents.

Some elements color the flame best at a gentle heat, others only at the highest heat attainable. A good method to cover all cases is to flatten the end of a platinum wire, dip it in hydrochloric acid, then in the finely-powdered substance. Hold first in the mantle flame near the wick and then at the hottest portion at the tip of the blue flame. It is possible in this way to obtain two distinct flames such as the red of calcium and the blue from copper.

Flame tests for Ca, Sr and Ba are not usually obtainable from silicates.

The important flame colorations are:

Yellows.

Reddish.—Sodium and all its salts. Invisible with blue glass.

Reds.

Carmine.—Lithium compounds. Masked by soda flame. Violet through blue glass. Invisible through green glass.

Scarlet.—Strontium compounds. Masked by barium flame. Violet red through blue glass. Yellowish through green glass.

Yellowish.—Calcium compounds. Masked by barium flame. Greenish gray through blue glass. Green through green glass.
Greens.

Yellowish.—Barium compounds, molybdenum sulphide and oxide; borates especially with sulphuric acid or boracic acid flux.

Pure Green.—Compounds of tellurium or thallium.

Emerald.—Most copper compounds without hydrochloric acid.

Bluish.—Phosphoric acid and phosphates with sulphuric acid.

Feeble.—Antimony compounds. Ammonium compounds.

Whitish.—Zinc.

Blues.

Light.—Arsenic, lead and selenium.

Azure.—Copper chloride.

With Green.—Copper bromide and other copper compounds with hydrochloric acid.

Violet.

Potassium compounds. Obscured by soda flame. Purple red through blue glass. Bluish green through green glass.

Volatilization.

In blowpipe analysis, antimony, arsenic, cadmium, zinc, tin, lead, mercury and bismuth are always determined by securing sublimates of either the metals themselves or of some volatile oxide, iodide, etc.

Other elements and compounds, such as sulphur, selenium, tellurium, osmium, molybdenum, ammonia, etc., are also volatilized and in part determined during volatilization as odors or by sublimates. Certain other compounds, particularly chlorides of sodium and potassium and of some other metals, such as copper, tin and lead, yield sublimates ordinarily disregarded.

Volatilization tests are commonly obtained on charcoal, or plaster or in open and closed tubes.

Treatment on Charcoal.

A shallow cavity, just sufficient to prevent the substance slipping, is bored at one end of the charcoal and a small fragment or a very little of the powdered substance is placed in it. The charcoal is held in the left hand, so that the surface is at right angles to the lamp but tipped vertically at about 120° to the direction in which the flame is blown.

A gentle oxidizing flame is blown, the blue flame not touching the substance but being just behind and in a line with it. After a
few moments the test is examined and all changes are noted, such as position and color of sublimates, color changes, odors, decrepitation, deflagration, formation of metal globules or magnetic particles. The heat is then increased and continued as long as the same reactions occur, but if, for instance, a sublimate of new color or position is obtained, it is often well to remove the first sublimate either by transferring the substance to another piece of charcoal or by brushing away the first formed sublimate after its satisfactory identification.

The same steps should then be followed using the reducing flame.

The sublimates differ in color and position on the charcoal; some are easily removed by heating with the oxidizing flame, some by the reducing flame, some are almost non-volatile, and some impart colors to the flame.

**Treatment on Plaster Tablets.**

Experience has shown that the sublimates obtained on charcoal and plaster supplement each other. The method of using is precisely the same and white sublimates are easily examined by first smoking the plaster surface by holding it in the lamp flame.

The coatings differ in position, and to some extent in color. Plaster is the better conductor, condenses the oxides closer to the assay, and therefore, the more volatile coatings are thicker and more noticeable on plaster, while the less volatile coatings are more noticeable when spread out on charcoal. Charcoal supplements the reducing action of the flame, and therefore is the better support where strong reduction is desired.

**Comparison of Important Sublimates on Charcoal and Plaster.**

1. **Without Fluxes.—Treated First in O. F., then in R. F.**

   **Arsenic.**—White volatile coat. On smoked plaster it is crystalline and prominent; on charcoal it is fainter and less distinct, but the odor of garlic is more marked.

   **Antimony.**—White pulverulent volatile coat, more prominent on charcoal.

   **Selenium.**

   *On Charcoal.—* Horse-radish odor and a steel-gray coat.

   *On Plaster.—* Horse-radish odor, brick-red to crimson coat.
TELLURIUM.

On Charcoal.—White coat with red or yellow border.
On Plaster.—Deep brown coat.

CADMIUM.

On Charcoal.—Brown coat surrounded by peacock tarnish.
On Plaster.—Dark brown coat shading to greenish-yellow and again to dark brown.

MOLYBDENUM.—Crystalline yellow and white coat with an outer circle of ultramarine blue. Most satisfactory on plaster.

LEAD.—1/2 Yellow sublimate with outer fringe of white. More noticeable on charcoal than on plaster.

BISMUTH.—White, not easily volatile coat, yellow while hot. Best on charcoal.

TIN.—White non-volatile coat close to assay, yellowish while hot. Best on charcoal.

II. With Bismuth Flux.*

LEAD.

On Plaster.—Chrome yellow coat.
On Charcoal.—Greenish-yellow, equally voluminous coat.

BISMUTH.

On Plaster.—Chocolate-brown coat, with an underlying scarlet; with ammonia it becomes orange-yellow, and later cherry-red.
On Charcoal.—Bright red band with a fringe of yellow.

MERCURY.

On Plaster.—Scarlet coat with yellow, but if quickly heated is dull yellow and black.
On Charcoal.—Faint yellow coat.

ANTIMONY.

On Plaster.—Orange coat stippled with peach-red.
On Charcoal.—Faint yellow coat.

ARSENIC.

On Plaster.—Yellow and orange coat, and not usually satisfactory.
On Charcoal.—Faint yellow coat.

TIN.

On Plaster.—Brownish-orange coat.
On Charcoal.—White coat.

* Two parts of sulphur, one part of potassium iodide, one part of acid potassium sulphate.
The following tests show only on the plaster:

Selenium.—Reddish-brown, nearly scarlet.
Tellurium.—Purplish-brown with darker border.
Molybdenum.—Deep ultramarine blue.

III. With Soda (Sodium Carbonate or Bicarbonate).

Soda on charcoal exerts a reducing action partly by the formation of sodium cyanide, partly because the salts sink into the charcoal and yield gaseous sodium and carbon monoxide. The most satisfactory method is to mix the substance with three parts of the moistened reagent and a little borax; then spread on the charcoal and treat with a good reducing flame until everything that can be absorbed has disappeared. Moisten the charcoal with water, break out and grind the portion containing the charge. Wash away the lighter part and examine the residue for scales and magnetic particles.

The reduction may result in:

1. Coating, but no reduced metal.
   - Volatile white coating and garlic odor, ... As.
   - Reddish-brown and orange coating with characteristic variegated border, ... Cd.
   - Non-volatile coating, yellow hot and white cold, ... Zn.
   - Volatile steel-gray coating and horseradish odor, ... Se.
   - Volatile white coating with reddish border, ... Te.

2. Coating with reduced metal.
   - Volatile thick white coating and gray brittle button, ... Sb.
   - Lemon-yellow coating and reddish-white brittle button, ... Bi.
   - Sulphur-yellow coating and gray malleable button, ... Pb.
   - Non-volatile white coating, yellow hot, and malleable white button, ... Sn.
   - White coating, made blue by touch of R. F., and gray infusable particles, ... Mo.

3. Reduced metal only.
   - Malleable buttons, ... Cu, Ag, Au.
   - Gray magnetic particles, ... Fe, Co, Ni.
   - Gray non-magnetic infusible particles, ... W, Pt, Pd, Ir, Rh.

The carbonate combines with many substances forming both fusible and infusible compounds. Many silicates dissolve with a little of the reagent, but with more are infusible; a few elements form colored beads with the reagent, especially on platinum.
BLOWPIPE ANALYSIS.

Infusible Compounds.—Mg, Al, Zr, Th, Y, Gl.
Fusible Compounds.—SiO₂ effervesces and forms a clear bead that remains clear on cooling if the reagent is not in excess.
TiO₂ effervesces and forms a clear yellow bead crystalline and opaque on cooling:
WO₃ and MoO₃ effervesce but sink in the charcoal.
Ba, Sr, Ta, V, Nb sink into the charcoal.
Ca fuses, then decomposes, and the soda sinks into the charcoal.
Colored Beads.—Mn forms a turquoise or blue-green opaque bead with soda on platinum wire in oxidizing flame.
Cr forms a chrome-yellow opaque bead with soda on platinum wire in oxidizing flame, which becomes green in reducing flame.

Tests in Closed Tubes and Matrasses.

The matrass is practically a glass tube closed at one end and blown to a bulb. In most cases better results are secured by using a plain narrow tube about 4 inches by 1/4 inch and closed at one end. The usual purpose is to note the effects of heat without essential oxidation; they are also used for effecting fusions with such reagents as KHSO₄, KClO₃, etc.

Enough of the substance is slid down a narrow strip of paper previously inserted in the tube to fill it to the height of about one-half inch; the paper is withdrawn and the slightly inclined tube heated at the lower end gradually to a red heat. The results may be: evolution of water, odorous and non-odorous vapors, sublimates of various colors, decrepitation, phosphorescence, fusion, charring, change of color, magnetization, etc.

Acid or alkaline moisture in the upper
part of tube, .................. H₂O.

Odorless gas that assists combustion (nitrates, chlorates
and per oxides), ................. O.
Pungent gas that whitens lime water, ............... CO₂.

Odors.
Odor of prussic acid, ............ CN.
Odor of putrid eggs, ............ H₂S.
Odor that suffocates, fumes colorless, bleaching action, .... SO₂.
Odor that suffocates, fumes violet, . . . . . I.*
fumes brown, . . . . . Br.
fumes greenish yellow, . . . . . Cl,
fumes etch the glass, . . . . . F.
Odor of nitric peroxide, fumes reddish-brown, . . . . . NO₂.
Odor of ammonia, fumes colorless or white, . . . . . NH₃,†

Sublimates.
Sublimate white, fusing yellow, . . . . . PbCl₂.
fusing to drops, disagreeable odor, and volatile, . . . . . Os.
yellow hot, infusible, . . . . . NH₄ (salts),
yellow hot, fusible, . . . . . HgCl₂.
fusible, needle crystals, . . . . . Sb₂O₃.
volatile, octahedral crystals, . . . . . As₂O₃.
fusible, amorphous powder, . . . . . TeO₂.
Sublimate mirror-like, collects in globules, . . . . . Hg.
does not collect in globules, . . . . . As, Cd, Te.

Sublimate red when hot, yellow cold, . . . . . S.
Sublimate dark red when hot, reddish-yellow cold, . . . . . As₂S₃.
Sublimate black when hot, reddish-brown cold, . . . . . Sb₂S₃.
Sublimate black, but becomes red when rubbed, . . . . . HgS.
Sublimate red to black, but becomes red when rubbed, . . . . . Se.

Color of substances changes
from white to yellow, cools yellow, . . . . . PbO₂.
from white to yellow, cools white, . . . . . ZnO.
from white to dark yellow, cools light yellow, . . . . . Bi₂O₃.
from white to brown, cools yellow, . . . . . SnO₂.
from white to brown, cools brown, . . . . . CdO.
from yellow or red to darker, after strong heat, cools green, . . . . . Cr₂O₃.
from red to black, cools red, . . . . . Fe₂O₃.
from blue or green to black, cools black, . . . . . CuO.

Tests in Open Glass Tubes.
By using a somewhat longer tube open at both ends and held in an inclined position a current of air is made to pass over the heated

* I, Br, Cl, F and NO₂ are assisted by mixing substance with acid potassium sulphate.
† NH₃, Hg, As, Cd are assisted by mixing with soda.
substance, and thus many substances not volatile in themselves absorb oxygen and release volatile oxides. The substance should be in state of powder.

Place the assay near the lower end of the tube and heat gently and then strongly, increasing the air current by holding the tube more and more nearly vertical.

Odor that suffocates, bleaching action, \( \text{SO}_2 \), indicating \( \text{S} \).
Odor of rotten horseradish, \( \text{SeO}_3 \), " Se."
Odor of garlic, \( \text{As}_2\text{O}_3 \), " As."
Sublime white volatile octahedral crystals, \( \text{As}_2\text{O}_3 \), " As."
Sublime white partially volatile, fusible to yellow drops, pearl gray cold, \( \text{PbOCl} \), " PbCl."
Sublime white non-volatile powder, dense fumes, \( \text{Sb}_2\text{O}_3 \), " Sh."
Sublime white non-volatile powder, fusible to colorless drops, \( \text{TeO}_2 \), " Te."
Sublime white non-volatile powder, fusible to yellow drops, white when cold, \( \text{PbSO}_4 \), " PbS."
Sublime white non-volatile fusible powder, \( \text{BiSO}_4 \), " BiS."
Sublime gray, red at distance, \( \text{SeO}_2 \), " Se."
Sublime yellow hot, white cold, crystalline near the assay, blue in reducing flame, \( \text{MoO}_3 \), " Mo."
Sublime brown hot, yellow cold, fusible, \( \text{Bi}_2\text{O}_3 \), " Bi."
Sublime metallic mirror, " Hg."

**Bead Tests with Borax and with Salt of Phosphorus.**

Preliminary to bead tests, many compounds, sulphides, arsenides, arsenates, etc., may be converted into oxides by roasting as follows:

Treat in a shallow cavity on charcoal at a dull red heat, never allowing the substance to fuse or even sinter. Use a feeble oxidizing flame to drive off sulphur, then a feeble reducing flame to reduce arsenical compounds, then reheat in an oxidizing flame. Turn, crush, and reroast until no sulphurous or garlic odor is noticeable.

Sodium tetraborate or borax may be considered as made up of sodium metaborate and boron trioxide. The boron trioxide at a high temperature combines with metallic oxides, driving out volatile
acids, and by the aid of the oxidizing flame the resulting borates fuse with the sodium metaphosphate to form double borates often of a characteristic color. The color may differ when hot and cold and according to degree of oxidation and reduction.

Sodium ammonium phosphate, or salt of phosphorus, by fusion loses water and ammonia and becomes sodium metaphosphate. The sodium metaphosphate at high temperatures combines with metallic oxides to form double phosphates and pyrophosphates, which like the double borates are frequently colored, although the colors often differ from those obtained with borax.

A bead of either flux is made on platinum wire as described on page 80, and the substance is added gradually to the warm bead and fused with it in the oxidizing flame. The ease of dissolving, effervescence, color, change of color, etc., should be noted.

We may greatly simplify the tabulation of results by the following division:

1. Oxides which Color neither Borax or Salt of Phosphorus, or at Most Impart a Pale Yellow to the Hot Bead when Added in Large Amounts.

<table>
<thead>
<tr>
<th>Oxides</th>
<th>Noticeable Distinctions</th>
</tr>
</thead>
<tbody>
<tr>
<td>Aluminum</td>
<td>Cannot be flamed opaque.</td>
</tr>
<tr>
<td>Antimony</td>
<td>Yellow hot in oxidizing flame, flamed opaque gray in reducing flame, on charcoal with tin black. Expelled by reducing flame in time.</td>
</tr>
<tr>
<td>Barium</td>
<td>Flamed opaque white.</td>
</tr>
<tr>
<td>Bismuth</td>
<td>Like antimony.</td>
</tr>
<tr>
<td>Cadmium</td>
<td>Like antimony, but not made black by fusion with tin.</td>
</tr>
<tr>
<td>Calcium</td>
<td>Like barium.</td>
</tr>
<tr>
<td>Lead</td>
<td>Like antimony, but not made black by fusion with tin.</td>
</tr>
<tr>
<td>Magnesium</td>
<td>Like barium.</td>
</tr>
<tr>
<td>Silicon</td>
<td>Only partially dissolved in salt of phosphorus.</td>
</tr>
<tr>
<td>Strontium</td>
<td>Like barium.</td>
</tr>
<tr>
<td>Tin</td>
<td>Like aluminum.</td>
</tr>
<tr>
<td>Zinc</td>
<td>Like antimony, but not made black by fusion with tin.</td>
</tr>
</tbody>
</table>
2. Oxides which Impart Decided Colors to the Beads.

The colors in hot and cold beads of both fluxes and under both oxidation and reduction may be briefly tabulated as follows. The abbreviations are h and h' hot beads, c c' cold beads (h and c relating to same bead, h' and c' to larger amount of oxide); sat = saturated; fl = flamed; op = opaque.
FLAMING.

Some substances yield a clear glass with borax or salt of phosphorus, which remains clear when cold, but at a certain point near saturation if heated slowly and gently or with an intermittent flame, or unequally, or by alternate oxidizing flame and reducing flame, the bead becomes opaque and enamel-like.

The reason is an incomplete fusion by which a part of the base is separated in the crystalline form.

Flaming is hindered or quite prevented by silica. The borax beads may in general be said to be colored more intensely by equal amounts of coloring oxides, than the salt of phosphorus beads while the latter may be said to yield the greater variety in color.

USE OF TIN WITH BEADS.

Reduction is sometimes assisted by transferring the borax or salt of phosphorus bead to charcoal and fusing it for a moment with a grain or two of metallic tin. The tin oxidizes and takes its oxygen partly from the oxides in the bead.

USE OF LEAD AND GOLD WITH BEADS.

Minute amounts of reduced metals, such as Cu, Ni, Co, may be collected from a bead by fusing it on charcoal with a small button of lead or gold. The glass bead can then be examined for the non-reducible oxides, and the lead or gold can by oxidation in contact with borax or salt of phosphorus, be made again to yield oxide colors from the reduced metals.

Separate the button and the slag, saving both, and heat the button with boracic acid to remove the lead, and then with frequently changed S. Ph. The metals which have united with the gold or lead will be successively oxidized, and their oxides will color the S. Ph. in the following order:

Co.—Blue, hot; blue, cold. May stay in the slag.
Ni.—Brown, hot; yellow, cold. May give green with Co or Cu.
Cu.—Green, hot; blue, cold. Made opaque red by tin and reducing flame.

The slag should contain the more easily oxidizable metals, and be free from Cu, Ni and Ag.

REDUCTION COLOR TESTS.

Saturate two S. Ph. beads with the substance in the oxidizing flame, treat one of them on charcoal with tin and strong reducing flame, pulverize and dissolve separately in cold dilute (1-4)
hydrochloric acid with the addition of a little tin. Let the solutions stand for some time and then heat them to boiling.

<table>
<thead>
<tr>
<th>The Oxidized Bead Yields</th>
<th>The Reduced Bead Yields</th>
</tr>
</thead>
<tbody>
<tr>
<td>In Cold Solution</td>
<td>In Hot Solution</td>
</tr>
<tr>
<td>W. Blue</td>
<td>Deep Blue</td>
</tr>
<tr>
<td>Mo. Green to Blue</td>
<td>Wine Brown</td>
</tr>
<tr>
<td>Ti. Faint Violet</td>
<td>Violet and Turbid.</td>
</tr>
<tr>
<td>V. Bluish Green</td>
<td>Green</td>
</tr>
<tr>
<td>Cr. Green</td>
<td>Green</td>
</tr>
<tr>
<td>Ur. Green</td>
<td>Green</td>
</tr>
</tbody>
</table>

Tests with Sodium Thiosulphate, $\text{Na}_2\text{S}_2\text{O}_3$.

A powdered metallic compound mixed with the dry flux, and either heated in a closed tube or upon a borax bead inside the blue flame will show the same color as would be produced by passing $\text{H}_2\text{S}$ through a solution of the compound.

White = Zn. Orange = Sb. Yellow = Cd, As.
Brown = Sn, Mo. Green = Cr, Mn.
Black = Pb, Fe, Co, Cu, Ni, Ur, Bi, Ag, Au, Pt, Hg.

Use of Acids.

Acids are chiefly used in blowpipe work to expel and detect volatile constituents, to determine ease of solubility or to assist flame tests.

Volatile constituents are released with bubbling (effervescence), and the constituent is detected by the odor, or sometimes by passing the gas into another reagent.

Solubility may be:

- With effervescence in the cold.
- With effervescence only on heating.
- Quiet and easy.
- Difficult and incomplete.
- With separation of perfect jelly.
- With separation of imperfect jelly.
- With separation of powder.
- With separation of crystals.
Tests with Cobalt Solution.

A dilute solution of cobalt nitrate imparts peculiar colors to various earths and oxides. The substance when moistened with the reagent and heated to redness in the oxidizing flame yields:

- **Blue**, fusible. Alkaline silicates, phosphates and borates, and some minerals containing aluminum, e.g., cryolite and natrolite.
- **Blue**, infusible $\text{Al}_2\text{O}_3$, $\text{SiO}_2$, earthy silicates.
- **Green** (bluish), Sn.
- **Green** (yellowish), Zn, Ti.
- **Green** (dark), Sb, Tb.
- **Gray**, Sr, Ca, Gl.
- **Violet**, Zr, magnesium phosphate and arsenate.
- **Flesh Color**, Mg, Ta, some magnesium silicates.
- **Brown**, Ba.

The alkaline earths strongly heated and when cold moistened with the reagent become without reheating:

- **Pink**, Al, Mg, Ba.
- **Blue** then green, Ca. **Blue** then brown, Sr.

Tests with Acid Potassium Sulphate.

This reagent may be used to decompose insoluble compounds preparatory to wet separation, but its use in blowpipe analysis is chiefly to release volatile vapors and as a component of bismuth flux and boric acid flux.

<table>
<thead>
<tr>
<th>Color of Fumes</th>
<th>Odor</th>
<th>Remarks</th>
<th>Indicating</th>
</tr>
</thead>
<tbody>
<tr>
<td>Brown</td>
<td>Pungent</td>
<td>From nitrates.</td>
<td>NO$_2$.</td>
</tr>
<tr>
<td>Brown</td>
<td>Choking</td>
<td>Turn starch paper</td>
<td>Br. yellow.</td>
</tr>
<tr>
<td>Violet</td>
<td>Choking</td>
<td>Turn starch paper</td>
<td>I. violet.</td>
</tr>
<tr>
<td>Yellowish-green</td>
<td>Chlorine</td>
<td>Explosive.</td>
<td>ClO$_2$.</td>
</tr>
<tr>
<td>Colorless</td>
<td>Burning sulphur</td>
<td>Corrodes the glass.</td>
<td>HF.</td>
</tr>
<tr>
<td>Colorless</td>
<td>Pungent</td>
<td>White vapors with</td>
<td>HCl. NH$_3$.</td>
</tr>
<tr>
<td>Colorless</td>
<td>Chlorine</td>
<td>Blacken lead acetate paper.</td>
<td>H$_2$S.</td>
</tr>
<tr>
<td>Colorless</td>
<td>Bad eggs</td>
<td>Whitens lime water.</td>
<td>HCN.</td>
</tr>
<tr>
<td>Colorless</td>
<td>Almonds</td>
<td>Whitens lime water.</td>
<td>CO$_2$.</td>
</tr>
</tbody>
</table>
Others of minor importance, acetic acid, chromic acid, organic acids, etc.

Tests with Potassium Chlorate.

Heat gradually in a matrass with the chlorate; finally there will be an energetic oxidation, and the fused mass will be:

Black = Ni, Cu. Bluish black = Co.

Tests with Boracic Acid Flux.

- Grind 4½ parts KHSO₄, 1 part CaF₂, to paste with water, add substance, thoroughly mixing. Heat at tip of the blue flame. Just after the water is driven off there may be yellow green flame of boron, or carmine flame of lithia.

Use of Boracic Acid.

Is used to separate lead and bismuth from antimony, copper, cadmium, silver, etc.
CHAPTER XII.

SUMMARY OF USEFUL TESTS WITH THE BLOWPIPE.

The details of ordinary manipulations, such as obtaining beads, flames, coatings and sublimates, are omitted and the results alone stated; unusual manipulations are described. The bead tests are supposed to be obtained with oxides; the other tests are true, in general, of all compounds not expressly excluded. The course to be followed in the case of interfering elements is briefly stated.

ALUMINUM, Al.

With Soda.—Swell and forms an infusible compound.
With Borax or S. Ph.—Clear or cloudy, never opaque.
With Cobalt Solution.*—Fine blue when cold.

AMMONIUM, NH₃.

In Closed Tube.—Evolution of gas with the characteristic odor. Soda or lime assists the reaction. The gas turns red litmus paper blue and forms white clouds with HCl vapor.

ANTIMONY, Sb.

On Coal, R. F.†—Volatile white coat, bluish in thin layers, continues to form after cessation of blast and appears to come directly off the mass.

With Bismuth Flux:

On Plaster.—Peach-red coat, somewhat mottled.
On Coal.—Faint yellow or red coat.

* Certain phosphates, borates and fusible silicates become blue in absence of alumina.
† This coat may be further tested by S. Ph. or flame.
In Open Tube.—Dense, white, non-volatile, amorphous sublimate. The sulphide, too rapidly heated, will yield spots of red.

In Closed Tube.—The oxide will yield a white fusible sublimate of needle crystals, the sulphide, a black sublimate red when cold.

Flame.—Pale yellow-green.

With S. Ph.—Dissolved by O. F. and fused on coal with tin in R. F. becomes gray to black.

INTERFERING ELEMENTS.

Arsenic.—Remove by gentle O. F. on coal.

Arsenic with Sulphur.—Remove by gentle heating in closed tube.

Copper.—The S. Ph. bead with tin in R. F. may be momentarily red but will blacken.

Lead or Bismuth.—Retard formation of their coats by intermittent blast, or by adding boracic acid. Confirm coat by flame, not by S. Ph.

ARSENIC, As.

On Smoked Plaster.—White coat of octahedral crystals.

On Coal.—Very volatile white coat and strong garlic odor. The oxide and sulphide should be mixed with soda.

With Bismuth Flux:

On Plaster.—Reddish orange coat.

On Coal.—Faint yellow coat.

In Open Tube.—White sublimate of octahedral crystals. Too high heat may form deposit of red or yellow sulphide.

In Closed Tube.—May obtain white oxide, yellow or red sulphide, or black mirror of metal. If the tube is broken and the mirror heated, a strong garlic odor will be noticed.

Flame.—Pale azure blue.

INTERFERING ELEMENTS.

Antimony.—Heat in closed tube with soda and charcoal, break and treat resulting mirror in O. F. for odor.

Cobalt or Nickel.—Fuse in O. F. with lead and recognize by odor.

Sulphur.—(a) Red to yellow sublimate of sulphide of arsenic in closed tube.

(b) Odor when fused with soda on charcoal.
USEFUL TESTS WITH THE BLOWPIPE.

BARIUM, Ba.

On Coal with Soda.—Fuses and sinks into the coal.

Flame.—Yellowish green improved by moistening with HCl.

With Borax or S. Ph.—Clear and colorless, can be flame opaque-white.

BISMUTH, Bi.

On Coal.—In either flame is reduced to brittle metal and yields a volatile coat, dark orange yellow hot, lemon yellow cold, with yellowish-white border.

With Bismuth Flux:* On Plaster.—Bright scarlet coat surrounded by chocolate brown, with sometimes a reddish border. The brown may be made red by ammonia.†

On Coal.—Bright red coat with sometimes an inner fringe of yellow.

With S. Ph.—Dissolved by O. F. and treated on coal with tin in R. F. is colorless hot but blackish gray and opaque cold.

INTERFERING ELEMENTS.

Antimony.—Treat on coal with boracic acid, and treat the resulting slag on plaster with bismuth flux.

Lead.—Dissolve coat in S. Ph. as above.

BORON, B.

All borates intumesce and fuse to a bead.

Flame.—Yellowish green. May be assisted by: (a) Moistening with H₂SO₄; (b) Mixing to paste with water, and boracic acid flux (4½ pts. KHSO₄, 1 pt. CaF₂); (c) By mixing to paste with H₂SO₄ and NH₄F.

BROMINE, Br.

With S. Ph. Saturated With CuO.—Treated at tip of blue flame, the bead will be surrounded by green and blue flames.

In Matrass With KHSO₄.—Brown choking vapor.

INTERFERING ELEMENTS.

Silver.—The bromide melts in KHSO₄ and forms a blood-red globule which cools yellow and becomes green in the sunlight.

* Sulphur 2 parts, potassic iodide 1 part, potassic bisulphate 1 part.
† May be obtained by heating S. Ph. on the assay.
CADMIUM, Cd.

On Coal R. F.—Dark brown coat, greenish yellow in thin layers. Beyond the coat, at first part of operation, the coal shows a variegated tarnish.

On Smoked Plaster with Bismuth Flux.—White coat made orange by (NH₄)₂S.

With Borax or S. Ph.—O. F. clear yellow hot, colorless cold, can be flamed milk-white. The hot bead touched to Na₂S₂O₃ becomes yellow.

R. F. Becomes slowly colorless.

INTERFERING ELEMENTS.

Lead, Bismuth, Zinc.—Collect the coat, mix with charcoal dust and heat gently in a closed tube. Cadmium will yield either a reddish brown ring or a metallic mirror. Before collecting coat treat it with O. F. to remove arsenic.

CALCIUM, Ca.

On Coal with Soda.—Insoluble and not absorbed by the coal.

Flame.—Yellowish red improved by moistening with HCl.

With Borax or S. Ph.—Clear and colorless, can be flamed opaque.

CARBON DIOXIDE, CO₂.

With Nitric Acid.—Heat with water and then with dilute acid. CO₂ will be set free with effervescence. The escaping gas will render lime-water turbid.

With Borax or S. Ph.—After the flux has been fused to a clear bead, the addition of a carbonate will cause effervescence during further fusion.

CHLORINE, Cl.

With S. Ph. Saturated with CuO.—Treated at tip of blue flame, the bead will be surrounded by an intense azure-blue flame.

On Coal with CuO.—Grind with a drop of H₂SO₄, spread the paste on coal, dry gently in O. F. and treat with blue flame, which will be colored greenish-blue and then azure-blue.

CHROMIUM, Cr.

With Borax or S. Ph.—O. F. Reddish hot, fine yellow-green cold.
R. F. In borax, green hot and cold. In S. Ph. red hot, green cold.

With Soda.—O. F. Dark yellow hot, opaque and light yellow cold.
R. F. Opaque and yellowish-green cold.

INTERFERING ELEMENTS.

Manganese.—The soda bead in O. F. will be bright yellowish-green.

COBALT, Co.

On Coal, R. F.—The oxide becomes magnetic metal. The solution in HCl will be rose-red but on evaporation will be blue.

With Borax or S. Ph.—Pure blue in either flame.

INTERFERING ELEMENTS.

Arsenic.—Roast and scorify with successive additions of borax. There may be, in order given: Yellow (iron), green (iron and cobalt), blue (cobalt), reddish-brown (nickel), green (nickel and copper), blue (copper).

Copper and other Elements which Color Strongly.—Fuse with borax and lead on coal in R. F. The borax on platinum wire in O. F. will show the cobalt, except when obscured by much iron or chromium.

Iron, Nickel or Chromium.—Fuse in R. F. with a little metallic arsenic, then treat as an arsenide.

Sulphur or Selenium.—Roast and scorify with borax, as before described.

COPPER, Cu.


Flame.—Emerald-green or azure-blue, according to compound. The azure-blue flame may be obtained:

(a) By moistening with HCl or aqua regia, drying gently in O. F. and heating strongly in R. F.

(b) By saturating S. Ph. bead with substance, adding common salt, and treating with blue flame.

With Borax† or S. Ph.—O. F. Green hot, blue or greenish-blue cold.

* Sulphur, selenium and arsenic should be removed by roasting. Lead necessitates a gentle heat.
† By repeated slow oxidation and reduction, a borax bead becomes ruby red.
R. F. Greenish or colorless hot, opaque and brownish-red cold. With tin on coal this reaction is more delicate.

INTERFERING ELEMENTS.

General Method.—Roast thoroughly, treat with borax on coal in strong R. F., and

If Button Forms.—Separate the button from the slag, remove any lead from it by O. F., and make either S. Ph. or flame test upon residual button.

If no Visible Button Forms.—Add test lead to the borax fusion, continue the reduction, separate the button and treat as in next test. (Lead Alloy.)

Lead or Bismuth Alloys.—Treat with frequently changed boracic acid in strong R. F., noting the appearance of slag and residual button.

Trace.—A red spot in the slag.

Over One Per Cent.—The residual button will be bluish-green when melted, will dissolve in the slag and color it red upon application of the O. F., or may be removed from the slag and be submitted to either the S. Ph. or the flame test.

FLUORINE, F.

Etching Test.—If fluorine is released it will corrode glass in cloudy patches, and in presence of silica there will be a deposit on the glass. According to the refractoriness of the compound the fluorine may be released:

(a) In closed tube by heat.
(b) In closed tube by heat and KHSO₄.
(c) In open tube by heat and glass of S. Ph.

With Conc. H₂SO₄ and SiO₂.—If heated and the fumes condensed by a drop of water upon a platinum wire, a film of silicic acid will form upon the water.

IODINE, I.

With S. Ph. Saturated with CuO.—Treated at the tip of the blue flame the bead is surrounded by an intense emerald-green flame.

In Matras with KHSO₄.—Violet choking vapor and brown sublimate.

* Oxides, sulphides, sulphates are best reduced by a mixture of soda and borax.
USEFUL TESTS WITH THE BLOWPIPE.

In Open Tube with Equal Parts Bismuth Oxide, Sulphur and Soda.—A brick-red sublimate.

With Starch Paper.—The vapor turns the paper dark purple.

INTERFERING ELEMENTS.

Silver.—The iodide melts in KHSO₄ to a dark red globule, yellow on cooling, and unchanged by sunlight.

IRON, Fe.

On Coal.—R. F. Many compounds become magnetic. Soda assists the reaction.

With Borax.*—O. F. Yellow to red hot, colorless to yellow cold.


With S. Ph.—O. F. Yellow to red hot, greenish while cooling, colorless to yellow cold.

R. F. Red hot and cold, greenish while cooling.

State of the Iron.—A borax bead blue from CuO is made red by FeO, and greenish by Fe₂O₃.

INTERFERING ELEMENTS.

Chromium.—Fuse with nitrate and carbonate of soda on platinum, dissolve in water and test residue for iron.

Cobalt.—By dilution the blue of cobalt in borax may often be lost before the yellow of iron.

Copper.—May be removed from borax bead by fusion with lead on coal in R. F.

Manganese.—(a) May be faded from borax bead by treatment with tin on coal in R. F.

(b) May be faded from S. Ph. bead by R. F.

Nickel.—May be faded from borax bead by R. F.

Tungsten or Titanium.—The S. Ph. bead in R. F. will be reddish-brown instead of blue or violet.

Uranium.—As with chromium.

Alloys, Sulphides, Arsenides, etc.—Roast, treat with borax on coal in R. F., then treat borax in R. F. to remove reducible metals.

LEAD, Pb.

On Coal†—In either flame is reduced to malleable metal and

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* A slight yellow color can only be attributed to iron, when there is no decided color produced by either flame in highly charged beads of borax and S. Ph.
† The phosphate yields no coat without the aid of a flux.
yields, near the assay, a dark lemon-yellow coat, sulphur-yellow
cold and bluish-white at border.

*With Bismuth Flux:
   *On Plaster.*—Chrome-yellow coat, blackened by \((\text{NH}_3)\)_2\(\text{S}\).
   *On Coal.*—Volatile yellow coat, darker hot.

*Flame.*—Azure-blue.

*With Borax or S. Ph.*—O. F. Yellow hot, colorless cold, flames
   opaque-yellow.
   R. F. Borax bead becomes clear, S. Ph. bead cloudy.

**INTERFERING ELEMENTS.**

*Antimony.*—Treat on coal with boracic acid, and treat the re-
sulting slag on plaster with bismuth flux.

*Arsenic Sulphide.*—Remove by gentle O. F.

*Cadmium.*—Remove by R. F.

*Bismuth.*—Usually the bismuth flux tests on plaster are sufficient.
In addition the lead coat should color the R. F. blue.

**LITHIUM, Li.**

*Flame.*—Crimson, best obtained by gently heating near the wick.

**INTERFERING ELEMENTS.**

* Sodium, (a) Use a gentle flame and heat near the wick. (b) Fuse
on platinum wire with barium chloride in O. F. The flame will be
first strong yellow, then green, and finally, crimson.

*Calcium or Strontium.*—As these elements do not color the flame
in the presence of barium chloride, the above test will answer.

*Silicon.*—Make into a paste with boracic acid flux and water, and
fuse in the blue flame. Just after the flux fuses the red flame will
appear.

**MAGNESIUM, Mg.**

*On Coal with Soda.*—Insoluble, and not absorbed by the coal.

*With Borax or S. Ph.*—Clear and colorless can be flamed opaque-
white.

*With Cobalt Solution.*—Strongly heated becomes a pale flesh
color.

**MANGANESE, Mn.**

*With Borax or S. Ph.*—O. F. Amethystine hot, reddens on cool-

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* With silicates this reaction is of use only in the absence of coloring oxides. The
  phosphate, arsenate and borate become violet-red.

† The colors are more intense with borax than with S. Ph.
ing. With much, is black and opaque. If a hot bead is touched to a crystal of sodium nitrate an amethystine or rose-colored froth is formed.

R. F. Colorless or with black spots.

*With Soda.*—O. F. Bluish-green and opaque when cold. Sodium nitrate assists the reaction.

**Interfering Elements.**

*Chromium.*—The soda bead in O. F. will be bright yellowish-green instead of bluish-green.

*Silicon.*—Dissolve in borax, then make soda fusion.

**MERCURY, Hg.**

*With Bismuth Flux.*

*On Plaster.*—Volatile yellow and scarlet coat. If too strongly heated the coat is black and yellow.

*On Coal.*—Faint yellow coat at a distance.

*In Matrass with Dry Soda or with Litharge.*—Mirror-like sublimate, which may be collected in globules.

**MOLYBDENUM, Mo.**

*On Coal.*—O. F. A coat yellowish hot, white cold, crystalline near assay.

R. F. The coat is turned in part deep blue, in part dark copper-red.

*Flame.*—Yellowish-green.

*With Borax.*—O. F. Yellow hot, colorless cold.

R. F. Brown to black and opaque.

*With S. Ph.*—O. F. Yellow-green hot, colorless cold.†

R. F. Emerald-green.

*Dilute (1/4) HCl Solutions.*—If insoluble the substance may first be fused with S. Ph. in O. F. If then dissolved in the acid and heated with metallic tin, zinc or copper, the solutions will be successively blue, green and brown. If the S. Ph. bead has been treated in R. F. the solution will become brown.

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*Gold-leaf is whitened by the slightest trace of vapor of mercury.

† Crushed between damp unglazed paper becomes red, brown, purple or blue, according to amount present.
BLOWPIPE ANALYSIS.

NICKEL, Ni.

On Coal.—R. F. The oxide becomes magnetic.

With Borax.—O. F. Violet hot, pale reddish-brown cold.

R. F. Cloudy and finally clear and colorless.

With S. Ph.—O. F. Red hot, yellow cold.

R. F. Red hot, yellow cold. On coal with tin becomes colorless.

INTERFERING ELEMENTS.

General Method.—Saturate two or three borax beads with roasted substance, and treat on coal with a strong R. F. If a visible button results, separate it from the borax, and treat with S. Ph. in the O. F., replacing the S. Ph. when a color is obtained.

If no visible button results, add either a small gold button or a few grains of test lead. Continue the reduction, and:

With Gold.—Treat the gold alloy on coal with S. Ph. in strong O. F.

With Lead.—Scorify button with boracic acid to small size, complete the removal of lead by O. F. on coal, and treat residual button with S. Ph. in O. F.

Arsenic.—Roast thoroughly, treat with borax in R. F. as long as it shows color, treat residual button with S. Ph. in O. F.

Alloys.—Roast and melt with frequently changed borax in R. F. adding a little lead if infusible. When the borax is no longer colored, treat residual button with S. Ph. in O. F.

NITRIC ACID, HNO₃.

In Matrass with KHSO₄ or in Closed Tube with Litharge.—Brown fumes with characteristic odor. The fumes will turn ferrous sulphate paper brown.

PHOSPHORUS, P.

Flame.—Greenish-blue, momentary. Improved by conc. H₂SO₄.

In Closed Tube with Dry Soda and Magnesium.—The soda and substance are mixed in equal parts and dried, and made to cover the magnesium. Upon strongly heating there will be a vivid incandescence, and the resulting mass, crushed and moistened, will yield the odor of phosphuretted hydrogen.

POTASSIUM, K.

Flame.—Violet, except borates and phosphates.
USEFUL TESTS WITH THE BLOWPIPE.

INTERFERING ELEMENTS.

Sodium.—(a) The flame, through blue glass, will be violet or blue.

(b) A bead of borax and a little boracic acid, made brown by nickel, will become blue on addition of a potassium compound.

Lithium.—The flame, through green glass, will be bluish-green.

SELENIUM, Se.

On Coal, R. F.—Disagreeable horse-radish odor, brown fumes, and a volatile steel-gray coat with a red border.

In Open Tube.—Steel-gray sublimate, with red border, sometimes white crystals.

In Closed Tube.—Dark-red sublimate and horse-radish odor.

Flame.—Azure-blue.

On Coal with Soda.—Thoroughly fuse in R. F., place on bright silver, moisten, crush, and let stand. The silver will be blackened.

SILICON, Si.

On Coal with Soda.—With its own volume of soda, dissolves with effervescence to a clear bead. With more soda the bead is opaque.

With Borax.—Clear and colorless.

With S. Ph.—Insoluble. The test made upon a small fragment will usually show a translucent mass of undissolved matter of the shape of the original fragment.

When not decomposed by S. Ph., dissolve in borax nearly to saturation, add S. Ph., and re-heat for a moment. The bead will become milky or opaque white.

SILVER, Ag.

On Coal.—Reduction to malleable white metal.

With Borax or S. Ph.—O. F. Opalescent.

Cupellation.—Fuse on coal with 1 vol. of borax glass and 1 to 2 vols. of test lead in R. F. for about two minutes. Remove button and scorify it in R. F. with fresh borax, then place button on cupel and blow O. F. across it, using a strong blast and as little flame as are consistent with keeping button melted.

If the litharge is dark, or if the button freezes before brightening, or if it brightens but is not spherical, rescorify it on coal with borax,
add more test lead, and again cupel until there remains only a white spherical button of silver.

**SODIUM, Na.**

*Flame.*—Strong reddish-yellow.

**STRONTIUM, Sr.**

*On Coal with Soda.*—Insoluble, absorbed by the coal.

*Flame.*—Intense crimson, improved by moistening with HCl.

*With Borax or S. Ph.*—Clear and colorless; can be flamed opaque.

**INTERFERING ELEMENTS.**

*Barium.*—The red flame may show upon first introduction of the sample into the flame, but it is afterward turned brownish-yellow.

*Lithium.*—Fuse with barium chloride, by which the lithium flame is unchanged.

**SULPHUR, S.**

*On Coal with Soda and a Little Borax.*—Thoroughly fuse in the R. F., and either:

(a) Place on bright silver, moisten, crush and let stand. The silver will become brown to black. Or,

(b) Heat with dilute HCl (sometimes with powdered zinc); the odor of H₂S will be observed.

*In Open Tube.*—Suffocating fumes. Some sulphates are unaffected.

*In Closed Tube.*—May have sublimate red when hot, yellow cold, or sublimate of undecomposed sulphide, or the substance may be unaffected.

*With Soda and Silica* (equal parts).—A yellow or red bead.

*To Determine Whether Sulphide or Sulphate.*—Fuse with soda on platinum foil. The sulphide only will stain silver.

**TELLURIUM, Te.**

*On Coal.*—Volatile white coat with red or yellow border. If the fumes are caught on porcelain, the resulting gray or brown film may be turned crimson when moistened with conc. H₂SO₄ and gently heated.
USEFUL TESTS WITH THE BLOWPIPE.

On Coal with Soda.—Thoroughly fuse in R. F. Place on bright silver, moisten, crush and let stand. The silver will be blackened. Flame.—Green.
In Open Tube.—Gray sublimate fusible to clear drops.
With \( \text{H}_2\text{SO}_4 \) (conc.).—Boiled a moment, there results a purple violet solution, which loses its color on further heating or on dilution.

TIN, Sn.

On Coal.—O. F. The oxide becomes yellow and luminous.
R. F. A slight coat, assisted by addition of sulphur or soda.
With Cobalt Solution.—Moisten the coal, in front of the assay, with the solution, and blow a strong R. F. upon the assay. The coat will be bluish-green when cold.
With CuO in Borax Bead.—A faint blue bead is made reddish-brown or ruby-red by heating a moment in R. F. with a tin compound.

INTERFERING ELEMENTS.

Lead or Bismuth (Alloys).—It is fair proof of tin if such an alloy oxidizes rapidly with sprouting and cannot be kept fused.
Zinc.—On coal with soda, borax and charcoal in R. F. the tin will be reduced, the zinc volatilized; the tin may then be washed from the fused mass.

TITANIUM,\(^*\) Ti.

With Borax.—O. F. Colorless to yellow hot, colorless cold, opalescent or opaque-white by flaming.
R. F. Yellow to brown, enamel blue by flaming.
With S. Ph.—O. F. As with borax.
R. F. Yellow hot, violet cold.

HCl Solutions.—If insoluble the substance may first be fused with S. Ph. or with soda and reduced. If then dissolved in dilute acid and heated with metallic tin, the solution will become violet after standing. Usually there will also be a turbid violet precipitate, which becomes white.

INTERFERING ELEMENTS.

Iron.—The S. Ph. bead in R. F. is yellow hot, brownish-red cold.

TUNGSTEN, W.

With Borax.—O. F. Colorless to yellow hot, colorless cold, can be flamed opaque-white.

\(^*\) If the substance is mixed with sodium fluoride, fused on platinum with a little sodium pyrosulphate and dissolved by boiling in a very weak solution of sulphuric acid, the addition of a few drops of hydrogen peroxide will produce a color like that of ferric chloride.
BLOWPIPE ANALYSIS.

R. F. Colorless to yellow hot, yellowish-brown cold.

With S. Ph.—O. F. Clear and colorless.

R. F. Greenish hot, blue cold. On long blowing or with tin on coal, becomes dark green.

With Dilute HCl.—If insoluble, the substance may first be fused with S. Ph. The solution heated with tin becomes dark blue; with zinc it becomes purple and then reddish-brown.

INTERFERING ELEMENTS.

Iron.—The S. Ph. in R. F. is yellow hot, blood-red cold.

URANIUM, U.

With Borax.—O. F. Yellow hot, colorless cold, can be flamed enamel yellow.

R. F. Bottle-green, can be flamed black but not enamelled.

With S. Ph.—O. F. Yellow hot, yellowish-green cold.

R. F. emerald-green.

INTERFERING ELEMENTS.

Iron.—With S. Ph. in R. F. is green hot, red cold.

VANADIUM, V.

With Borax.—O. F. Colorless or yellow hot, greenish-yellow

R. F. Brownish hot, emerald-green cold.

With S. Ph.—O. F. Dark yellow hot, light yellow cold.

R. F. Brown hot, emerald-green cold.

H₂SO₄ Solutions.—Reduced by Zn become successively yellow, green, bluish-green, blue, greenish-blue, bluish-violet and lavender.

ZINC, Zn.

On Coal.—O. F. The oxide becomes yellow and luminous.

R. F. Yellow coat, white when cold, assisted by soda and a little borax.

With Cobalt Solution.—Moisten the coal, in front of the assay, with the solution, and blow a strong R. F. upon the assay. The coat will be bright yellow-green when cold.
USEFUL TESTS WITH THE BLOWPIPE.

Interfering Elements.

Antimony.—Remove by strong O. F., or by heating with sulphur in closed tube.

Cadmium Lead or Bismuth.—The combined coats will not prevent the cobalt solution test.

Tin.—The coats heated in an open tube, with charcoal dust by the O. F., may yield white sublimate of zinc.
CHAPTER XIII.

SCHEMES FOR QUALITATIVE BLOWPIPE ANALYSIS.*

Test I.—Heat a portion gently with O. F. upon charcoal or a plaster tablet which has been blackened in the lamp flame.

As.—White very volatile crystalline coat, best on plaster.

The coat disappears before R. F., tingeing it pale blue and evolving a characteristic garlic odor.

Confirmation As.—The coating may be dissolved in solution of KOH, placed in a test tube, a small piece of sodium amalgam added, and the tube covered with a piece of filter paper moistened with a slightly acid solution of AgNO₃. The paper will be stained black by the AsH₃ evolved.

Sb.—White pulverulent volatile coat, best on charcoal.

A good distinguishing feature between As and Sb is as follows: They both usually continue to give off fumes after removal of the flame, but while still hot the As₂O₃ fumes are not visible within one-half inch of assay, while Sb₂O₃ fumes appear to come immediately off of the mass.

Confirmation Sb.—The coating disappears before R. F., tingeing it a pale yellow-green, or, if scraped together, dissolved in S. Fh. and just fused on charcoal in contact with it will form a gray or black opaque bead.

If the coating be scraped off and dissolved in tartaric acid + HCl, and the solution placed in a platinum capsule with a piece of zinc, Sb, if present, will give a black adherent stain. This may be confirmed by washing the stain with water, then dissolving it in a few drops of hot tartaric acid plus a drop or two of HCl; on adding H₂S, an orange precipitate Sb.

Test I. may also yield non-volatile coatings of Sn or Zn near the assay, yellow hot and white cold; yellow coatings of Po or Bi; crystalline yellow and white coating of Mo; brick red to crimson coating and horseradish odor of Se and deep brown coatings of Cd and Te. All of these will be detected with greater certainty by later tests.

Test II.—Mix a portion with a spoonful of soda and a little borax and heat strongly upon charcoal with R. F. for three or four minutes. Preserve the fused mass for subsequent examination.

SCHEMES FOR QUALITATIVE ANALYSIS

As.—Garlic odor and a white volatile coat.
Cd.—Dark brown volatile coat, sometimes shading to greenish-yellow and usually surrounded by a variegated coloration resembling the colors of peacock feathers.

CONFIRMATION Cd.—The coat forms at first heating, and, if mixed with Na₂S₂O₇ and fused in a borax bead, will form a bright yellow mass of CdS.

Zn.—White not easily volatile coat, yellow when hot.
Sn.—White non-volatile coat close to assay, yellow while hot and usually small in amount.

CONFIRMATION Zn and Sn.—If any coat forms, moisten it with cobalt solution and blow a strong blue flame on the substance. The coatings from other elements will not prevent the cobalt coloration. The zinc coat is made bright yellowish-green. The tin coat becomes bluish-green.

Test II. may also yield white coats from Pb, Bi or alkalies, yellow coats from Pb or Bi, brown or red coats from Cu or Mo, and the ash of the coal may be white or red.

Test III.—Crush and pulverize the soda of Test II.; collect any magnetic particles with the magnet; dissolve some of the magnetic particles in a borax bead with the O. F. Try also effect of R. F.; then also place some of the non-magnetic portion of the powder upon a bright silver surface; moisten with water and let stand.*

Fe.—The bead is: O. F. hot, yellow to red; O. F. cold, colorless to yellow; R. F. cold, bottle-green.

CONFIRMATION Fe.—The magnetic particles yield with HNO₃ a brown solution from which, after evaporating excess of acid, K₄FeC₇O₄ throws down a blue precipitate.

Ni.—The bead is: O. F. hot, intense violet; O. F. cold, pale brown; R. F. cold, colorless.

CONFIRMATION Ni.—If the excess of acid is driven off by evaporation, KC₇O₄ added in excess, and the solution then made strongly alkaline with KOH, two or three drops of pure bromine will give a black precipitate of Ni₂(OH)₄.

Co.—The bead is: O. F. and R. F. hot or cold, a deep pure blue; if greenish when hot, probably Fe or Ni is also present.

* There may be contained in the soda also metallic particles or buttons, which may be roughly recognized by color and tenacity, as follows:
MALLEABLE.—Ag., silver-white; Sn, white; Pb, gray; Au, yellow; Cu, red.
BRITTLE.—Sb, white; Bi, reddish-white.
CONFIRMATION Co.—The magnetic particles yield with HNO₃ a rose-red solution which becomes bluish on evaporation.

S, Se, Te.—The bright silver is stained black or dark-brown, and unless the horseradish odor of Se or the brown coatings of Se and Te with bismuth flux have been already obtained, this stain will prove sulphur.

CONFIRMATIONS S.—The soda fusion will evolve H₂S when moistened with HCl. By holding in the gas a piece of filter paper moistened with a drop or two of lead acetate (test is made more sensitive by adding a drop of ammonia to the acetate), the paper will be stained black.
CONFIRMATION Se.—Characteristic disagreeable horseradish odor during fusion.
CONFIRMATIONS Te.—If a little of the original substance is dropped into boiling concentrated H₂SO₄, a deep violet color is produced; this disappears on further heating.
The quite cold soda fusion added to hot water produces a purple-red solution.

TEST IV.—Mix a portion of the substance with more than an equal volume of bismuth flux,* and heat gently upon a plaster tablet with the oxidizing flame.

Pb.—Chrome-yellow coat, darker hot, often covering the entire tablet.
CONFIRMATION Pb.—If the test is made on charcoal, the coat is greenish-yellow, brown near the assay.

Hg.—Gently heated, bright scarlet coat, very volatile, and with yellow fringe; but if quickly heated, the coat formed is pale yellow and black.
CONFIRMATION Hg.—If the substance is heated gently in a closed tube or matrix with dry soda or litharge, a mirror-like sublimate will form, which may be collected into little globules of Hg by rubbing with a match end. The test with bismuth flux on charcoal yields only a faint yellow coat.

Bi.—Bright chocolate-brown coat, with sometimes a reddish fringe.
CONFIRMATIONS Bi.—The coat is turned orange-yellow, then cherry-red, by flames of NH₃, which may conveniently be produced by heating a few crystals of S. Ph. on the assay. The test with bismuth flux on charcoal yields a bright-red band, with sometimes an inner fringe of yellow.

Sb.—Orange to peach-red coat, very dark when hot.

* Formed by grinding together 1 part KI, 1 part KHSO₄, 2 parts S.
SCHEMES FOR QUALITATIVE ANALYSIS.

Confirmation Sh.—The coat becomes orange when moistened with \((\text{NH}_3)_2\)S. Test IV. may yield colored sublimates with large amounts of certain other elements, and on smoked plaster certain white sublimates are obtainable. In all cases the elements are detected with greater certainty by other tests, but for convenience they are here summarized: Se, brownish-orange; As, reddish-orange; Se, reddish-brown; Te, purplish-brown, with deep brown border; Mo, deep ultramarine blue; Cu, Cd, Zn, white on smoked plaster.

Test V.—Dissolve substance in salt of phosphorus in O. F. so long as bead remains clear on cooling. Treat then for three or four minutes in a strong R. F. to remove volatile compounds. Note the colors hot and cold, then re-oxidize and note colors hot and cold.

Fe, Ti, Mo, W.—The bead in O. F. cold is colorless or very faint yellow.

Confirmation Fe.—The bead in its previous treatment should have been O. F. hot, yellow to red; O. F. cold, colorless; R. F. cold, bottle green.

Confirmation Ti.—The bead is reduced on charcoal with tin, pulverized and dissolved in \(\frac{1}{2}\) HCl with a little metallic tin. The reduced bead is violet, the solution is violet and turbid.

Confirmations Mo.—Tested as above on charcoal with tin, etc., the reduced bead is green, the solution is dark brown. Heat a little of the substance on platinum foil with a few drops of cone HNO\(_3\). Heat until excess of HNO\(_3\) has all volatilized, then add few drops of strong H\(_2\)SO\(_4\) and heat until copious fumes are evolved; cool, and breathe upon the cooled mass; an ultramarine blue = Mo.

Confirmation W.—Tested on charcoal with tin, etc., as above, the reduced bead is green, the solution is deep blue.

Ur, V, Ni.*—The bead in O. F. cold, is colored yellow or greenish-yellow.

* If the absence of Ni is not proved, or Co obscures the tests, dissolve the substance in borax on charcoal to saturation, and treat for five minutes in hot R. F.

If a visible button results, separate it from the borax, and treat with S. Ph. in the O. F., replacing the S. Ph. when a color is obtained.

If no visible button results, add either a small gold button or a few grains of test lead. Continue the reduction, and, if lead has been used, scorify the button with frequently changed borax acid to small size, stoppering the instant the boraxic acid is colored by Co, Ni, or Cu, blue, yellow, or red, respectively.

Complete the removal of lead by O. F. on coal, and treat as below.

Treat the gold alloy, or the residual button from the lead alloy, on coal, with frequently changed S. Ph., in strong O. F.

The metals which have united with the gold or lead, will be successively oxidized and their oxides will color the S. Ph. in the following order:

Co.—Blue, hot; blue, cold. May stay in the slag.

Ni.—Brown, hot; yellow, cold. May give green with Co or Cu.

Cu.—Green, hot; blue, cold. Made opaque red by tin and R. F.

The slag should contain the more easily oxidizable metals, and be free from Cu,
CONFIRMATION U.—The bead in R. F. is dull green, hot; fine green, cold. Make a Na₂CO₃ fusion, dissolve in HCl or H₂SO₄, add a few drops of H₂S water, and if it gives any precipitate, add it in excess and filter; to filtrate add a few drops of HNO₃ and boil, then add NH₄OH to alkaline reaction, filter, wash precipitate with ammonia water, and then treat precipitate with a concentrated solution of (NH₄)₂CO₃ + NH₄OH, filter, acidify filtrate with HCl, and add K₃Fe(CN)₆. Brown ppt. = Ur.

CONFIRMATION V.—In R. F. the bead will be brownish hot, fine green cold. Fuse substance with Na₂CO₃ in O. F., and dissolve fusion in a few drops of dilute H₂SO₄ or HCl, add a piece of zinc and warm; blue color changing to green and finally violet = V.

CONFIRMATION Ni.—A borax bead in O. F. will be intense violet, and in R. F. will be reddish hot, yellow cold.

Mn.—The bead in O. F., cold, is colored violet; if touched while hot to a crystal of nitre, it is made deep permanganate color.

CONFIRMATION Mn.—Fused on platinum wire in O. F., with a paste of soda, and nitre, manganese yields an opaque bluish-green bead.

Cr.—The bead in O. F., cold, is colored green.

There may be a green bead from admixture of a blue and a yellow. If Cr is not proved, examine in such a case for Ur, V, Cr, etc., with unusual care.

CONFIRMATION Cr.—If the substance is fused on platinum wire in the O.F. with a paste of soda and nitre, an opaque yellow bead is produced; and if the soda bead is dissolved in water, filtered, acidified with acetic acid, and a drop or two of lead acetate added, a yellow precipitate will be formed.

Co, Cu.—The bead in O. F., cold, is colored blue.

CONFIRMATION Co.—The bead is deep blue, hot and cold, in both flames.

CONFIRMATION Cu.—The bead is green, hot, greenish blue, cold, and on fusion with tin on coal becomes opaque brownish-red.

With larger percentage of copper, the substance will yield a mixed azure-blue and green flame on heating with HCl.

SiO₂, Al₂O₃, TiO₂, SnO₂.—The saturated bead contains an appreciable amount of insoluble material, in the form of a translucent cloud, jelly-like mass, or skeleton form of the original material.

CONFIRMATION SiO₂.—Mix the dry substance with a little dry calcium fluoride free from SiO₂, place in a dry test tube and add cone. H₂SO₄ and heat gently, hold in fumes given off, a drop of water in loop of platinum wire; SiO₂ will be separated on coming in contact with the water and form a jelly-like mass.

Ni, and Ag. Test a portion with S. Ph. and tin to prove absence of Cu. If present, it must be removed by further reduction with lead. Pulverize the slags and dissolve a portion in S. Ph., and examine by Test V.
SCHEMES FOR QUALITATIVE ANALYSIS.

Silica or silicates fused with soda unite with noticeable effervescence.

**Confirmation** Al₂O₃, TiO₂, SnO₂, SiO₂—If infusible, moisten the pulverized mineral with dilute cobalt nitrate solution and heat strongly.

Al₂O₃—Beautiful bright blue.

TiO₂—Yellowish green.

SnO₂—Bluish green.

SiO₂—Faint blue; deep blue, if fusible.

There may also be blues from fusible phosphates and borates, greens from oxides of Zn, Sb, violet from Zr, various indefinite browns and grays, and a very characteristic pale pink or flesh color from Mg.

**Confirmation** SnO₂—Treat the finely pulverized mineral with Zn and HCl in contact with platinum. Dissolve any reduced metal in HCl and test with HgCl₂. There will be white or gray ppt.

Ba, Ca, Sr, Mg.—The saturated bead is white and opaque and the nearly saturated bead can be flamed white and opaque.

**Confirmation** Ba, Ca, Sr.—Moisten the flattened end of a clean platinum wire with dilute hydrochloric acid, dip it in the roasted substance, and heat strongly at the tip of the blue flame, and gently near the wick. Remoisten with the acid frequently.

Ba.—Yellowish-green flame, bluish-green through green glass.

Ca.—Yellowish-red (brick-red) flame, green through green glass.

Sr.—Scarlet-red flame, faint yellow through green glass.

There may also be produced Li, carmine-red flame, invisible through green glass. K, rose-violet flame, reddish-violet through blue glass. Na, orange-yellow flame, invisible through blue glass. Cu, azure-blue and emerald green. Se and As, pale blue. Mo, Sh, Te, pale green.

**Confirmation** Mg.—Moisten the roasted substance with cobalt solution, and heat strongly. The substance will be colored pale pink or flesh color, or violet if present as either arsenate or phosphate.

**Test** VI.—Cupellation for silver and gold. Fuse one vol. of the roasted substance on charcoal with 1 vol. of borax glass, and 1 to 2 vol. of test lead in R. F. for about two minutes. Remove button and scorify it in R. F. with fresh borax, then place button on cupel and blow O. F. across it, using as strong blast and as little flame as are consistent with keeping the button melted. If the litharge is dark, or if the button freezes before brightening, or if it brightens but is not spherical, re-scorify it on charcoal with borax, add more test lead, and again cupel until there remains only a bright spherical button unaltered by further blowing.

Ag.—The button is white.

Au.—The button is yellow or white.

**Confirmation** Ag and Au.—Dissolve in a drop of HNO₃, and add a drop of
BLOWPIPE ANALYSIS.

HCl, producing a white curd-like precipitate. If gold is present there will be a residue insoluble in HNO₃ which will become golden yellow on ignition.

TEST VII.—Heat substance in matraas with acid potassium sulphate.

N₂O₅, Br.—Reddish brown vapor.

CONFIRMATION N₂O₅.—The gas turns ferrous sulphate paper brown. Nitrates decompose violently when fused on charcoal.

Cl.—Colorless or yellowish green vapor, with odor of chlorine.

I.—Violet choking vapor.

CONFIRMATION Br, Cl, I.—Saturate a salt of phosphorus bead with CaO₂, add substance, and treat in air. Br, azure blue and emerald green flame. Cl, azure blue flame with a little green. I, emerald green flame.

Fuse with Na₂CO₃, pulverize and mix with MnO₂ and add a few drops of conc. H₂SO₄ and heat. Cl, yellowish green gas that bleaches vegetable colors. Br, red fumes.

Fuse with Na₂CO₃ dissolve in water, make slightly acid with H₂SO₄ and add Fe₂(SO₄)₃ / ferric alum may be used, and boil. I, violet fumes (turn starch paper blue).

F.—The glass of the matras is corroded, and if SiO₂ is present a film of SiO₂ is often deposited on the glass.

CONFIRMATION F.—If the substance be mixed with silica and then heated with concentrated sulphuric acid, and the fumes caught on a drop of water held in a loop of platinum wire, gelatinous silica will form in the water.

TEST VIII.—Heat the substance gently with water to remove air bubbles and then with dilute hydrochloric acid.

CO₂.—Effervescence continuing after heat is removed.

H₂S, Cl and H are sometimes evolved, but usually the odor will distinguish these.

CONFIRMATION CO₂.—If the gas is passed into lime water, a white cloud and ppt. will be produced.

TEST IX.—Place a piece of Mg wire in a closed tube; and cover the wire with a mixture of soda and the substance. Heat till the mass takes fire, cool and add water.

P.—Evolution of phosphine, recognized by odor.

CONFIRMATION P.—Fuse a little of the substance, previously roasted if it contains As, with two or three parts Na₂CO₃ and one of NaNO₃, dissolve in HNO₃, and add excess of
SCHEMES FOR QUALITATIVE ANALYSIS.

(NH₄)₂MoO₄; yellow ppt. = P₂O₅. In presence of SiO₂ it is well to confirm this ppt. by dissolving it in dilute NH₄OH, allowing it to stand for half an hour and filtering off any SiO₂ that separates, then to filtrate adding magnesia mixture (MgCl₂ + NH₄Cl + NH₄OH); white ppt. = P₂O₅.

Phosphates yield a pale momentary bluish green flame when moistened with concentrated H₂SO₄ and treated at the tip of the blue flame.

TEST X.—Make a paste of four parts KHSO₄, one part CaF₂, water and substance. Treat at tip of blue flame. Just after water is driven off the flame will be colored.

B.—Bright green.
Li.—Carmine.

CONFIRMATION B.—Heat some of the substance gently on platinum wire, then add a drop of concentrated H₂SO₄, heat very gently again, just enough to drive off excess of H₂SO₄, dip in glycerine, hold in flame until glycerine begins to burn, remove from flame, and the mass will continue burning with a green flame.

SPECIAL SCHEME FOR DETECTION OF THOSE METALS WHICH WHEN PRESENT AS SILICATES USUALLY FAIL TO YIELD SATISFACTORY TESTS BEFORE THE BLOWPIPE.

Remove the volatile constituents as thoroughly as possible by roasting, then heat gently in a platinum capsule, with HF and a few drops of concentrated H₂SO₄ as long as fumes are given off; add a little more HF and H₂SO₄, and heat again in the same way. When fusion is quite cold, dissolve in cold water and filter.

Filtrate 1.—Divide into four parts and test as follows:
1. Add a piece of Zn or Sn and a little HCl, and heat.
   Ti.—A violet or blue solution.

CONFIRMATIONS Ti.—Nearly neutralize solution, and then add Na₂S₂O₃, and boil. White ppt. = Ti.
Or, make solution slightly alkaline, and then acidify slightly with HCl, and add Na₃HPO₄. White ppt. = Ti.

2. Add excess of KOH or NaOH, boil and filter, and to filtrate add excess of NH₄Cl. and boil.
   Al.—White precipitate.
   Dissolve ppt., produced by the KOH or NaOH, in HCl, and add K₄Fe(C₅H₄O₆)₃.
BLOWPIPE ANALYSIS.

Fe.—Blue precipitate.
3. Add HCl; then make alkaline with NH₃OH and add (NH₄)₂S + (NH₄)₂CO₃ in slight excess, filter; to filtrate add Na₂HPO₄.
Mg.—White crystalline precipitate.

Confirmation Mg.—If phosphates are present, this test would not be reliable for Mg. In such cases test a few drops of the solution with H₂S; if it causes any precipitate, saturate the whole of the solution with it, filter, and to filtrate add a few drops of HNO₃, and boil to oxidize FeO, nearly neutralize with solution of Na₂CO₃. If iron is not present, add a few drops of Fe₃(C₁₆O₄)₃ enough to give a red precipitate with the sodium acetate, then dilute and add excess of sodium acetate, and boil, filter, and to filtrate add NH₄OH + (NH₄)₂S, filter, to filtrate add Na₂HPO₄. White crystalline precipitate = Mg.

4. Add BaCl₂ as long as it gives a precipitate, then Ba(OH)₂ to alkaline reaction, boil, filter, and to filtrate add (NH₄)₂CO₃ and NH₄OH and heat, filter; evaporate filtrate to dryness and ignite to drive out NH₄ salts. Test residue in flame for K and Na; dissolve residue in a few drops of water, filter if necessary, and then add solution of PtCl₄ and alcohol.
K.—Yellow crystalline precipitate.

Confirmation Na, K.—Mix 1 part of the silicate with 3-5 parts of precipitated CaCO₃ and 1 part of NH₄Cl, heat to redness in platinum capsule for thirty minutes being careful to apply heat gently at first, digest shrunken mass in hot water, and filter; to filtrate add (NH₄)₂CO₃ and NH₄OH, heat and filter, evaporate filtrate to dryness and ignite gently until all ammonium salts are driven off, then determine Na and K as above.

Residue a.—Boil with strong solution of (NH₄)₂SO₄ and filter.
Filtrate a.—Add a few drops of H₂S water; if any precipitate forms, saturate with H₂S and filter, and to filtrate add NH₄OH and (NH₄)₂C₇O₃.
Ca.—A white precipitate.
Residue b.—Moisten with concentrated HCl and try coloration of flame.
Ba.—Yellowish-green flame.
Sr.—Scarlet flame.

Confirmation Ba and Sr.—Fuse residue b with two to three pcs. of soda in a platinum capsule; treat fusion with boiling water, filter, reject filtrate, dissolve residue in acetic acid, add a few drops of H₂S water, if it gives any precipitate, saturate with H₂S and filter, and to filtrate add K₂Cr₂O₇. Ba = yellow precipitate. Filter, and to filtrate add CaSO₄ warm and let stand. Sr = white precipitate.
PART III.

DESCRIPTION MINERALOGY.

CHAPTER XIV.

CHARACTERS OF MINERALS.

All elements and definite chemical compounds which have not been formed by living growth belong to the Third or Mineral Kingdom of Nature; and, in the broadest sense, mineralogy treats of all such substances. The magnitude of such a Science of Mineralogy has, however, forced an arbitrary division into several sciences, which are separated by more or less definite lines. All artificial compounds are referred to Chemistry, although the chemist’s laboratory and Nature employ the same forces and produce substances identical in all respects. The consideration of the remaining compounds or minerals, which are:

(a) Found ready-formed in Nature;
(b) Not the results of living growth;
(c) Possess definite chemical composition;

is then further divided between

A.—MINERALOGY: The appearance, composition and character of minerals; the methods of determination by composition, form and structure; the economic uses, etc.

B.—LITHOLOGY: The rocks considered as composed of minerals.

C.—CHEMICAL GEOLOGY: The origin and mode of formation of minerals.

The essential characters of any mineral may be classed under the headings of Form, The Various Physical Characters and Chemical Composition. Crystalline form has already been discussed in Part I.
FORM, other than that of Individual Crystals.

Various terms are used in describing the shape or structure of minerals which have no reference to their individual crystals. Some of the most common are as follows:

**Massive.**—Not very definitely used, but applied to masses without definite crystalline form. The same substance often occurs both massive and crystallized.

**Amorphous.**—Without any indication of crystalline structure and without power to polarize light.

**Pseudomorphous.**—Occurring in crystals, the form and angles of which belong to some other species. Frequently are simply casts made in cavities left after the solution of some other mineral; or they are uniform deposits upon another mineral; or the original mineral may have been changed into a new compound by the loss or gain of one or more ingredients.

**Granular.**—Made up of grains which may be coarse, fine or impalpable.

**Columnar.**—Having the form of columns. As distinguished from fibrous, the individuals are coarser and larger. Columns may be parallel or not parallel, long or short.

**Fibrous.**—Made up of slender threads or filaments, which may be parallel, radiating, crossed or reticulated, and stellated or star-like.

**Aecicular.**—Like a needle.

**Capillary.**—Like hair.

**Foliated, Lamellar, Micaeous, Scaly.**—Made up of scales, leaves, or plates.

**Mammillary.**—Having low and broad rounded protuberances.

**Globular.**—Having rounded or hemispherical protuberances.

**Botryoidal.**—Having something of the appearance of a bunch of grapes, being made up of several globular individuals close together.

**Reniform.**—Having the general shape of a kidney.

**Nodular.**—Occurring in separate rounded individual lumps or nodules.

**Striated.**—Marked with fine parallel straight lines.

**Incrusted.**—Covered with a hard crust or coat of mineral matter. Such a covering is called an incrustation.

**Stalactitic.**—The shapes of icicles. Hanging cones, columns, etc.
CHARACTERS OF MINERALS.

Drusy.—A drusy surface is made up of the ends of minute implanted crystals.

LUSTRE.

The lustre of a mineral is dependent on the manner the light is reflected from its surface in distinction from the color or kind of light reflected. It may be called the kind of brilliancy or shine of the mineral.

Metall ic lustre is the lustre of metals.
Non-metallic lustre may be vitreous, adamantine, resinous, pearly, silky, greasy, waxy, etc.
Vitreous, when it has the lustre of glass or of quartz crystals.
Adamantine, the lustre of the uncut diamond or cerussite.
Resinous, the lustre of resin or sphalerite.
Pearly, the lustre of mother-of-pearl or of foliated talc.
Silky, the lustre of silk or of satin spar.
Dull: A mineral without lustre or shine of any kind is said to be dull. Kaolin is a good example.

The words, sub-metallic, sub-vitreous, etc., are used to express imperfect lustre of the kind to which the prefix sub is affixed.

The words splendid, shining, glistening, glimmering and dull are terms of intensity dependent on the quantity of light reflected.

Lustre should, when possible, be determined by a comparison with minerals of known lustre, and should always be observed on a fresh or unaltered surface.

The degree or kind of lustre is always the same on like faces of a crystal.

COLOR.

The color of minerals is one of their least definite characteristics, often varying with different specimens of the same species, and sometimes within the widest limits. Minerals of metallic or sub-metallic lustre vary much less in color than non-metallic minerals, and their color is, therefore, a more useful characteristic.

In describing color, white, gray, brown, black, blue, green, yellow and red are used often with prefixes, which are terms of common use, and which convey to the mind the color of some familiar object. These, consequently, need no explanation.

Play or Change of Colors.—A more or less rapid succession of prismatic colors appearing as the mineral is turned.

Iridescence.—Prismatic colors, from the interior of a mineral.
Turnish.—A surface which has been exposed to the air is often of different color from the fresh fracture.

Opalescence.—A milky or pearly reflection from below the surface rather than from the surface itself.

Phosphorescence.—The power of emitting light.

Fluorescence.—The property of making visible rays of the spectrum beyond the violet.

Pleochroism (Dichroism, Trichroism).—On account of differences in absorption crystals sometimes appear to be of different colors when looked through in different directions.

STREAK.

The streak of a mineral is the powder which it leaves when drawn across a piece of hard white material such as novaculite or unglazed porcelain, or it may be obtained less perfectly by scratching the mineral with a knife or file, or by pulverizing the specimen. The color of the streak often varies widely from the color of the mass and is nearly constant for any species. When not white it is a characteristic very useful in determination.

TRANSLUCENCY.

The translucency of a mineral is its power to transmit light.

A mineral is said to be:

*Transparent*, when objects can be seen through it with clearness.

*Subtransparent*, when objects can be indistinctly seen through it.

*Translucent*, when light passes through but not enough to distinguish objects.

*Subtranslucent*, when only the thin edges permit any light to pass.

*Opaque*, when no light whatever passes even through thin edges.

HARDNESS.*

Hardness is resistance to abrasion.

The determination of the hardness of a mineral is always by comparison with some substance of known hardness and is always

* Accurate determinations of the hardness of minerals have been made with an instrument called a sclerometer. The mineral is placed on a movable carriage with the surface to be experimented upon horizontal; this is brought in contact with a steel point (or diamond-point), fixed on a support above; the weight is then determined which is just sufficient to move the carriage and produce a scratch on the surface of the mineral.
CHARACTERS OF MINERALS.

recorded in terms of Moh's decimal scale in which ten common minerals are used as units, as follows:

1. Talc, common laminated light-green variety.
2. Gypsum, crystallized variety.
3. Calcite, transparent variety.
4. Fluorite, crystalline variety.
5. Apatite, transparent variety.
6. Orthoclase, white cleavable variety.
7. Quartz, transparent.
8. Topaz, transparent.
10. Diamond.

In the absence of these minerals the hardness may be determined approximately by use of finger nail, copper coin, and knife or file in terms of Moh's scale.

Finger Nail, scratches 1 very easily, 2 easily.
Copper Coin, is a little harder, just scratching 3.
Knife, scratches 4 easily, 5 with pressure, 6 with great difficulty if at all.
File, scratches 6.
Glass, is scratched by 6 or over.

The hardness can be best tried on a plane surface though to save the specimen some inconspicuous place is selected. Care must be taken to distinguish between a streak or line of powder left on a mineral and a true scratch, in which a knife-point will catch.

The knife or a pointed fragment of the standard mineral is moved back and forth several times on the same line a short distance (½ inch) across the surface of the mineral under trial. If the mineral is not scratched it is harder than the standard used. If it is scratched it may be either softer or of the same hardness as the standard. If it is of the same hardness it will in turn scratch the surface of the standard, but if it is softer it will have no effect.

By means of such an instrument the hardness of the different faces of a given crystal has been determined in a variety of cases. It has been found that different planes of a crystal differ in hardness, and the same plane differs as it is scratched in different directions. In general, the hardest plane is that which is intersected by the plane of most complete cleavage. And of a single plane, which is intersected by cleavage planes, the direction perpendicular to the cleavage direction is the softer, those parallel to it the harder.—E. S. Dana, Text-Book Mineralogy, 1891, p. 121.
In practice the knife, or file, is most used for minerals 6 or under, and a comparison is made between the ease with which the knife cuts the mineral under trial and the members of the Moh's scale. If the mineral under trial is scratched by the knife as easily as apatite, its hardness is called 5; if scratched a little more easily than apatite and not so readily as fluorite, its hardness is called 4-5, etc.

TENACITY.

A mineral is said to be:

Brittle, when it falls to powder before a knife or hammer and cannot be shaved off in slices.

Sectile, when small shavings or slices can be cut off which fall to powder when hammered.

Malleable, when slices can be shaved off and these slices hammered flat.

Elastic, when it will bend and then spring back to its original position when the bending force is removed.

Flexible, when it will bend and remain bent.

CLEAVAGE.*

Crystals and crystalline masses can usually be easily broken parallel to certain crystallographic planes; for instance galenite breaks parallel to planes of the cube, calcite parallel to a rhombohedron with dihedral angles of 105° 5', barite parallel to a prism with an angle of 101° 37', and also parallel to the basal pinacoid, the micas parallel to the basal pinacoid, etc. These cleavages can be continued without change of ease or angles down to minute grains and plates, and the limit is only a mechanical one.

Cleavage is usually obtained by placing the edge of a knife or small chisel upon the mineral parallel to the direction of cleavage and striking a light blow upon it with a hammer.

In some instances the cleavage is produced by heating and suddenly plunging the mineral in water.

* Gliding planes (Gleitflächen) are planes produced in some minerals by pressure. For example, if two opposite dodecahedral edges of a cubic cleavage mass of rock salt are regularly filed away, and the mass then subjected to pressure in this direction, a Gleitfläche is obtained parallel to the dodecahedral face.

Fracture figures are produced by a blow on a rounded steel point, placed perpendicular to the natural or cleavage face of a crystal and appear as cracks diverging from the point where the blow has been made.
CHARACTERS OF MINERALS.

When cleavage exists in more than one direction, the cleavage angles are as absolute as the angles of the crystals and as they can easily be obtained from any of the many possible crystal forms and frequently from the masses, the angles of cleavage as well as the ease are useful characters in determination.

Cleavage is perfect or eminent when obtained with great ease, affording smooth, lustrous surfaces. Inferior degrees of cleavage are distinct, indistinct or imperfect, interrupted, in traces, difficult.

Cleavage parallel to the basal section is called basal; parallel to the prism, it is called prismatic; parallel to the faces of the cube, octahedron, dodecahedron, or rhombohedron, it is called cubic, octahedral, dodecahedral, rhombohedral.

FRacture.

When a mineral breaks in directions which are not planes the surface or form obtained is called the fracture. It may be
Conchoidal, rounded and curved like a shell.
Even, approximately plane.
Uneven, rough and irregular.
Hackly, jagged and sharp.
Spintry, Etc., etc.

SPECIFIC GRAVITY.

The specific gravity of a substance is its weight divided by the weight of an equal volume of distilled water at 15° C.

The Jolly balance, Fig. 179, is a simple piece of apparatus for obtaining the specific gravity of a solid. The lower scale pan is kept submerged; three readings are made by noting the heights at which the index on the wire and its image in the graduated mirror coincide with the line of sight when the spiral comes to rest.

A. Instrument reading, nothing in either scale pan.
B. Reading with mineral in upper scale pan.
C. Reading with same fragment transferred to lower scale pan.

\[ \frac{B - A}{B - C} = \text{Specific Gravity.} \]
In using an ordinary chemical balance the fragment is first weighed and then suspended from one scale pan by a hair, or platinum wire, or spiral in a glass of water and reweighed. The weight of platinum wire, hair or spiral must be deducted.

\[
\text{Specific Gravity} = \frac{\text{Wt. in air}}{\text{Wt. air} - (\text{Wt. water} - \text{Wt. spiral})}
\]

Very porous minerals and powders are determined by weighing in a little glass bottle the stopper of which ends in a fine tube. The mineral is weighed and the bottle full of water is also weighed. The mineral is then added to the bottle and displaces its bulk of water, and the difference between the new weight and the sum of the other two weights is the weight of the displaced water.

**TASTE.**

Some minerals have a decided taste which is usually either:
- *Astringent*, the taste of alum or of alunogen.
- *Saline or Salty*, the taste of salt or halite.
- *Bitter*, the taste of epsomite.
- *Alkaline*, the taste of soda.
- *Acid*, the taste of lemons or sassolite.

**ODOR.**

The terms used in describing odors are in general self explanatory, *garlic, horse-radish, sulphurous, bituminous, fetid* like hydrogen sulphide, *argillaceous* like moistened clay, etc.

**FEEL.**

These terms, *smooth, greasy, harsh*, etc., are also well known.
CHAPTER XV.

CHEMICAL COMPOSITION AND REACTIONS.

As has already been stated, minerals are distinguished from rocks by something of regularity in their chemical structure. While all minerals may be best considered as derived from definite chemical types they are, however, very far from being of definite and invariable composition and it is often difficult to represent the results of analysis by an exact formula. This is readily understood when the laws of isomorphism and the conditions underlying the formation of minerals are studied.

Isomorphism.

Certain chemical substances, having an equal number of atoms in their molecules and presenting a close resemblance in their reactions, crystallize in forms which are either identical or very closely related. Such isomorphic substances cannot be separated from each other by ordinary crystallization as the analogous compounds crystallize together, and the crystals formed show by analysis the most varied quantitative proportions of the isomorphic substances present in the liquid.

Most minerals are isomorphic mixtures. They have, as a rule, been formed by crystallization either from solution or from fusion. Some, as limonite, have been formed by a process of sedimentation but such are uncrystallized, and are generally quite impure. Others are the results of alteration from atmospheric agencies and frequently contain in the same specimen the original mineral and its alteration product.

Whenever a mineral has crystallized from solution or from fusion it is always more or less modified by the elements which may be present and which are foreign to its own typical structure. Three cases present themselves:

1. If the liquid contains no other substance than the compound of which the mineral is made then it crystallizes out in a state of purity and is as definite in its composition as any compound made in the laboratory.
2. If the liquid contains several other substances but none which is isomorphic with the compound of which the mineral is made, it may crystallize in all degrees of purity, tending always to form crystals of definite composition but the composition of the mass varying with the degree with which the liquid is saturated with the foreign substances. This gives rise usually to a series of fractional crystallizations especially apparent in beds of rock salt or in mica and orthoclase veins. If the substances are in solution that one is first deposited whose saturation point is first reached by any process of concentration, the others following in their respective order. Where the case is one of fusion those substances with the highest melting points will tend to crystallize out first and in a state of comparative purity.

3. The liquid may contain two or more isomorphic compounds in which case the resulting mineral will contain each of these substances usually in about the relative proportion in which they were present. Isomorphic compounds are generally salts of the same acids with the metallic elements different.

Composition and Formula.

It will thus be seen that many factors besides the results of analysis must be taken into consideration in giving a formula to any mineral. When, however, the errors of calculation, arising from the impurities and from the replacing of certain elements by others of different atomic weight but isomorphic with them, are eliminated, it is generally possible to assign a typical formula to the species. The difficulty becomes greater when the polysilicates and some other complicated minerals are studied and in no case must the formula for the species be considered as absolutely invariable for the individual. The results of alteration through atmospheric agencies, infiltration of water, etc., tend at times to so alter the individual that its composition varies widely from the type while at times this alteration is carried on so regularly and so far that new species of quite definite composition are formed. In expressing the composition by formulas the ordinary chemical symbols are used. The letter R is used to represent a varying group of isomorphic or equivalent elements, and it may have the valency of these elements designated by dots above and to the right of the letter. When two elements as (Fe.Mg) are placed in parenthesis
CHEMICAL COMPOSITION AND REACTIONS.

with a period between it, indicates that the two replace each other in all proportions in the different individuals of the species.

Types.

The most prominent types found among minerals are as follows:
1. The Elements, as Au, Ag, Cu, Sb, C, S. These are frequently alloyed with other elements as copper with silver, sulphur with selenium, etc.
2. The Oxides and Hydroxides for which water, H₂O, serves as a type, as cuprite, Cu₂O, brucite, Mg(OH)₂. It is not necessary that the hydrogen atom or atoms be replaced by a single element. This replacement may be by a group of elements as in diaspor, Al₂(OH)₃ or on the other hand the oxygen may be partially replaced by sulphur as in kermesite, Sb₂S₃.
3. The Sulphides, derivatives of H₂S, and to a lesser extent their analogues the Selenides, Tellurides, Arsenides and Antimonides, as galenaite, PbS; clausenthalite, PbSe; hessite, Ag₂Te; niccolite, NiAs. The hydrogen may be replaced by more than one element as in chalcopyrite, CuFeS₂, or the sulphur may be partially replaced by arsenic as in arsenopyrite, FeAsS, by antimony as in stephanite, Ag₃SbS₂, and also by selenium and by tellurium, but to a lesser extent and with smaller tendency to form distinct species.
4. The Chlorides, derivatives of HCl, and to a lesser extent their analogues the Fluorides, Bromides, and Iodides as halite, NaCl, fluorite, CaF₂, bromyrite, AgBr, iodyrite, AgI.

More than one metal may replace the hydrogen as in the double fluoride cryolite, Na₃AlF₆ and chlorides, bromides, iodides or fluorides may crystallize together as in embolite, Ag(Cl·Br).
5. Nitrate, derivatives of HNO₃, as nitre, KNO₃; soda nitre, NaNO₃; isomorphous or basic modifications are rare.
6. Carbonates, derivatives of H₂CO₃, as calcite, CaCO₃; siderite, FeCO₃, etc. Isomorphous combinations are common, as dolomite (Ca, Mg)CO₃. The carbonates of Zn, Fe, Co, Mn, Ca and Mg are isomorphous, and also the carbonates of Ca, Ba, Sr and Pb. Consequently, minerals containing various combinations of these carbonates are found. Many basic salts of carbonic acid also occur, as malachite, Cu₂(OH)₂CO₃; azurite, Cu₂(OH)₂CO₃. Carbonates are also frequently found containing water of crystallization as natron, Na₂CO₃ + 10H₂O. In a few instances a carbonate and a halogen salt crystallize together as in phosgenite, Pb₃Cl₂CO₃.
7. Sulphates, derivatives of $\text{H}_2\text{SO}_4$, as anhydrite, $\text{CaSO}_4$; barite, $\text{BaSO}_4$, etc. Isomorphous combinations are more common than simple sulphates. Among these may be noted sulphates containing two or more metals, as glauberite, $\text{Na}_2\text{Ca}(...)$; those containing a sulphate and chloride, as kainite, $\text{MgSO}_4\cdot\text{KCl} + 3\text{H}_2\text{O}$. Basic sulphates are also numerous as brochantite, $\text{Cu}_2(\text{OH})_2\cdot\text{SO}_4\cdot2\text{Cu}(\text{OH})_2$, and some individuals of any of the previous types crystallize with water of crystallization, as copiapite, $\text{Fe}_2(\text{Fe}\text{OH})_2\cdot\text{SO}_4\cdot5\text{H}_2\text{O}$.

8. Chromates, derivatives of $\text{H}_2\text{CrO}_4$, as crocoite, $\text{PbCrO}_4$, and derivatives of $\text{HCrO}_4$, as chromite, $\text{FeCr}_2\text{O}_4$. These are the two important mineral chromates. Two or three rare basic compounds are also known.

9. Molybdates, derivatives of $\text{H}_2\text{MoO}_4$, as Wulfenite, $\text{PbMoO}_4$, which is the only important natural molybdate.

10. Tungstates, derivatives of $\text{H}_2\text{WO}_4$, as scheelite, $\text{CaWO}_4$. Tungstates also are rare. One or two isomorphous combinations are known, as in Wolframite, $(\text{Fe,Mn})\text{WO}_4$.

11. Borates, derivatives of $\text{HBO}_2$, $\text{H}_2\text{BO}_3$ or of $\text{H}_2\text{BO}_4$, as sassolite, $\text{H}_2\text{BO}_3$; borax, $\text{Na}_2\text{B}_2\text{O}_3 + 10\text{H}_2\text{O}$. Metaborates are rare. Ulexite, $\text{CaNa}_2\text{B}_2\text{O}_6 + 6\text{H}_2\text{O}$, may be considered as a molecular combination of $\text{CaB}_2\text{O}_7 + \text{NaBO}_4$, while colemannite, $\text{CaB}_2\text{O}_7 + 5\text{H}_2\text{O}$, would consist of $\text{CaB}_2\text{O}_7 + \text{Ca}(\text{BO}_3)_2$. Most natural borates contain water of crystallization, and a few basic combinations are found.

12. Aluminates, derivatives of $\text{HAIO}_3$, as spinel, $\text{Mg}(\text{AlO}_2)_3$; chrysoberyl, $\text{G}(\text{AlO}_2)_3$. The aluminates are isomorphous with the ferrates and metachromates, consequently the Al may be partially replaced by Fe or Cr, while, on the other hand, the common aluminates are themselves isomorphous, and the Mg, Fe, Zn and Mn salts replace each other in their characteristic spinels to a limited extent.

13. Phosphates, derivatives of $\text{H}_3\text{PO}_4$, as vivianite, $\text{Fe}_2(\text{PO}_4)_3 + 8\text{H}_2\text{O}$. By far the majority of mineral species of phosphates are either isomorphous modifications or basic salts, both with and without water of crystallization. Simple phosphates may crystallize together, as in triphyllite, $\text{Li}(\text{Fe,Mn})\text{PO}_4$. Phosphates may crystallize with chlorides and fluorides, as in apatite, $\text{Ca}_5(\text{Cl,F})_3(\text{PO}_4)_3$. Basic salts may be simple, as in turquois, $\text{Al}_2(\text{OH})_2\text{PO}_4 + \text{H}_2\text{O}$, or may contain several metals, as in lazulite, $(\text{Mg,Fe,Ca})\text{Al}_2(\text{OH})_2(\text{PO}_4)_2$. 
CHEMICAL COMPOSITION AND REACTIONS.

14. Arsenates, derivatives of $\text{H}_3\text{AsO}_4$, form compounds very similar to the phosphates in molecular structure, as scorodite, $\text{FeAsO}_4 + 2\text{H}_2\text{O}$, a hydrous ferric arsenate; mimetite, $3\text{Pb}_2\text{AsO}_4\cdot\text{PbCl}_2$, a combination of the isomorphic arsenate and chloride; olivenite, $\text{Cu}_2(\text{OH})\text{AsO}_4$, a basic copper arsenate.

15. Vanadinites and Columbates, derivatives of $\text{H}_3\text{VO}_4$ and $\text{HCl}_3\text{O}_4$. The chief vanadinites are vanadinite, $3\text{Pb}_2(\text{VO}_4)\cdot \text{PbCl}_2$, a molecular combination of lead vanadinate and chloride, and desclouizite (Pb.Zn) (Pb.OH)$\text{VO}_4$, a basic lead vanadinate containing zinc. The most important natural columbite is the mineral columbite, $\text{Fe(FeO)}_3$.

16. Silicates.—By far the largest number of minerals known fall under this subdivision. Isomorphic combinations are the rule, and these combinations are at times so complicated that it is almost impossible to give even a typical formula to the species. Basic and acidic salts are common, but the silicates do not show as great tendency to crystallize with water of crystallization as is possessed by some of the other classes of compounds. Those which do contain water of crystallization are commonly considered in a class by themselves, on account of their many resemblances. The basic elements most commonly replacing each other are Ca, Mg, Fe, Zn and Mn; Na, Li and K, and Al, B, Cr and Fe. The silicon is itself sometimes partially replaced by Al, as in anorthite, or by Ti, as in titanite.

Calculation of Formulas.

In expressing the composition of a mineral by a formula we have only the atomic weights of its component elements and the results of analysis from which to calculate. Hence the formulas given do not of necessity express the structure of the molecule, but only the composition ratio. In fact, the symbols adopted are always the simplest which can express the proportions shown by analysis to exist between the atoms and which satisfy their valences. The true molecular formulas are probably always some unknown multiple of these symbols. For the purposes of mineralogy, however, the composition formulas are sufficient.

An example may make this point clearer. A very pure specimen of beryl gave the following results on analysis:
The sum of the atomic weights for each group is:

\[
\begin{align*}
\text{G} & = 25, \\
\text{Al}_2\text{O}_3 & = 102, \\
\text{SiO}_2 & = 60.
\end{align*}
\]

The results of analysis represent the proportion in which the groups are present in the molecule. Consequently, the relation between the number of groups must be:

<table>
<thead>
<tr>
<th>Percentage Composition</th>
<th>Atomic Weights</th>
<th>Proportionate Number of Groups</th>
</tr>
</thead>
<tbody>
<tr>
<td>14.01</td>
<td>25</td>
<td>.56</td>
</tr>
<tr>
<td>19.26</td>
<td>102</td>
<td>.189</td>
</tr>
<tr>
<td>66.37</td>
<td>60</td>
<td>1.106</td>
</tr>
</tbody>
</table>

Now, as fractional atoms cannot exist, our problem is simply to find the smallest number of whole groups which stand to each other in this relation, and, as \(.56 : .189 : 1.106 = 3 : 1 : 6\), very nearly, therefore, the composition is represented by \(3\text{G} + \text{Al}_2\text{O}_3 + 6\text{SiO}_2\), or, as it at once becomes evident that the proportion between silicon and oxygen is that of a mica-like, \(3\text{G}_3\text{Al}_2(\text{SiO}_3)_6\).

It will now be found, on calculating the theoretical percentage composition of \(3\text{G}_3\text{Al}_2(\text{SiO}_3)_6\), that it agrees within the limits of error with that found by analysis, and as the twelve affinities of the six \(\text{SiO}_2\) radicals are satisfied by those of \(\text{G}\) and \(\text{Al}\) atoms, the formula probably represents the composition of the compound. The true molecular formula is, however, \(n\text{G}_3\text{Al}_2(\text{SiO}_3)_6\) wherein \(n\) represents some whole number.

The calculation is not generally as simple as the above example might indicate. Usually, minerals contain elements which seem foreign to their true composition, and which are present either as impurities or which replace analogous elements of the true molecule. In fact, many micas contain \(\text{Cs}, \text{H}_2\), \(\text{Na}_8\), \(\text{Ca}\), or \(\text{Mg}\) replacing \(\text{G}\); and \(\text{Fe}\) or \(\text{Cr}\) replacing \(\text{Al}\). Such replacing elements, if present only in small quantities, must be converted into their equiv-
eralents of Gl or Al before the calculation for formula is made. No representative formula can ever be assigned from an analysis of impure material unless the nature and extent of the impurities are known.

Clues are often obtained as to the constitution of the molecule which are entirely foreign to the percentage composition, but which materially assist in the construction of the formula. Thus $\text{H}_2\text{O}$, present as water of crystallization, is driven off at comparatively low temperatures, while the hydrogen of hydroxides or of acid or basic salts is usually expelled as water only under a temperature approaching that of ignition. Orthosilicates are known to be much less stable than metasilicates, and frequently are found altered to metasilicates. This fact sometimes aids in determining the formula of a compound which otherwise might be referred to either class. For instance, analytical results have been obtained for both andalusite and cyanite, which are satisfied by the formula $\text{Al}_2\text{SiO}_x$. This represents more oxygen than is present in any of the silicic acids, and part of the oxygen is therefore undoubtedly in combination with the aluminium. Two rational formulas now become possible, one an orthosilicate $\text{Al(AlO)}\text{SiO}_x$, the other a metasilicate $(\text{AlO})_2\text{SiO}_x$. Andalusite is much more easily decomposable than cyanite, which is not so easily altered. The first symbol is therefore assigned to andalusite and the second to cyanite.
CHAPTER XVI.

THE IRON MINERALS.


Economic Importance.

The iron minerals have important and varied uses, which may briefly be described under the following heads:

I.—In natural state.
II.—For extraction of metal (ores of iron).
III.—For extraction of acid constituents.
IV.—For extraction of included metals.

I.—Uses in Natural State.

These are rather limited, the principal one being the use of the oxides for mineral paints, ochres, etc. In the ten years, 1889 to 1890, 126,661 tons were mined for this purpose* in the United States. Limonite, or clay and limonite, and hæmatite are principally used.

II.—Minerals Used as Ores of Iron.

In the United States, the minerals smelted for iron are, in order of quantity used,† hæmatite, limonite, magnetite, and siderite. Goethite is commercially included with limonite under the name brown hæmatite, and undoubtedly more or less menacanite is smelted with other ores. The residues from the roasting of py-

† John Birkinfield, in Mineral Resources of United States, 1892, gives as amounts mined for one year: Hæmatite, 11,646,619 tons; limonite and goethite, 2,485,107 tons; magnetite, 1,971,985 tons; siderite, 192,987 tons.
rites are sometimes used as a source of iron, but in this country are not smelted to any extent.

The greater portion of the $50,000,000$ tons or more of iron-ore mined each year is converted into pig-iron. That is, the ore is deprived of its oxygen by the action of incandescent fuel and the hot reducing gases resulting from its combustion, and becomes a liquid mass of metallic iron, combined and mixed with a little carbon, silicon, phosphorus, sulphur, and other impurities. The furnace used is a vertical shaft, everywhere circular in horizontal section, but usually widening from the top downwards to a certain level, and then again narrowing to the hearth. Hot air is forced into the furnace through nozzles called tuyères, entering just above the hearth.

The ore and fuel are analyzed and some flux is added, which, when combined with the ash of the fuel and the foreign ingredients of the ore, will form a definite silicate of known fusibility, called the slag. The temperature of the furnace will differ at different levels, but be practically the same at all times at any one level.

The ore, charged in at the top, in alternate layers, with fuel and flux, will, as it descends, pass through zones of different temperatures, and will be reduced, carbonized, fused, and flow into the hearth. The slag will form in a definite zone after the complete reduction of the iron, and will fall also to the hearth, but, being lighter, will float on the melted iron until drawn off. From time to time the metal will be run out into sand moulds, forming the pigs or pig-iron, about $7,000,000$ tons of which are produced yearly in the United States.

This pig-iron, by various processes, is converted into wrought-iron, cast-iron, and steel.

The mineral franklinite, after treatment for zinc, and certain manganiferous hematites and siderites, are smelted, and yield spiegeleisen, an alloy of iron and manganese. In 1890 about $150,000$ tons of spiegeleisen were manufactured in this country, to be used as a source of carbon and manganese in the manufacture of steel.

III.—Minerals Used for Extraction of Acid Constituents.

(a) For Sulphur.—Pyrite, and, to a less extent, marcasite and pyrrhotite, are very extensively used in the manufacture of sulphuric acid. In 1892, $317,000$ tons were so used in the United States.
The minerals are burned in furnaces with grates, and the gases are converted into sulphuric acid. The residues frequently contain, in addition to iron, copper, nickel, or gold, and these are usually worked up as by-products.

(b) For Arsenic.—The mineral arsenopyrite is the chief source of arsenic.

(c) For Chromium.—Practically all the chromium compounds derive their chromium from the mineral chromite. In 1892 some 3000 tons* of this mineral were mined in California. The most important compounds manufactured are potassium bichromate used in calico printing, oxidizing rubber, bleaching indigo and in manufacturing the chrome paints and matches; potassium chromate used in the manufacture of aniline colors, etc., and ferrochromium, which added to steel produces the tough alloy known as chrome-steel.

(d) For Tungsten.—Tungsten and the tungstates are extracted from wolframite and scheelite, chiefly from wolframite. The world’s product is not more than 400 to 500 tons, and is chiefly employed in the manufacture of crude tungsten for tungsten steel and sodium tungstate for rendering fabrics non-inflammable.

IV.—Included Metals.

(a) Gold and Silver.—Both pyrite and arsenopyrite frequently carry gold and a little silver, and this is very often extracted either directly by stamping and amalgamation, or by treatment of the roasted residues.

(b) Nickel.—Pyrrhotite frequently carries nickel, and in 1892 about 2000 tons of nickel were extracted from the pyrrhotite of Sudbury, Ontario.

IRON.

Composition.—F₂ with more or less Ni, Cr, Co, Mn.

General Description.—Masses and imbedded particles of white to gray metal, resembling the manufactured iron. Crystals rare (isometric); but meteoric masses, when polished and etched, usually exhibit lines or bands, due to crystalline structure.


Before Blowpipe, Etc.—Insoluble. Soluble in acids. In borax or salt of phosphorus, reacts only for iron.

† Ibid., p. 348.
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Remarks.—Occurs in large masses on Disco Island, Greenland, and sparingly in some basalts, pyritic nodules, etc., and locally reduced by heat from the carbonate. Also found in most meteorites either as chief constituent or as a spongy matrix or in disseminated grains.

PYRRHOTITE.—Magnetic Pyrites, Mundic.

Composition.—Fe₃S₈ + r. Fe₇S₈ to Fe₁₁S₄₂, with frequently small percentages of cobalt or nickel.

General Description.—Usually a massive bronze metallic mineral, which is attracted by the magnet and can be scratched with a knife. Sometimes occurs in tabular hexagonal crystals.


Streak, grayish-black.

Color, bronze-yellow to bronze-red, but subject to tarnish.

Attracted by the magnet.

Before Blowpipe, Etc.—Fuses readily on charcoal to a black magnetic mass, evolves fumes of sulphur dioxide, but does not take fire. In closed tube, yields a little sulphur. In open tube, gives fumes of sulphur dioxide. Soluble in hydrochloric acid, with evolution of hydrogen sulphide and residue of sulphur.

Similar Species.—Pyrrhotite resembles pyrite, bornite and niccolite at times, but differs in being attracted by the magnet and by its bronze color on fresh fracture.

Remarks.—Pyrrhotite is found in gabbros and schists and occasionally in the older egyptite rocks, also frequently in meteorites. It alters to pyrite, limonite and siderite.

Immense quantities are found at Strafford and Ely, Vermont; Sudbury, Canada, and Lancaster Gap, Pennsylvania. The last two deposits are nickeliferus, and are mined for this metal. Smaller beds are common.

Uses.—It is one of the chief ores of nickel, probably from included minerals; and to some extent is an ore of sulphur.

PYRITE.—Iron Pyrites, Fool's Gold.

Composition.—FeS₂ (Fe 46.7, S 53.3 per cent.), often containing small amounts of Cu, As, Ni, Co, Au.

General Description.—A brass-colored, metallic mineral, frequently in cubic or other isometric crystals or in crystalline masses, which may be any shape, as botryoidal, globular, stalactitic, etc. Less frequently in non-crystalline masses.
Crystallization.—Isometric: cubes, octahedrons and pentagonal dodecahedrons—less frequently other forms. Striations parallel to cube edges are frequent on cube faces, the striations on one face being perpendicular to those on adjoining faces.

Physical Characters. H., 6 to 6.5. Sp. gr., 4.9 to 5.2.
Lustre, metallic. Opaque.
Streak, greenish-black. Tenacity, brittle.
Color, pale to full brass-yellow and brown from tarnish.
Cleavage, imperfectly cubic.

Before Blowpipe, Etc.—On charcoal, takes fire and burns with a blue flame, giving off fumes of sulphur dioxide, and leaving a magnetic residue which, like pyrrhotite, dissolves in hydrochloric acid with evolution of hydrogen sulphide. In closed tube, gives a sulphur deposit. Insoluble in hydrochloric acid, but soluble in nitric acid with separation of sulphur.

Similar Species.—Pyrite is harder than chalcopyrite, pyrrhotite, or gold. It differs from gold, also, in color, streak, and brittleness.

Remarks.—Pyrite is being formed to-day by the action of the hydrogen sulphide of thermal springs upon soluble iron salts. It has been developed in many rocks by the action of hot water on iron salts in the presence of decomposing organic matter.
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It may be, also, of igneous origin. Pyrite is found in rocks of all ages, associated with other metallic sulphides and with oxides of iron. In compact specimens it is not easily altered, but granular masses readily oxidize and are decomposed, forming sulphate of iron and sulphuric acid, thus acting as a vigorous agent in the decomposition of rocks. The final products are usually limonite and sulphates of calcium, sodium, magnesium, etc. Few minerals are of such general or wide-spread occurrence. The most celebrated locality is the Rio Tinto region, in Spain, from which immense quantities of a gold- and copper-bearing pyrite are annually procured. The largest deposits worked in the United States are at Rowe, Mass.; Hermon, N. Y.; and at several localities in Virginia. Immeasurable large deposits are known.

Uses.—Pyrite is burned, for the manufacture of sulphuric acid, in enormous quantities. Pyrite containing copper or gold is sometimes treated for these metals, but the treatment is frequently preceded by a burning for sulphuric acid. The use of pyrite for the manufacture of copperas has been superseded by a process of galvanizing iron in which copperas is a by-product.

MARCASITE—White Iron Pyrites.

Composition.—FeS₂, as in pyrite.

General Description.—Ferric sulphide is dimorphous. Marcasite differs from pyrite in crystalline form, and in little else. It occurs in orthorhombic forms, and in crystalline masses. The compound crystals have given rise to such names as cockscomb pyrites, spear pyrites, etc., from their resemblance to these objects. Often, with radiated structure. Color on fresh fracture is usually whiter than in pyrite.

Fig. 185. Fig. 186. Fig. 187.

I and 0. Cockscomb. I, 0 and 32 - T.

Crystallization.—Orthorhombic, 3 : 6 : c = 0.7652 : 1 : 1.2342. I \( \perp I = 105^\circ 35' \), 0 \( \perp 32 = 157^\circ 39' \). Crystals usually tabular, parallel to base; often compound; sometimes pyramidal.
Physical Characters. H., 6 to 6.5. Sp. gr., 4.6 to 4.9.

Lustre, metallic. Opaque.

Streak, nearly black. Tenacity, brittle.

Color, pale brass-yellow, darker after exposure.

Cleavage, imperfect prismatic (angle of 105° 3').

Before Blowpipe, Etc.—As for pyrite.

Similar Species.—As for pyrite, from which it is only distinguishable by crystalline form, cleavage, and, to a slight degree, by lighter color.

Remarks.—Marcasite is more readily decomposed than pyrite, and is, therefore, an even less desirable constituent in building material, etc. It is found at Cammington, Mass.; Warwick, N. Y.; Joplin, Mo.; Haverhill, N. H.; and in many other localities and is usually mistaken for pyrite.

Uses, are the same as for pyrite.

Leucopirite.—Lollingite.

Composition.—Fe₃As₂ to Fe₅As₃, sometimes with Co, Ni, Au or S.

General Description.—Massive silver-white or gray metallic mineral sometimes occurring in orthorhombic crystals, closely agreeing in angles with crystals of arsenopyrite.


Before Blowpipe, Etc.—Like arsenopyrite, except that sulphur reactions are less pronounced or do not appear at all.

Magnetite.—Lodestone, Magnetic Iron Ore.

Composition.—Fe₃O₄ (Fe, 72.4 per cent.) often contains Ti, Mg.

General Description.—A black mineral with black streak and metallic lustre, strongly attracted by the magnet and occurring in all conditions from loose sand to compact coarse or fine grained masses.

Fig. 188. Fig. 189. Fig. 190.

1. 1. 1 and 1', striated.
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Frequently in octahedral crystals and loosely coherent masses of imperfect crystals. Other isometric forms occur, especially the rhombic dodecahedron.

Physical Characters.  H., 5.5 to 6.5.  Sp. gr., 4.9 to 5.2.  
Lustre, metallic to submetallic.  Opaque.  
Color and Streak, black.  Tenacity, brittle.  
Strongly attracted by magnet and sometimes itself a magnet (lodestone).  Breaks parallel to octahedron.

Before Blowpipe, Etc.—Fusible with difficulty in the reducing flame. Soluble in powder in hydrochloric but not in nitric acid.

Similar Species.—No other black mineral is strongly attracted by the magnet.

Remarks.—Magnetite occurs chiefly in crystalline metamorphic rocks and in eruptive rocks partly derived from slates containing iron. It is little altered by exposure but organic matter reduces it to ferrous oxide which by oxidation becomes hematite, Fe₂O₃.

It makes up about 12 per cent. of the iron ore mined in America, being obtained especially from the States of Pennsylvania, New York, New Jersey and Michigan. Smaller amounts are obtained elsewhere and it is present in many localities. In this country, lodestones are obtained mainly from Magnet Cove, Ark. Whole mountains are made up of this mineral in Sweden and it is practically the only iron-ore mined in that country.

Uses.—It is an important iron ore highly valued for its purity.

FRANKLINITE.

Composition.—(Fe,Mn,Zn)₄(Fe,Mn)₂O₁₀.  
General Description.—Black mineral resembling magnetite. Occurs in compact masses, rounded grains and octahedral crystals. Only slightly magnetic and generally with brown streak. The red zincite and yellow to green willemite are frequent associates. The crystals are modified octahedrons rarely sharp cut as in magnetite.

Physical Characters.  H., 6 to 6.5.  Sp. Gr., 5 to 5.2.  
Lustre, metallic or dull.  Opaque.  
Streak, brown to black.  Tenacity, brittle.  
Color, black.  
Slightly magnetic at times.  Breaks parallel to octahedron.

SIMILAR SPECIES.—Distinguished from magnetite and chromite by bead tests and associates.

REMARKS.—The only noteworthy locality is that in the vicinity of Franklin Furnace, New Jersey. Here, however, the deposit is large and has been extensively developed.

USES.—The zinc is recovered as zinc white and the residue is smelted for speiegelisen an alloy of iron and manganese used in steel manufacture. Franklineite has also been ground for a dark paint.

ARSENOPYRITE.—Mispickel.

COMPOSITION.—FeAsS. (Fe 34.4, As 46.0, S 19.6 per cent.) sometimes with replacement of iron by cobalt, or arsenic by antimony in part.

GENERAL DESCRIPTION.—Silver white to gray mineral with metallic lustre. Usually compact or in granular masses or disseminated grains. Less frequently in orthorhombic crystals or columnar.

CRYSTALLIZATION.—Orthorhombic \( a:b:c = 0.677 : 1 : 1.188 \). \( I \cap I = 111^\circ \ 47' \ 0 \cap \frac{x}{2} - \frac{\gamma}{x} = 163^\circ \ 27 \frac{1}{2} \). Prismatic forms often with striated domes. Also compound and star shaped.

FIG. 192.


LUSTRE, metallic. OPAQUE.

STREAK, grayish-black. TENACITY, brittle.

COLOR, silver white to steel gray.

CLEAVAGE, prismatic (111\(^\circ\) 47).

BEFORE BLOWPIPE, ETC.—In closed tube yields a red sublimate, yellow when cold. On charcoal yields abundant white fumes and arsenical odor and coating and fuses to a magnetic globule. After short treatment the residue is soluble in hydrochloric acid with evolution of hydrogen sulphide and precipitation of the yellow sulphide of arsenic. The residue may react for cobalt. Insoluble in hydrochloric acid. Soluble in nitric acid with separation of sulphur.
SIMILAR SPECIES.—Massive varieties of the metallic cobalt minerals and varieties of leucopyrite resemble arsenopyrite and are only safely distinguished by blowpipe tests. Smaltite when massive can be distinguished from cobaltiferous arsenopyrite only by its slight reaction with hydrochloric acid after fusion.

REMARKS.—Arsenopyrite is found chiefly in crystalline rocks with other metallic sulphides and arsenides. Throughout the Rocky Mountains it is a common mineral and frequently auriferous. A large deposit at Deloro, Canada, is mined for both arsenic and gold. The arsenopyrite found in New England usually contains cobalt.

USES.—Arsenopyrite is the source of most of the arsenic of commerce, and occasionally contains enough gold or cobalt to pay for extraction.

HEMATITE.—Specular Iron, Red Iron Ore.

COMPOSITION.—$\text{Fe}_2\text{O}_3$, (Fe 70 per cent.), often with $\text{SiO}_2$, $\text{MgO}$, etc., as impurities.

GENERAL DESCRIPTION.—Occurs in masses varying from brilliant black metallic to blackish red and brick red with little luster. The black is frequently crystallized, usually in thin tabular crystals set on edge in parallel position, less frequently in larger highly modified forms and finally in scale-like to micaceous masses. The red varieties vary from compact columnar, radiated and kidney-shaped masses to loose earthy red material. In all varieties the streak is red.

\begin{align*}
R, \varnothing \text{ and } \tau - 2. & \quad \tau, \varnothing - 2 \text{ and } \tau.
\end{align*}

CRYSTALLIZATION.—Hexagonal $\varepsilon = 1.36557$. Rhombohedrons and scalenohedrons predominate and small thin tabular forms are the rule. $R \land R = 86^\circ; \varnothing \land \frac{1}{2} - 2 = 118^\circ 47' \land \frac{1}{2} - 2 = 128^\circ 1'$.  

10
Physical Characters. H., 5.5 to 6.5. Sp. gr., 4.9 to 5.3.

Lustre, metallic to dull. Opaque.

Streak, brownish red to cherry red. Tenacity, brittle un-

Color, iron black, blackish red to cherry red. Less micaceous.

Sometimes slightly magnetic.

Before Blowpipe, etc.—Infusible. Becomes magnetic in re-

ducing flame. Soluble in hot hydrochloric acid. In borax reacts

for iron.

Varieties.

Specular Iron.—Brilliant micaceous or in crystals. Black in

color.

Red Hematite.—Submetallic to dull, massive, blackish red to

brownish red in color.

Red Ochre.—Earthy impure hematite usually with clay. Often

pulverulent.

Clay Ironstone.—Hard compact red material mixed with much clay or sand.

Martite.—Octahedral crystals, probably pseudomorphs.

Similar Species.—Resembles at times the other iron-ores and

massive cuprite. It is distinguished by its streak and strong mag-

netism after heating in reducing flame.

Remarks.—Usually in metamorphic rocks, probably formed from bog iron-ore by

pressure and heat. Also found in igneous rocks. Changes by action of atmosphere,

water, organic matter, etc., into limonite, siderite and magnetite. About 72 per cent.

of the iron-ore mined in the United States is hematite. By far the larger part is obtained

from the Marquette and Gogebic ranges of Michigan and from the Mesabi range in

Minnesota. Smaller but by no means inconsiderable amounts are mined in New York,

Alabama, Missouri and other states.

Uses.—In this country it supplies over two-thirds of all the iron-

ore mined, and ranks with magnetite in purity. The earthy varieties

are used for a cheap paint, and some massive varieties are ground

for paint or polishing material.

MENACCANITE—Ilmenite, Titanic Iron-Ore.

Composition.—(Fe,Ti)O, sometimes small amounts of Mg or

Mn.

General Description.—An iron-black mineral, usually massive

or in thin plates or imbedded grains or as sand. Also, in tabular

hexagonal crystals and forms closely like those of hematite in angle.

($c = 1.38458$).
THE IRON MINERALS.

Physical Characters.—H., 5 to 6. Sp. gr., 4.5 to 5.
Lustre, submetallic. Opaque.
Streak, black to brownish-red. Tenacity, brittle.
Color, iron-black. Slightly magnetic.

Before Blowpipe, etc.—Infusible in oxidizing flame; slightly fusible in reducing flame. In salt of phosphorus gives a red bead which, on treatment in reducing flame becomes violet, slowly soluble in hydrochloric acid and the solution boiled with tin is violet and on evaporation becomes rose-red.

Similar Species.—Differs from magnetite and hematite in the titanium reactions.

Remarks.—Menacanite occurs in crystalline rocks, often with magnetite. It is sometimes altered to limonite and to titanite.

Immensely beds occur at Bay St. Paul, Quebec, and other points in Canada. Found also in the county of Orange, N. Y., in Massachusetts, Connecticut, and elsewhere. A Norwegian locality Kragø, is, for its large crystals, perhaps the most celebrated.

Uses.—It is used as a constituent of the lining of puddling furnaces. Its freedom from impurities, such as phosphorus, would make it a very desirable iron-ore if it were not for the relatively large amount of fuel needed to reduce it.

GOETHITE.

Composition.—FeO(OH). Fe₂O₃ per cent.
General Description.—A yellow, red or brown mineral, occurring in small, distinct, prismatic crystals (orthorhombic), often flattened like scales, or needle-like, or grouped in parallel position. These shade into feather-like and velvety crusts. Occurs also massive like yellow ochre.
Physical Characters.—Opaque to translucent. Lustre, adamantine to dull. Color, yellow, reddish, dark-brown and nearly black. Streak, yellow or brownish-yellow. H., 5 to 5.5. Sp. gr., 4 to 4.4.
Before Blowpipe, etc.—Fuses in thin splinters to a black magnetic slag. In closed tube yields water. Frequently reacts for manganese. Soluble in hydrochloric acid.
Uses.—Goethite is an ore of iron, but is commercially classed with limonite under the name of brown hematite. Large deposits are reported in Minnesota.

LIMONITE.—Bog-Ore, Brown Hematite.

Composition.—Fe₂(OH)₅Fe₂O₃ (Fe₂, 59.8 per cent.). Frequently quite impure, from sand, clay, manganese, phosphorus, etc.
General Description.—Never found crystallized, but varies from the loose, porous bog-ore and earthy ochre of brown to yellow color, to compact varieties, often with black varnish-like surface.
It occurs in botryoidal, stalactitic, etc., shapes, very frequently with a fibrous radiated structure. Streak is yellowish-brown.

**Physical Characters.** H., 5 to 5.5. Sp. gr., 3.6 to 4.

Lustre, varnish like, silky, dull. Opaque.

Streak, yellowish-brown. Tenacity, brittle, earthy.

Color, brown, nearly black, yellow like iron rust.

Before Blowpipe, Etc.—In closed tube yields water, and becomes red. Fuses in thin splinters to a dark magnetic slag. Usually reacts for silica and manganese. Soluble in hydrochloric acid, and may leave a gelatinous residue.

**Varieties.**

Bog-iron, loosely aggregated ore from marshy ground, often intermixed with and replacing leaves, twigs, etc.

Yellow ochre, umber, etc., earthy material, intermixed with clay.

Brown clay ironstone, compact, often nodular masses, impure from clay.

**Similar Species.**—Distinguished from other iron-ores, except goethite, by its streak, and from the latter by lack of crystallization.

**Remarks.**—One usual result of the decomposition of any iron-bearing mineral is limonite. The decomposition by water, carbon dioxide and organic acids, produces soluble iron salts, which are carried to some valley by the streams, and by oxidation the relatively insoluble limonite forms as a scum on the water and then sinks to the bottom as bog-ore. In time, by pressure, heat, etc., these deposits are compacted.

Limonite constitutes about 15 per cent, of the iron-ore mined in the United States. The largest deposits which are regularly mined exist in the States of Virginia, Alabama, Pennsylvania, Michigan, Tennessee, and Georgia.

**Uses.**—It is the most abundant ore of iron, but is relatively impure and low in iron. The earthy varieties are used as cheap paints, and after burning are darker in color, and are called burnt umber, burnt sienna, etc.

**COPIAPITE.**—Misc.

**Composition.**—Fe₂(FeOH)₃(SO₄)₆ + 18H₂O, (Fe₂O₃ 30.6. SO₃ 38.3. H₂O 31.1 per cent.) often with some Al₂O₃ or MgO.

**General Description.**—Brownish-yellow to sulphur-yellow mineral, occurring granular massive, or in loosely compacted crystalline scales, rarely, as tabular monoclinic crystals. It has a disagreeable metallic taste.
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Physical Characters.  H., 2.5.  Sp. gr., 2.1.
Lustre, pearly, feeble,  TRANSLUCENT.
Streak, yellowish-white,  TASTE, metallic, nauseous.
Color, brown-yellow to sulphur-yellow.


Remarks.—Copiapite results from the oxidation of pyrite, marcasite and pyrhotite.  It occurs with these minerals and with other sulphates.

MELANTERITE.—Copperas.
Composition.—FeSO₄ · 7H₂O.  (Fe₂O₃ 25.9, SO₄ 23.8, H₂O 45.3 per cent.).
General Description.—A pale green fibrous efflorescence on pyrite or marcasite, or stalactitic massive or pulverulent.  It has a sweet astringent taste.  Rarely in monoclinic crystals.  On exposure it becomes dull yellowish white.
Before Blowpipe, Etc.—On charcoal fuses becoming successively brown, red, and finally black and magnetic.  With soda, yields sulphur test.  In closed tube yields water and both sulphuric and sulphurous acids.  Soluble easily in water, the solution becoming black (ink) on addition of nut galls.

VIVIANITE.—Blue Iron Earth.
Composition.—Fe₃(PO₄)₂ · 8H₂O.  (FeO 43.0, P₂O₅ 28.3, H₂O 28.7 per cent.).
General Description.—Usually found as a blue to bluish green earthy mineral, often replacing organic material as in bones, shells, horn, tree roots, etc.  Also found as glassy crystals (monoclinic), colorless before exposure, but gradually becoming blue.
Physical Characters.—Transparent to opaque.  Lustre, vitreous to dull.  Color and streak, colorless before exposure, but usually blue to greenish.  H = 1.5 to 2.  Sp. gr., = 2.58 to 2.69.  Brittle.
Before Blowpipe, Etc.—Fuses easily to a black magnetic mass and colors flame pale bluish-green, especially after moistening with concentrated sulphuric acid.  In closed tube yields water.  Soluble in hydrochloric acid.  The dried powder is brown.

TRIPHYLITE.
Composition.—Li₂(Fe, Mn)₂PO₄·
General Description.—Usually a translucent bluish-gray, massive mineral with somewhat resinous lustre, and two easy cleavages at 90° to each other.  Also in nearly black orthorhombic crystals.
SCORODITE.

COMPOSITION.—FeAsO₄ + 2H₂O. (FeO 34.8 As₂O₅ 49.8. H₂O 15.8 per cent.)

GENERAL DESCRIPTION.—Usually found as small pointed orthorhombic crystals, or druses of crystals of either a pale bluish-green or dark brown color. More rarely occurs earthy.


BEFORE BLOWPIPE, ETC.—On charcoal fuses easily, with a pale blue flame and odor like garlic, to a brown or black magnetic mass. Easily soluble in hydrochloric acid but insoluble in nitric acid.

PHARMACOSIDERITE.—Cube Ore.

COMPOSITION.—Fe(FeOH)₃ (As₂O₅)₃ + 6H₂O. (Fe₂O₃ 40.0. As₂O₅ 43.1. H₂O 16.9 per cent.)

GENERAL DESCRIPTION.—Groups of small translucent cubes or modified tetrahedrons of green or yellowish-brown color. More rarely granular.

PHYSICAL CHARACTERS.—Translucent. Lustre, adamantine. Color, emerald or olive-green, or yellowish-brown. Streak, paler than color. H., 2.5. Sp. gr., 2.9 to 3. Slightly sectile.

BEFORE BLOWPIPE, ETC.—As for scorodite.

SIDERITE.—Spathic Ore.

COMPOSITION.—FeCO₃ (FeO 62.1. CO₂ 37.9 per cent.) usually with some Ca, Mg or Mn.

GENERAL DESCRIPTION.—Agrees closely in many characters with the group of which calcite and dolomite are the most important members. It occurs granular massive of a gray or brown color and also in cleavable masses and hexagonal crystals. At times it is quite black from included carbonaceous matter.

CRYSTALLIZATION.—Hexagonal c = 0.8184. R = 107°. O = 136° 37'. Usually rhombohedral, often with curved (composite) faces like those of dolomite.
Lustre, vitreous to pearly.  Opaque to translucent.
Streak, white or pale yellow.  Tenacity, brittle.
Color, gray, yellow, brown or black.
Cleavage, rhombohedral $R \times R = 107^\circ$.

Before Blowpipe, Etc.—Decrepitates, become black and magnetic and fuses with difficulty. Soluble in warm acids with effervescence. Slowly soluble in cold acids. May react for manganese.

Similar Species.—It is heavier than dolomite and becomes magnetic on heating. Some stony varieties resemble varieties of sphalerite.

Remarks.—Siderite occurs as beds in gneiss, mica and clay-slate, etc., and as stony impure material in the coal formation. Frequently with metallic ores. It is probably chiefly formed by the action of decaying vegetation on limonite. An impure siderite forms the chief ore in Cornwall and other English mines. It is found at Catskill, N. Y., and in the coal regions of Pennsylvania, Ohio, Virginia, and Tennessee, in varying quantities, but forms only a little over one per cent. of American iron ore.

Uses.—It is used as an ore of iron and when high in manganese it is used for the manufacture of spiegelisen.

Chromite.—Chromic Iron.

Composition.—$\text{FeCr}_2\text{O}_4$, $(\text{FeO} \cdot 3\text{O}, \text{Cr}_2\text{O}_3, 68 \text{ per cent.})$, sometimes with $\text{Al}_2\text{O}_3$ or $\text{MgO}$ as replacing elements.

General Description.—Usually a massive black mineral resembling magnetite. Occurs either granular or compact or as disseminated grains. Rarely in small octahedral crystals. Frequently with more or less serpentine, mechanically intermixed, giving rise to green and yellow spots and streaks.

Physical Characters.  H., 5.5.  Sp. gr., 4.3 to 4.5.
Lustre, sub-metallic to metallic.  Opaque.
Streak, dark-brown.  Tenacity, brittle.
Color, black.  May be slightly magnetic.

Before Blowpipe, Etc.—Infusible, sometimes slightly fused by reducing flame, and then becomes magnetic. In salt of phosphorus, in oxidizing flame, gives yellow color hot, but on cooling becomes a fine emerald-green. With soda and nitre on platinum fuses to a mass, which is chrome-yellow when cold. Insoluble in acids.
SIMILAR SPECIES.—Chromite is distinguished from other black minerals by the salt of phosphorus reactions, and to a considerable extent by the serpentine with which it occurs.

REMARK.—Chromite occurs in veins and masses in serpentine and has been found in large isolated pockets in Southern Pennsylvania and around Baltimore, Md., but the richest ore has been exhausted, and most of the ore now used is brought from Turkey and from New Caledonia. Extensive deposits are also found in Del Norte, San Luis Obispo, Shasta and Placer Counties, California, but of somewhat lower grade.

USES.—Chromite is the source of the various chromium compounds, such as potassium dichromate, the chrome colors, etc. It is also used in the manufacture of a hard chrome steel.

COLUMBITE.—Tantalite.

COMPOSITION.—Fe₂(ÇO₃)₁₂. (FeO 17.3, Ç₂O₃ 82.7), but grading into tantalite. Fe (TaO₂)₁₂ without change of crystalline form. Mn is often present.

GENERAL DESCRIPTION.—Black, often iridescent prismatic crystals, in veins of granite. More rarely massive.


BEFORE BLOWPIPE, ETC.—Infusible. Fused with potassium hydroxide and boiled with tin gives deep-blue solution. Insoluble in acids.

WOLFRAMITE.

COMPOSITION.—(Fe,Mn) WO₄. (About 76.5 per cent. WO₄.)

GENERAL DESCRIPTION.—Heavy dark-gray to black sub-metallic crystals, orthorhombic in appearance, and also in granular or columnar masses.


Physical Characters. H., 5 to 5.5. Sp. gr., 7.1 to 7.55.

LUSTRE, sub-metallic.

STREAK, dark-brown to black.

COLOR, dark-gray to black.

OPAQUE.

TENACITY, brittle.

Slightly magnetic.

BEFORE BLOWPIPE, ETC.—Fuses readily to a crystalline globule, which is magnetic. In salt of phosphorus yields a reddish-yellow glass, which in reducing flame becomes green, and if this bead is pulverized and dissolved with tin, in dilute hydrochloric acid, a blue solution results.
THE IRON MINERALS.

Partially soluble in hydrochloric acid, the solution becoming blue on addition of tin.

Similar Species.—Distinguished by its fusibility and specific gravity from similar iron and manganese minerals.

Remarks.—Wolframite occurs in tin veins and deposits and with other metallic minerals. It occurs altered to Scheelite and also pseudomorphous after scheelite. It is common in the Cornwall and Zinnwald tin mines. It is also found at Flume Mountain, N. C., Monroe and Trumbull, Ct., Black Hills, Dakota, Mine la Motte, Mo., and elsewhere.

Uses.—It is used to make an alloy of tungsten with steel, especially valued for permanent magnets, and as a source of tungsten salts, especially tungstic acid and sodium tungstate, which are used in dyeing, and as material to render cotton less inflammable.
CHAPTER XVII.

THE MANGANESE MINERALS.

The minerals described are* Sulphide.—Alabandite. Oxides.—Braunite, Hausmannite, Pyrolusite, Manganite, Psilomelane, Wad. Phosphates.—Triplite. Carbonate.—Rhodochrosite.

The principal economic use of manganese minerals is in the production of alloys with iron spiegeleisen and ferromanganese used in the manufacture of steel. About nine-tenths of all the manganese ore mined is† used for this purpose. The method of preparation is very like that used in the manufacture of pig-iron.

Minor uses are in manufacture of chlorine, oxygen, disinfectants, driers for varnishes; as a decolorizer of glass and to color glass, pottery and bricks; in dyeing calico, making paints, etc.

In the West, especially Colorado and Arizona, manganese ores often carry silver, and are smelted with other silver-bearing minerals, the manganese acting as a flux. About 20,000 tons were so used in 1889‡.

The only manganese minerals important as ores are the oxides pyrolusite, psilomelane (including wad), braunite and manganite. These frequently occur together and grade into each other, and as all are black, their distinction is not easy. In 1889 the world produced§ 143,997 tons, of which the United States used about 30,000 tons.

Alabandite.—Manganblende.

Composition.—MnS. (Mn 63.1, S 36.9 per cent.).

General Description.—A dark iron black metallic mineral with an olive green powder or streak. Usually massive, with easy cubic cleavage and occasionally in cubic or other isometric crystals. Also massive granular.


* The common silicate, rhodonite, which has no economic importance, is described under the silicates.
† Bulletin 50, 11th Census.
‡ Mineral Industries, 1892, p 337.
BRAUNITE.

COMPOSITION.—Mn₃O₄, but usually containing MnSiO₃.

GENERAL DESCRIPTION.—Brownish black granular masses and occasional minute tetragonal pyramids almost isometric, ε = 0.983.

Physical Characters. H., 6 to 6.5. Sp. gr., 4.75 to 4.82.
Lustre, submetallic. Opaque.
Streak, brownish black. Tenacity, brittle.
Color, brownish black to steel gray.

Before Blowpipe, Etc.—Infusible. With borax an amethystine bead. Soluble in hydrochloric acid, evolving chlorine and generally leaving gelatinous silica.

Similar Species.—Resembles hausmannite, but has a darker streak and is harder.

Uses.—It occurs in large quantities in India and smaller amounts elsewhere, and is an ore of manganese.

HAUSMANNITE.

COMPOSITION.—Mn₃O₄. (Mn₂O₃ 59.0, MnO 31.0 per cent.).

GENERAL DESCRIPTION.—Black granular strongly coherent masses occasionally in simple and twinned tetragonal pyramids which are more acute than those of braunite, ε = 1.174.

Streak, chestnut brown. H., 5 to 5.5. Sp. gr., 4.75 to 4.85. Strongly coherent.

Similar Species.—Differs from braunite in hardness, streak and absence of silica.

PYROUSITE.—Black Oxide of Manganese.

COMPOSITION.—Mn₂O₃. (Mn 63.2 per cent.).

GENERAL DESCRIPTION.—A soft black mineral of metallic lustre. Frequently composed of short indistinct crystals or radiated needles, but also found compact, massive, stalactitic, and as velvety crusts. Also is the common dendrites. Usually soils the fingers. Frequently in alternate layers with psilomelane.
Physical Characters.  H., 1 to 2.5.  Sp. gr., 4.7 to 4.86.
Lustre, metallic or dull.  Opaque.
Streak, black.  Tenacity, rather brittle.
Color, black to steel gray.


Similar Species.—Distinguished by its softness and black streak from other manganese minerals.

Remarks.—Pyrolusite results from the dehydration of manganite and the alteration of alabandite and rhodochrosite.  It is usually with psilomelane, hematite, limonite or manganite.

By far the larger part of all that is mined in this country is obtained from Crimora, Va.; Cartersville, Ga., and Batesville, Ark.  Other deposits exist in California, Vermont and North Carolina.  Large amounts are annually imported from Cuba.  The parent material for use in glass making is obtained near Sussex, N. B., and from the Tenny Cape district, Nova Scotia.

Uses.—Pyrolusite is used in the manufacture of chlorine and oxygen, and in the preparation of spiegelisen.  Also in coloring and decolorizing glass and as an oxidizing agent in varnishes, linseed oil, etc.

Manganite.

Composition.—MnO(OH), (Mn 62.4, O 27.3, H2O 10.3 per cent.).

General Description.—Occurs in long and short prismatic (orthorhombic) crystals often grouped in bundles with fluted or rounded cross-section and undulating terminal surface, rarely massive, granular or stalactitic.

Lustre, submetallic.  Opaque.
Streak, reddish brown to black.  Tenacity, brittle.
Color, steel gray to iron black.

Before Blowpipe, Etc.—Like pyrolusite, but yields decided test for water and very little oxygen.

Remarks.—Frequently formed by deposition from water.  By alteration it forms other manganese minerals such as pyrolusite.
THE MANGANESE MINERALS.

PSILOMELANE.—Black Hematite.

Composition.—Perhaps MnO₂ + (H₂O, K₂O or BaO) or H₂MnO₄, with replacement by Ba or K.

General Description.—A smooth black massive mineral commonly botryoidal, stalactitic or in layers with pyrolusite. Never crystallized.


Lustre, submetallic or dull.  Opaque.

Streak, brownish black.  Tenacity, brittle.

Color, iron black to dark gray.

Before Blowpipe, Etc.—Infusible.* In closed tube yields oxygen and usually water. Soluble in hydrochloric acid, with evolution of chlorine. A drop of sulphuric acid added to the solution will usually produce a white precipitate of barium sulphate.

Similar Species.—Distinguished from pyrolusite by its hardness, and from limonite by its streak.

Remarks.—Its localities are the same as for pyrolusite, and the two minerals are usually mined together.

Uses.—As for pyrolusite; the products, however, are less pure.

WAD.—Bog Manganese.

Composition.—Mixture of manganese oxides, with often oxides of metals other than manganese such as cobalt, copper and lead.

General Description.—Earthy to compact indefinite mixtures of different metallic oxides, in which those of manganese predominate. Dark brown or black in color; often soft and loose, but sometimes hard and compact.


Before Blowpipe, Etc.—As for psilomelane, but often with strong cobalt or copper reactions.

Uses.—Wad is used as a paint and in the manufacture of chlorine.

TRIPLITE.

Composition.—(RF)R₂O₅.  chiefly manganese and iron.

General Description.—A resinous, brown to nearly black mineral, usually massive and often showing cleavage in two directions at 90° to each other. Sometimes occurs as a stain on other minerals.


Before Blowpipe, Etc.—Fuses very easily to a black magnetic mass. Yields a bluish-green flame, which sulphuric acid makes paler. Colors borax bead amethystine. When heated with sulphuric acid, evolves fluorine. Soluble in hydrochloric acid.

* May become magnetic from impurities.
RHODOCHROSITE.

COMPOSITION.—MnCO₃ (MnO 61.7, CO₂ 38.3 per cent.) with partial replacement by Ca, Mg or Fe.

GENERAL DESCRIPTION.—One of the calcite-dolomite-siderite group, occurring in rhombohedral crystals, with curved faces, but more frequently massive, either cleavable, granular or compact. Less frequently globular, columnar or incrusting.

CRYSTALLIZATION.—Hexagonal \( c = 3.184 \). \( R \times R = 107^\circ \). Angles the same as in siderite. Form usually the rhombohedron.

PHYSICAL CHARACTERS.  H., 3.5 to 4.5.  Sp. gr., 3.3 to 3.6.
LUSTRE, vitreous to pearly.  TRANSPARENT to opaque.
STREAK, white.  TENACITY, brittle.
COLOR, light pink, rose red, brownish red and brown.
CLEAVAGE, parallel to rhombohedron (angle 107°).

BEFORE BLOWPIPE, ETC.—Infusible, but decrepitates violently and becomes dark colored. In borax yields amethystine bead. Soluble in warm hydrochloric acid, with effervescence, slowly soluble in the cold acid.

SIMILAR SPECIES.—Distinguished from rhodonite by form, cleavage, effervescence and infusibility.

REMARKS.—Principally found in ore-veins, especially with ores of manganese and silver. On exposure, sometimes loses color or becomes spotted by oxide. Found at Mine Hill, N. J.; Butte, Montana; Austin, Nev. and elsewhere. It is not mined, however, in this country. The only producing localities are Merionethshire, Wales, and Cheyron, Belgium.

* May become magnetic from impurities.
CHAPTER XVIII.

NICKEL AND COBALT MINERALS.

The cobalt minerals described are: Sulphides and Arsenides, Linneite, Cobaltite, Smaltite; Arsenates, Erythrite.

The nickel minerals described are; Sulphide, Millerite; Arsenide, Niccolite; Arsenate, Annabergite; Carbonate, Zaratite; Silicate, Garnierite.

Both nickel and cobalt are found at times in arsenopyrite, and nickel in pyrrhotite and chalcopyrite.

The metal cobalt has, as yet, no important use; the oxide is used to impart a blue color to glass and pottery. The chief commercial compound is Smalt, a cobalt glass, the cobalt replacing the calcium of ordinary glass. This is ground and used as a fine blue pigment, which is unaltered by exposure.

Cobalt blue and Rimmann's green are compounds of cobalt with alumina and zinc oxide respectively.

Metallic nickel is extensively used in different alloys, and, indeed, was used as an alloy before it was obtained as a distinct metal. It was first obtained as a residue in the manufacture of smalt, as an alloy with copper, iron and arsenic. In this form it constituted the useful material called German silver or nickel silver, so largely used in plated silverware. Later, a large use for it was found in coins, the United States mint alone using nearly one million pounds between 1857 and 1884. In this application copper is added in large proportion, the alloy of the present five-cent piece being 23 per cent. nickel, 75 per cent. copper, in other coins the percentage of copper being still greater.

More recent alloys* are nickel-steel for armor plates and a nickel-copper alloy for casing rifle bullets.

A sulphate of nickel and ammonium is also manufactured in large amounts for use in nickel-plating.

DESCRIPTIVE MINERALOGY.

The nickel of commerce is nearly all obtained either from the garnierite of New Caledonia or from the deposit of nickel-bearing chalcopyrite and pyrrhotite at Sudbury, Ontario. The garnierite* is smelted in a low-blast furnace, with coke and gypsum, and the compound (matte) of nickel, iron and sulphur thus produced is alternately roasted and fused with sand, in a reverberatory furnace, until nearly all the iron has been removed. The nickel sulphide, by oxidation, is converted into oxide.

Nickel oxide is obtained from pyrrhotite and chalcopyrite in almost the same way, but is preceded by a roasting, to remove much of the sulphur. Copper is removed from the matte by roasting with salt and dissolving out the resulting copper chloride with water.

The oxide is reduced to metal by mixing with charcoal and heating, white hot, in a graphite crucible.

The extraction of cobalt from such a matte is an elaborate chemical operation involving solution in hydrochloric acid, precipitation of manganese and iron as basic carbonates, and of other metals as sulphides, leaving a solution of chloride of nickel and cobalt. From these the cobalt is precipitated with great care, by means of calcium hypochlorite, as cobaltic hydroxide, after which the nickel is precipitated as hydroxide by lime-water.

A new method both for the extraction of nickel from its ore and for its separation from cobalt promises to supersede those now in use. The process is based on the recent discovery that when carbon monoxide is passed over heated nickel, volatile nickel carbonyl, \( \text{Ni(CO)}_5 \), is formed. This is the only volatile nickel compound known, and as cobalt does not react in any similar fashion, the separation of nickel free from cobalt is easily accomplished. The reconversion of the nickel carbonyl into nickel and carbon monoxide is a simple operation.

THE COBALT MINERALS.

LINNÆITE.—Cobalt* Pyrites.

**Composition.**—(Co,Ni)\(_2\)S\(_4\), often with some Fe or Cu replacing.

**General Description.**—A steel-gray metallic mineral, usually in granular or compact masses intermixed frequently with chalcopyrite; also in small isometric crystals, usually octahedrons.

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* Ibid., 352.
**Nickel and Cobalt Minerals.**

**Physical Characters.** H., 5.5. Sp. gr., 4.8 to 5.
- Lustre, metallic. Opaque.
- Streak, nearly black. Tenacity, brittle.
- Color, steel-gray, with reddish-tarnish.
- Cleavage, cubic imperfect.

**Before Blowpipe, Etc.**—On charcoal fuses to a magnetic globule, and gives off fumes of sulphur dioxide. In borax bead gives a deep blue color, and with frequent replacement of borax the red bead of nickel may be obtained. Soluble in nitric acid to a red solution and with separation of sulphur.

**Remarks.**—Occurs with other cobalt and nickel minerals and with chalcopyrite, pyrrhotite, bornite, at Mine La Monte, Mo., Lovelock’s Station, Nev., and in a few other American localities.

**Uses.**—Does not occur in large amounts, but is used as a source of both cobalt and nickel.

**Cobaltite.**—Cobalt Glance.

**Composition.**—CoAsS, (Co 35.5, As 45.2, S 19.3 per cent.)

**General Description.**—A silver white to gray metallic mineral resembling linnaeite in massive state but in crystals differing in that the forms are the hemihedral isometric forms in which pyrite occurs.

**Physical Characters.** H., 5.5. Sp. gr., 6 to 6.1.
- Lustre, metallic. Opaque.
- Streak, black. Tenacity, brittle.
- Color, silver white to gray.
- Cleavage, cubic.

**Before Blowpipe, Etc.**—On charcoal fuses to a magnetic globule and evolves white fumes with garlic odor. Unaltered in closed tube. Soluble in warm nitric acid to rose-red solution, with residue of sulphur and arsenious oxide.

**Uses.**—It is used in the manufacture of smalt and in porcelain painting.

**Smaltite.**

**Composition.**—(Co,Ni) As, varying widely in proportion of cobalt and nickel, and usually containing some iron also.
GENERAL DESCRIPTION.—A tin-white to steel-gray metallic mineral resembling linnaeite and cobaltite. Usually occurs granular massive, but also in isometric crystals, especially modified cubes with curved faces.

Lustre, metallic.  
Streak, black.  
Color, tin-white to steel-gray.  
Opaque.  
Tenacity, brittle.  
Cleavage, octahedral.

BEFORE BLOWPIPE, ETC.—On charcoal fuses, yields white fumes with garlic odor and leaves a magnetic residue, which, when oxidized in contact with frequently replaced borax, yields successively slags colored by iron, cobalt, nickel and possibly by copper. In closed tube yields arsenical mirror. Soluble in nitric acid to a red to green solution according to proportion of cobalt and nickel. Partially soluble in hydrochloric acid, especially so after fusion, but yields no voluminous precipitate of yellow arsenic sulphide, as does arsenopyrite when similarly treated.

SIMILAR SPECIES.—Differs from linnaeite and cobaltite in cleavage, specific gravity and blowpipe reactions. Differs from most arsenopyrite and tetrahedrite in the cobalt blue slags which it yields. It can best be distinguished from coalsaltiferous arsenopyrite by the reaction in acids after fusion.

REMARKS.—By oxidation produces arsenates of cobalt (erythrite) and nickel (annabergite). Occurs in veins with other metallic minerals, especially ores of copper, silver, nickel and cobalt. Especially abundant in the nickel mines of Saxony. Found at Chatham, Ct., Franklin Furnace, N. J., and in California.

USES.—It is the chief ore of cobalt.

ERYTHRITE.

COMPOSITION.—Co₅(AsO₄)₂·SH₂O.  (CoO 37.5, As₂O₅ 38.4, H₂O 24.1 per cent.).

GENERAL DESCRIPTION.—Groups of minute peach red or crimson crystals forming a drusy or velvety surface. Also in small globular forms or radiated or as an earthy incrustation of pink color.

PHYSICAL CHARACTERS.—Translucent. Lustre, adamantine or pearly. Color, crimson, peach red, pink and pearl gray. Streak, paler than color. H., 1.5 to 2.5. Sp. gr., 2.91 to 2.95. Flexible in laminae.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily, evolves white fumes with garlic odor, and leaves a magnetic residue, which imparts the characteristic blue to borax bead. Soluble in hydrochloric acid to a light red solution.
THE NICKEL MINERALS.

MILLERITE.—Capillary Pyrites.

COMPOSITION.—NiS. (Ni 64.4 per cent.).

GENERAL DESCRIPTION.—A brass-colored mineral with metallic lustre, especially characterized by its occurrence in hair-like or needle crystals, often interwoven or in crusts made up of radiating needles visible on fracture. Hexagonal.

Physical Characters. H., 3 to 3.5. Sp. gr., 5.3 to 5.65.

Lustre, metallic. Opaque.

Streak, greenish-black. Tenacity, crystals elastic.

Color, brass or bronze yellow.

BEFORE BLOWPIPE, ETC.—On charcoal fuses and fuses to a brittle magnetic globule, which will color borax red. Soluble in aqua regia to a green solution, from which potassium hydroxide precipitates a green nickelous hydroxide which is again soluble in ammonia to a blue solution.

REMARKS.—Millerite has probably been formed in the same way as pyrite. It is probable that the nickel in pyrrhotite is there as millerite. Other associates are siderite, hematite and dolomite. In the United States it has been obtained chiefly from the Lancaster Gap mine, in Pennsylvania, and at Antwerp, N. Y.

USES.—It is a valued ore of nickel.

NICCOLITE.—Copper Nickel.

COMPOSITION.—NiAs. (Ni 43.9 per cent.). As is replaced to some extent by Sb or S, and Ni by Fe or Co.

GENERAL DESCRIPTION.—A massive mineral of metallic lustre, characteristic pale copper red color and smooth impalpable structure. Sometimes the copper-red kernel has a white metallic crust. Occasionally occurs in small indistinct hexagonal crystals.

Physical Characters. H., 5 to 5.5. Sp. gr., 7.3 to 7.67.

Lustre, metallic. Opaque.

Streak, brownish-black. Tenacity, brittle.

Color, pale copper red with dark tarnish.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily, giving off white fumes with garlic odor and leaving a magnetic residue, which will color borax bead red and sometimes blue, in which case the borax must be renewed until the cobalt is all removed. In
open tube yields a white sublimate and a yellowish-green pulverulent residue. Soluble in concentrated nitric acid to a green solution, which may be tested as under millerite.

Similar Species.—Differs from copper in hardness, black streak and brittleness.

Remarks.—Its most abundant American localities are at Lovelock's, Nevada, and Tink Cove, Newfoundland. Also obtained at Chatham, Conn., and Thunder Bay, Lake Superior.

Uses.—It is an important ore of nickel.

Annabergite.—Nickel Bloom.

Composition.—Ni₃(AsO₄)₆SH₂O. (NiO 37.4, As₂O₃ 38.5, H₂O 24.1 per cent.).

General Description.—Pale apple-green crusts, and occasionally very small hair-like crystals. Usually occurs on niccolite or smaltite.


Before Blowpipe, etc.—On charcoal, fuses easily to a magnetic button, and becomes dull and yellow during fusion, evoking garlic odor. In closed tube, yields water and darkens. With borax, gives red bead. Soluble in nitric acid.

Remarks.—Results from the oxidation of niccolite or smaltite in moist air.

Zaratite.—Emerald Nickel.

Composition.—NiCO₃·2Ni(OH)₂·4H₂O. (NiO 39.6, CO₂ 11.7, H₂O 48.7 per cent.).

General Description.—Occurs only as a thin varnish-like coating upon nickel-bearing chrome or magnetite.


Before Blowpipe, etc.—Inflatable. Colors borax bead red. In closed tube, yields water. Soluble in warm dilute hydrochloric acid, with effervescence, to a green solution.

Garnierite.—Noumeite.

Composition.—H₂(Ni,Mg)SiO₄ + H₂O or 2(Ni,Mg)₅Si₃O₁₂·3H₂O.

General Description.—Loosely compacted masses of brilliant dark-green to pale-green mineral, somewhat unctuous. Structure often small mammeloned, with dark-green, varnish-like surfaces, enclosing dull green to yellowish ocherous material. Easily broken and earthy.

Physical Characters. H., 2 to 3. Sp. gr., 2.27 to 2.38.

Lustre, varnish-like, to dull. Opaque.

Streak, light green to white. Tenacity, friable.

Color, deep green to pale greenish-white.

SIMILAR SPECIES.—Differs from malachite and chrysocolla in structure and unctuous feeling. Differs from serpentine in deep color and nickel reaction.

REMARKS.—Occurs in New Caledonia in veins in serpentine, with chromite and talc. Possibly derived from a nickel-bearing chrysolite. Deposits are also known at Riddles, Oregon and Webster, N. C.

USES.—It is now the chief source of nickel.
CHAPTER XIX.

ZINC AND CADMIUM MINERALS.


The only cadmium mineral is Greenockite.

The important ores of zinc are sphalerite, smithsonite, and calamine; and, in New Jersey, willemite and zincite occur in quantity sufficient to be considered ores.

In this country, Missouri and the adjoining States yield most of the zinc ore, although other important regions are Pennsylvania, New Jersey, and Virginia. The western ore contains lead ore, from which it is separated by jigging and concentration. In all, in 1889, this country produced* 234,503 tons of zinc ore, from which 53,860 tons of metallic zinc and 16,970 tons of zinc oxide were manufactured.

The principal uses of metallic zinc are in galvanizing iron wire or sheets and in manufacturing brass. A smaller amount is made into sheet zinc, etc.

Metallic zinc is always obtained by distillation of its roasted ores with carbon. The sulphide and carbonate, by roasting, are converted into oxide, and the silicates are calcined to remove moisture. The impure oxides, or the silicate, are mixed with fine coal and charged in tubes or vessels of clay, closed at one end and connected at the other end with a sheet-iron condenser. These are submitted to a gradually increasing temperature, by which the ore is reduced to metallic zinc, and, being volatile, distils, and is caught in the condenser.

Zinc oxide, ground in oil, constitutes the paint zinc white. The oxide may be made from the metal by heating it to a temperature at which the zinc takes fire and drawing the fumes into suitable condensers; or, as in this country, it may be made directly from the ore.

* Bulletin 80, Eleventh Census.
About five tons per year of cadmium are obtained from the Silesian zinc ores. The first fumes are redistilled and finally reduced with carbon. The metal is used in fusible alloys and the sulphide forms a splendid yellow pigment unaltered by exposure.

THE ZINC MINERALS.

SPHALERITE.—Blende, Black Jack.

Composition.—ZnS. (Zn, 67 per cent.). Often contains Cd, Mn, Fe.

General Description.—A somewhat resinous mineral shading in color from yellow through brown to nearly black and more or less transparent. Even in darkest specimens there is somewhere to be seen in most instances some partially transparent "honey yellow" to brown portion. It occurs most frequently cleavable massive but also in isometric crystals, hemihedral and often very complex, and in compact fine-grained masses or concentric alternate layers with galenite.

Physical Characters. H., 3.5 to 4. Sp gr., 3.9 to 4.1.

Lustre, resinous. Transparent to translucent.

Streak, white to pale brown. Tenacity, brittle.

Color, yellow, brown, black; rarely red, green or white.

Cleavage, parallel to rhombic dodecahedron (angles 120° and 90°).

Before Blowpipe, Etc.—On charcoal fuses with difficulty, but readily yields a sublimate, sometimes brown at first from cadmium and later yellow while hot, white when cold and becoming bright green if moistened and ignited with cobalt solution. With soda gives a sulphur reaction. Soluble in hydrochloric acid with effervescence of hydrogen sulphide.

Similar Species.—Smaller crystals sometimes slightly resemble garnet or cassisiterite, but are not so hard.

Remarks.—Sphalerite has probably been formed by precipitation from water by H₂S or with the aid of decaying organic matter. By oxidation it changes to sulphate which in turn may be decomposed by carbonates and silicates forming carbonates and
silicates of zinc. Sphalerite is a common associate of lead and silver ores and is detrimental, as it makes their treatment more difficult. It also occurs with other sulphides and with other zinc ores. It is mined in southwest Missouri, at Friedensville, Pa., in the southwestern part of Wisconsin, at Pulaski, Va., and at other places. In small quantities it is of very common occurrence.

USES.—It is an important ore of zinc and also is the source of most of the cadmium of commerce.

ZINCITE.—Red Zinc Ore.

COMPOSITION.—ZnO, (Zn 80.3 per cent.) with usually some Mn or Fe.

GENERAL DESCRIPTION.—A deep red to brick-red adamantine mineral occurring in lamellar or granular masses, either in calcite or interspersed with grains and crystals of black franklinite and yellow to green willemite. A few hexagonal pyramids have been found.

Physical Characters. H., 4 to 4.5. Sp. gr., 3.4 to 5.7.
LUSTRE, sub-adamantine. TRANSLUCENT.
STREAK, orange yellow. TENACITY, brittle.
COLOR, deep red to orange red.
CLEAVAGE, basal and prismatic yielding hexagonal plates.

Before Blowpipe, Etc.—Infusible. On charcoal gives reactions for zinc as described under sphalerite. In closed tube blackens, but is again red on cooling. With borax usually gives amethystine bead. Soluble in hydrochloric acid without effervescence.

Similar Species.—Differs from realgar and cinnabar in its associates, infusibility and slow volatilization.

Remarks.—Occurs in quantity only in Sussex County, N. J., at the franklinite localities and is smelted with the associated franklinite, willemite, etc., and the zinc recovered.

GOSLARITE.—Zinc Vitriol.

Composition.—ZnSO₄ • 7H₂O, (ZnO 28.2, S0₉ 37.9, H₂O 43.9 per cent.).

General Description.—A white or yellowish earthy mineral with nauseous astrin- gent taste. Usually an incrustation or mass shaped like the original sphalerite or in stalactites. Rare needle-like orthorhombic crystals.

Physical Characters.—Translucent. Lustre, vitreous to dull. Color, white, yellowish, or bluish. Streak, white. H., 2 to 2.5. Sp. gr., 1.9 to 2.1.

Before Blowpipe, Etc.—Fuses easily. Yields water in closed tube. With soda gives a white coat and a sulphur test. Easily soluble in water.

Remarks.—Goslarite is formed by the oxidation of sphalerite in damp locations.
ZINC AND CADMIUM MINERALS.

SMITHSONITE.—Dry Bone, Calamine.

Composition.—ZnCO₃ (ZnO, 64.8; CO₂, 35.2 per cent.).

General Description.—Essentially a white vitreous mineral but often colored yellowish or brownish by iron. Structure stalactitic or botryoidal, or with drusy crystal surface; also in chalky cavernous masses and granular. Sometimes of marked colors as deep green or bright yellow from copper or cadmium respectively.

Crystallization.—Hexagonal. \( \alpha = 0.8063 \).
\[ R \wedge R = 107^\circ 32^\prime, \quad O \wedge R = 137^\circ 2^\prime, \]
usually in small rhombohedral forms like those of siderite.

Physical Characters. H., 5. Sp. gr., 4.3 to 4.5.
Lustre, vitreous to dull. Translucent to opaque.
Streak, white. Tenacity, brittle.
Color, shades of white, more rarely yellow, green, blue, etc.
Cleavage, parallel to rhombohedron (107°).

Before Blowpipe, Etc.—Infusible but readily yields white sublimate on coal, often preceded by brown of cadmium. The sublimate becomes yellow when heated and becomes bright green when moistened with cobalt solution and then heated. Soluble in acids with effervescence.

Similar Species.—Distinguished from calamine by its effervescence and from other carbonates by its hardness.

Remarks.—Smithsonite is a secondary product formed usually by action of carbonated waters on other zinc ores and sometimes by atmospheric action. It occurs with the other ores of zinc, especially calamine, and with ores of lead, copper and iron. In this country it is most abundant in the Missouri, Virginia and Wisconsin zinc regions.

Uses.—Smithsonite, being easily reduced with little fuel, is a valuable zinc ore, but as it is found chiefly near the surface, the deposits have been nearly exhausted.

HYDROZINCITE.—Zinc Bloom.

Composition.—ZnCO₃·Zn(OH)₂ (ZnO 75.3, CO₂ 15.6, H₂O 11.1 per cent.).

General Description.—Usually a soft white incrustation upon other zinc minerals, or as dazzling white stalactites, or earthy and chalky like.

Physical Characters.—Opaque. Lustre, dull or pearly. Color, pure white to yellowish. Streak shining white. H., 2 to 2.5. Sp. gr., 3.5 to 3.8.
Descriptive Mineralogy.


Willemite.—Troostite.

Composition.—Zn₂SiO₄, (ZnO, 72.9; SiO₂, 27.1); often with much manganese replacing zinc.

General Description.—A greenish yellow to apple green or sulphur yellow mineral when pure, but often flesh red or brownish from manganese or iron. Usually occurs granular, but also as hexagonal crystals and massive. The New Jersey variety is known by its associates, franklinite and zirconite.

Crystallization.—Hexagonal ε = 0.6775
R × R = 115° 30', −i × −i = 143° 13'. Long slender prisms of yellowish color and coarse thick prisms of flesh red color occur at Franklin locality; the Moresnet, Belgian crystals are small and brown in color.

Physical Characters. H., 5.5. Sp. gr., 3.89 to 4.2.
Lustre, resinous. Transparent to opaque.
Streak, nearly white. Tenacity, brittle.
Color, greenish to sulphur yellow, apple green, white, flesh red.
Cleavage, basal and prismatic.

Before Blowpipe, Etc.—Fusable in thin splinters only upon the edges to a white enamel. On charcoal with soda and a little borax yields the zinc coat. Soluble in hydrochloric acid leaving a gelatinous residue.

Similar Species.—Red crystals resemble apatite but differ in terminations, rhombohedral in willemite but pyramidal in apatite. Willemite is also heavier than apatite and gelatinizes.

Uses.—In association with the other minerals of Franklin, N. J., it constitutes a valuable ore of zinc. This, however, is its only important locality.

Calamite.—Electric Calamine.

Composition.—(ZnOH)₂SiO₄, (ZnO, 67.5; SiO₂, 25.0; H₂O, 7.5 per cent.).
ZINC AND CADMIUM MINERALS.

General Description.—A stony or vitreous mineral resembling smithsonite in color and structure. Usually yellowish or brownish white and frequently showing a drusy surface and, more rarely, distinct small, more or less transparent crystals. Also in radiated groups of crystals the free ends of which form a ridge or cockscomb. It occurs also granular, stalactitic, botryoidal and as a constituent of clay.

Crystallization.—Orthorhombic, \( a : b : c = 0.738 : 1 : 0.478 \). Often flattened and tabular, the broad face being the brachy pinacoid, and the prism relatively \( \times 4 \), \( l, 0, 3-4, 2-2 \), small. \( l \parallel l = 103^{\circ} 51' \). \( O \parallel 3-1 = 113^{\circ} 49' \). and \( 3-4 \).

Physical Characters. H., 4.5 to 5. Sp. gr., 3.4 to 3.5.
Lustre, vitreous to pearly. Opaque to transparent.
Streak, white. Tenacity, brittle.
Color, yellow to brown, white, colorless, rarely blue or green.
Cleavage, prismatic.

Before Blowpipe, Etc.—Fusible only in finest splinters. With soda and borax, on charcoal yields a white coating, which is made bright green by heating with cobalt solution. In closed tube, yields water. With acids, dissolves, leaving a gelatinous residue.

Similar Species.—It is softer than prehnite, harder than cerussite, and gelatinizes with acids. It differs from willemite in water reaction, and from stilbite in difficulty of fusion.

Remarks.—Cadmite seems to be formed by the action of hot silica bearing waters upon other zinc ores, especially sphalerite. It is often disseminated through a clay, from which it is gradually segregated and crystallized. Its most important locality in America is at Granby, Mo. It is also found in quantity at Sterling Hill, N. J., and Bertha, Va. Abroad, it is exported from Greece, and is mined in large amounts in Silesia and the Rhenish Provinces of Germany.

Uses.—It is a valuable ore of zinc, usually free from volatile impurities.

THE CADMIUM MINERALS.

GREENOCKITE.

Composition.—CdS, (Cd, 77.7 per cent.)

General Description.—Usually a bright yellow powder upon sphalerite, or a yellow coloration in smithsonite. Very rarely as small hemimorphic hexagonal crystals, \( l = 0.81 \).
PHYSICAL CHARACTERS.—Translucent. Luster earthy or adamantine. Color yellow to orange yellow or bronze yellow. Streak orange yellow. H., 3 to 3.5. Sp. gr., 4.9 to 5.0.

BEFORE BLOWPIPE, ETC.—Infusible, but is easily volatilized in the reducing flame, coating the coal with a characteristic brown coat and a iridescent tarnish. In closed tube, turns carmine red on heating, but is yellow on cooling. Soluble in strong hydrochloric acid, with effervescence of hydrogen sulphide.
CHAPTER XX.

TIN AND TITANIUM MINERALS.

THE TIN MINERALS.

The minerals described are: Sulphide; Stannite; Oxide; Cassiterite. Tin is also found as an occasional constituent of tantalite and other tantalates.

Cassiterite is the only ore of tin, and while it occurs or has been reported from nine or ten States, very little tin is yet produced* in this country. The world’s supply of tin, amounting in 1893† to 67,864 long tons, comes chiefly from the East India Islands, Australia and Cornwall, England.

The principal uses of tin are for the manufacture of tin plate—sheet-iron coated with tin—which is used for canning purposes and in household utensils, etc. It is also largely used in alloys, such as bronze, bell metal, pewter, solder and tin amalgam. Tin-foil is also made from it.

The ore as mined is first separated from gangue and impurities by washing, jigging, etc., and is then calcined or roasted, to remove volatile elements, such as sulphur, arsenic, antimony. The fumes produced are usually condensed and sold to the arsenic manufacturers. If wolframite is present, the ore is then mixed with just enough soda to combine with the tungstic acid, and the mixture is heated to a bright red, forming sodium tungstate. This is removed by dissolving it in water, and is sold.

The residue is then mixed with coal and heated in a reverberatory furnace, at a gradually increasing temperature, for several hours. An impure metal is obtained, which is purified by slowly heating and separating the portions melted first, which are nearly pure tin, from the remainder. The residue still contains some tin and this is again worked up.

* The Temescal mines of California produced about 70 tons in 1892.
† Mineral Industry, 1893.
STANNITE.—Tin Pyrites.

Composition.—(Cu, Sn, Fe)S. Uncertain.

General Description.—A massive, granular mineral, of metallic lustre and steel-gray color. It is often intermixed with the yellow chalcopyrite.


Before Blowpipe, Etc.—In the reducing flame fuses. In the oxidizing flame yields SO₂ and is covered by white oxide, which becomes bluish green when heated with cobalt solution. Soluble in nitric acid to a green solution, with separation of sulphur and oxide of tin. With soda, gives sulphur reaction.

CASSITERITE.—Stream Tin. Tin Stone.

Composition.—SnO₂, (Sn 78.6 per cent.), and usually with some Fe₂O₃, and sometimes Ta₂O₅, As₂O₃, SiO₂, or MnO₂.

General Description.—A hard and heavy brown to black mineral occurring either in brilliant adamantine crystals or more frequently in dull botryoidal and kidney-shaped masses and rounded pebbles, often with a concentric or fibrous radiated structure.

![Fig. 204.](image)

![Fig. 205.](image)

\[ i, i - i, 1, 1 - i \] twinned \[ i, i - 2, 3 - \frac{i}{3}, 1 \text{ and } 1 - i \]

Crystallization.—Tetragonal \( c = 0.673 \). \( i \cap 1 = 126° 41' \). \( 1 - i \cap 1 - i = 133° 32' \). \( i \cap 1 = 133° 33' \). Usually short twinned forms, sometimes slender with acute pyramidal terminations.

Physical Characters. H., 6 to 7. Sp. gr., 6.8 to 7.1.

Lustre, adamantine to dull. Opaque to translucent.
Streak, white or pale brown. Tenacity, brittle.
Color, brown to nearly black, sometimes red, gray, or yellow.
Cleavages, indistinct pyramidal and prismatic.

Before Blowpipe, Etc.—Invisible, but in powder becomes yellow and luminous. With cobalt solution the powder or any sublimate is made bluish green. On charcoal with soda may be re-
TIN AND TITANIUM MINERALS.

duced, yielding metallic button and a faint white sublimate close to the assay. Insoluble in acids and almost so in salt of phosphorus or borax in which it usually gives some manganese or iron reaction.

VARIETIES.

Tin Stone.—Crystals and granular masses.

Wood Tin.—Masses with concentric structure, the zones being of different color and internally fibrous.

Stream Tin.—Rounded pebbles and grains found in alluvial deposits.

SIMILAR SPECIES.—The high specific gravity distinguishes it from silicates which it resembles, and the fusibility and insolubility distinguish it from wolframite, etc.

REMARKS.—Cassiterite is found in veins in granite, gneiss, mica, schist and similar rocks with quartz, wolframite and scheelite, and also with certain sulphides and oxides. It occurs also in alluvial deposits, as stream tin. It is practically unchanged by atmospheric influences. The East Indian settlements of Malacca, Banca and Bilitong are the greatest producers of tin ore. They are closely followed by the mines in New South Wales, Queensland and Tasmania. Tin is also mined in large quantities at the ancient localities in Cornwall, England. In America the chief localities are in the Harney Peak region in South Dakota; near Temescal, California, and at Durango, Mexico. It has been found also in New Hampshire, Virginia, Maine, Massachusetts, Alabama, Wyoming and Montana but has not yet been obtained from any American locality in quantity sufficient to be called important.

USES.—All tin is made from cassiterite. The artificial oxide is used as a polishing powder.

THE TITANIUM MINERALS.

The minerals described are: Oxides—Rutile, Octahedrite, and Brookite. Titanium is also a constituent of menaccanite, and titanite, elsewhere described, and occurs in some other minerals.

Oxide of titanium is used in giving an ivory-like appearance to porcelain, but otherwise is of no commercial importance.

A few hundred pounds (6150 pounds between 1880 and 1890) are marketed each year in the United States.

The metal is only produced as a chemical curiosity or for the study of its properties. It can not be prepared in the presence of air as it unites with nitrogen at high temperatures. The method ordinarily used is to reduce the double fluoride of potassium and titanium by means of the vapor of sodium in an atmosphere of hydrogen.
RUTILE.—Nigrine.

Composition.—TiO₂. (Ti 61 per cent.).

General Description.—Brownish red to nearly black prismatic crystals often included in other minerals in hair-like or needle-like penetrations. Also coarse crystals embedded in quartz, feldspar, etc., or in parallel and crossed and netted needles upon hematite or magnetite. Occasionally massive when black and iron bearing.

Crystallization.—Tetragonal \( c = 0.644 \), \( 1 \hat{\alpha} 1 = 123^\circ 7\frac{1}{2}' \), \( 1-\hat{i} \hat{1}-\hat{i} = 134^\circ 58' \), \( 1 \hat{\alpha} 1 = 132^\circ 20' \). Very close to cassiterite in angle and form. Often twinned in knees and rosettes. Prisms often striated vertically.

Physical Characters. H., 6 to 6.5, Sp. gr., 4.15 to 4.25.


Before Blowpipe, Etc.—Infusible. In salt of phosphorus dissolves very slowly in the oxidizing flame to a yellow bead which becomes violet in the reducing flame. Insoluble in acids.

Similar Species.—It is redder and of lower specific gravity than cassiterite. The nearly metallic lustre, weight and infusibility separate it from garnet, tourmaline, vesuvianite, pyroxene, etc.

Remarks.— Widely distributed and associated with many minerals in which it is usually embedded. Little altered by atmospheric influences. Found in many American localities; prominent among them are Lincoln County, Ga., Habersham County, Ga., Warwick, N. Y., Warren, Me. and Magnet Cove, Ark.
TIN AND TITANIUM MINERALS.

USES.—Rutile is used to color porcelain yellow and to give the desired bluish white tint to artificial teeth.

OCTAHEDRITE.—Anatase.

COMPOSITION.—TiO₂.

GENERAL DESCRIPTION.—Very bright brown, deep steel blue and black mineral in pyramidal crystals, sometimes acute and sometimes obtuse but always small.

FIG. 208. FIG. 209.

\[ \frac{a}{b} = \frac{c}{1}, \frac{c}{1}, \frac{c}{1} \text{ and } 1-c. \]

CRYSTALLIZATION.—Tetragonal \( \epsilon = 1.777 \). \( \alpha \perp I = 97° 51' \). \( \beta \perp I = 138° 15' \).


BEFORE BLOWPIPE, ETC.—As for rutile.

REMARKS.—After heating the specific gravity becomes 4.11 to 4.16 or about that of rutile.

BROOKITE.

COMPOSITION.—TiO₂.

GENERAL DESCRIPTION.—Either brown translucent crystals which are thin and tabular, or black opaque crystals of pyramidal type.

FIG. 210. FIG. 211.

\[ I \text{ and } \frac{c}{1}. \]

CRYSTALLIZATION.—Orthorhombic \( \frac{a}{b} : \frac{c}{1} = 0.842 : 1 : 0.944 \). \( \alpha \perp I = 99° 30' \).

\[ \frac{c}{1} \perp I = 129° 14'. \quad I \perp \frac{c}{1} \text{ and } I \perp \frac{c}{1} = 101° 39'. \]

PHYSICAL CHARACTERS.—Translucent to opaque. Lustre, submetallic to adamantine. Color, brown, yellow or black. Streak, white or yellow. H., 5.5 to 6. Sp. gr., 3.57 to 4.01. Cleavage, indistinct prismatic and basal.

BEFORE BLOWPIPE, ETC.—As for rutile and octahedrite.
CHAPTER XXI.

LEAD AND BISMUTH MINERALS.

THE LEAD MINERALS.

The minerals described are: Metal, Lead; Sulphides and Se-
lenides, Galena, Bouronite, Jamesonite, Clausthalite; Oxides,
Minium; Sulphates, Anglesite, Linarite; Phosphates, Pyromorph-
ite; Arsenate, Mimetite; Carbonates, Cerussite and Phosgen-
ite; Chromate, Crocoite; Vanadates, Vanadinite, Descoizite;
Molybdate, Wulfenite; Tungstate, Stolzite.

The most important ores of lead are galenite and cerussite, and
with the latter, near the surface, other oxidized compounds—es-
pecially anglesite and pyromorphite—are apt to occur.

The world uses about 600,000 tons of lead per year, of which
this country produces over 200,000 tons.* Only 10 to 15 per
cent. of the latter is pure lead, free from silver and gold; indeed,
it may be noted that by far the most important use of lead ore is
in the recovery of silver and gold by smelting mixtures of the lead
and silver ores together, whereby metallic lead containing silver
and gold is obtained.

The principal use of metallic lead is in the manufacture of white
lead, and, next to this, the preparation of shot, lead pipe and sheet
lead. A certain amount of lead containing antimony is used in
type and in alloys for friction-bearing.

The argentiferous† lead ores of the west, which ordinarily run
low in lead—say ten per cent.—are smelted exclusively in blast-
furnaces. The ore, if galena or if it contains much sulphur, is
first roasted, to remove the sulphur and other volatile constitu-
ents, and is then fused, forming a silicate, which is charged in the
blast-furnace with the proper proportions of fuel and flux (lime-
stone, hematite, etc.). The reduction takes place under the action

* 1892, 218,500 tons.—Mineral Industries, 1892.
† O. H. Hahn: Mineral Resources of U. S., 1882, p. 324, and H. O. Holman: The
of the blast. Metallic lead, carrying most of the silver, is produced, and if either sulphur or arsenic is present, a sulphide (matte) and an arsenide (speiss) of iron, copper, etc., will form, and above all these will float the slag composed of the gangue and the flux.

The furnace is usually oblong in section, and the hearth is connected, by a channel from the bottom, with an outer basin or well, so that the metal stands at the same level in each and can easily be ladled out. Above the hearth, and enclosing the smelting zone, are what are called the water jackets, in which cold water circulates. The furnace gases pass through a series of condensing chambers.

The matte, speiss and the dust collected in the condensing chambers are all treated for silver, gold, lead, copper, etc., usually at different works. The metallic lead, or base bullion, is desilverized by remelting in large kettles, raising it to the melting-point of zinc, adding metallic zinc and cooling to a point between the melting-points of zinc and lead. The lighter solidified zinc separates, carrying with it the silver, and forms a crust on the surface of the lead, from which it is skimmed.

The lead is further purified and the zinc is distilled, leaving the silver and a little lead behind.

LEAD.—Native Lead.

Composition.—Pb, with sometimes a little Sb or Ag.

General Description.—Usually small plates or scales or globular masses embedded in other minerals. Very rarely in octahedrons or dodecahedrons.


Before Blowpipe, etc.—Fuses easily, coating charcoal with yellow oxide, and tinging flame light blue. Soluble in dilute nitric acid.

GALENITE.—Galena.

Composition.—PbS, (Pb 86.6 per cent.) usually with some silver and frequently sulphide of antimony, bismuth, cadmium, etc.

General Description.—A soft, heavy, blue-gray mineral, with metallic lustre and extremely easy cubical cleavage. Sometimes in isometric crystals, usually cubes or octahedrons or their combination. Rarely fine-grained or fibrous.
Physical Characters.—H., 2.5. Sp. gr., 7.4 to 7.6.
Lustre, metallic. Opaque.
Streak, lead-gray. Tenacity, brittle.
Color, lead-gray. Cleavage, cubic, very easy.

Before Blowpipe, Etc.—On charcoal decrепitates and fuses easily, yielding in O. F. a white sulphate coat, and in R. F. a yellow coat and metallic button of lead. With bismuth flux, gives a strong iodide coat, which appears chrome-yellow on plaster and greenish-yellow on charcoal. With soda, yields malleable lead and a sulphur test. Soluble in excess of hot hydrochloric acid, from which white lead chloride separates on cooling. Soluble also in strong nitric acid, with separation of sulphur and lead sulphate.

Similar Species.—Characterized by its cleavage, weight and appearance, except in some fine-grained varieties.

Remarks.—Galena is the common and parent ore of lead. It occurs with other sulphides, especially sphalerite, pyrite and chalcopyrite, with a gangue of quartz, fluorite, barite or calcite. Also with ores of silver and gold. It changes easily to cerussite, anglesite and other lead minerals. Besides the silver-producing States of Colorado, Utah and Montana, which also produce the most lead, Kansas, Wisconsin and Missouri manufacture much soft lead from their deposits of galena.

Uses.—It is the chief ore of lead, and as it usually contains silver, the silver-bearing deposits are more frequently worked than the purer galena, and both the lead and silver are recovered.

Bourbonite.

Composition.—PbCuSbSb₃r (Pb 42.5, Cu 13.0, Sb 24.7, S 19.8 per cent.).

General Description.—A gray metallic mineral, nearer steel-gray than galena, and occurring fine-grained, massive and in thick tabular crystals. More like tetradrite than galena when massive.

Crystallization.—Orthorhombic, a : b : c = 0.938 : 1 : 0.897; β = 111° 17'; γ = 95° 40'; O = 1.46° 43'. Usually short prismatic or tabular, with vertically striated faces, or, from twinning, having cross and "cog-wheel" shapes.

**Fig. 213.**

**Fig. 214.**

Cross Twin.

Physical Characters.—Opaque. Lustre, metallic. Color, steel-gray to nearly.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses easily, yielding heavy white sublimate, and later a yellow sublimate. With bismuth flux yields strong greenish-yellow coat on charcoal and a mingling of chrome yellow and peach red on plaster. After sublimates have formed, the residue will color the flame deep green, or if moistened with a drop of hydrochloric acid, will color the flame bright azure blue. Soluble in nitric acid to a green solution, with formation of a white insoluble residue.

JAMESONITE.—Feather Ore.

COMPOSITION.—PbSbS₃, (Pb 59.8, Sb 29.5, S 19.7 per cent.).

GENERAL DESCRIPTION.—Steel-gray to dark-gray metallic needle crystals, or hair-like and felted; also compact and fibrous massive.


BEFORE BLOWPIPE, ETC.—Decrepitates and fuses very easily, and is volatilized, coating the charcoal white and yellow as in bournonite. With bismuth flux, reacts like bournonite. In closed tube, yields dark-red sublimate, nearly black while hot. Soluble in hot hydrochloric acid, with effervescence of hydrogen sulphide.

CLAUSTHALITE.

COMPOSITION.—PbSeO₄, (Pb 72.4, Se 27.6 per cent.). May contain silver or cobalt.

GENERAL DESCRIPTION.—Bluish gray fine granular masses of metallic lustre. Rarely foliated. Resembles galenite.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, bluish lead gray. Streak, grayish black. H., 2.5 to 3; Sp. gr., 7.6 to 8.8.

BEFORE BLOWPIPE, ETC.—On charcoal fuses and yields odor like decayed horseradish, coats the charcoal with a white sublimate with red border, and later a yellow coat forms. In open tube gives a red sublimate. With soda yields a mass which blackens silver.

MINIUM.

COMPOSITION.—Pb₂O₄, (Pb 90.6 per cent.).

GENERAL DESCRIPTION.—A vivid red powder or loosely compacted mass of dull or greasy lustre. Often intermixed with yellow.


BEFORE BLOWPIPE, ETC.—Is reduced to metallic lead, and yields the characteristic lead sublimate.

REMARKS.—The artificial product is the red lead of commerce.

ANGLESITE.

COMPOSITION.—PbSO₄, (PbO 73.6, SO₄ 26.4 per cent.).

GENERAL DESCRIPTION.—A very brittle, colorless or white mineral of adamantine lustre, sometimes colored by impurities. Usually massive, frequently in concentric layers around a core of unaltered galenite.
**Crystallization.**—Orthorhombic \( a : b : c = 0.785 : 1 : 1.289 \).
\( I \wedge I = 103^\circ 43\frac{1}{2}' \), \( O \wedge \frac{1}{2} - \frac{3}{2} = 146^\circ 36\frac{1}{2}' \), \( O \wedge 1 - 2 = 123^\circ 12' \).
Forms rarely twinned. Crystals are sometimes tabular but prismatic and dome faces predominate.


**Lustre,** adamantine to vitreous.  **Transparent** to opaque.

**Streak,** white.

**Color,** colorless, white, gray; rarely yellow, blue or green.

**Cleavage,** basal and prismatic (90° and 103° 43').

**Before Blowpipe, Etc.**—On charcoal decrepitates and fuses easily to a glassy globule pearly white on cooling. In R. F. is reduced and yields metallic lead and the yellow sublimate. With soda yields the sulphur reaction. Insoluble in hydrochloric acid but is converted into chloride. Slowly soluble in nitric acid.

**Similar Species.**—It differs from the carbonate, cerussite, in absence of twinned crystals and of effervescence in acids. It is heavier than barite and celestite, and yields lead.

**Remarks.**—Anglesite is formed by the oxidation of galenite. It alters to the carbonate, cerussite, by interchange with calcium carbonate in solution. It is found throughout the United States wherever exposed deposits of galenite occur. The lead mines of Missouri, Wisconsin, Colorado, etc., all contain this mineral. It occurs in large quantities in Mexico and Australia.

**Uses.**—It is an ore of lead.

**LINARITE.**

**Composition.**—\([\text{Pb, Cu} \text{O}_3]_n \text{SO}_4\), \((\text{PbO} 55.7, \text{CuO} 19.3, \text{SO}_4 20.0, \text{H}_2\text{O} 4.5 \text{ per cent.})\).
LEAD AND BISMUTH MINERALS.


PHYSICAL CHARACTERS.—Translucent. Lustre, vitreous or adamantine. Color, deep azure blue. Streak, pale blue. H., 2.5. Sp. gr., 3.3 to 5.45. Brittle. Cleavages at 77° to each other.

BEFORE BLOWPIPE, ETC.—Loses color and fuses easily to a pearly glass. In R. F. is reduced to metal yielding yellow coat and ultimately red button, which when moistened with hydrochloric acid will color flame deep blue. Soluble in nitric acid with separation of lead sulphate.

PYROMORPHITE.

COMPOSITION.—3Pb₃(PO₄)₂·PbCl₂ or Pb₃Cl(PO₄)₃. (PbO 82.2, P₂O₅ 15.7, Cl 2.6 per cent.) often with some As, Fe or Ca.

GENERAL DESCRIPTION.—Short hexagonal prisms and branching and tapering groups of prisms in parallel position. The color is most frequently green, brown, or gray. Also in moss-like interlaced fibres and angular groups and masses of imperfectly developed crystals. Less frequently in globular and reniform masses.

CRYSTALLIZATION.—Hexagonal \( c = 0.736 \). \( \alpha \setminus \gamma = 139°38' \). Usually prisms with flat ends.

Physical Characters. H., 3.5 to 4. Sp. gr., 5.9 to 7.1. Lustre, resinous. Translucent to opaque. Streak, white to pale yellow. Tenacity, brittle. Color, green, gray, brown; also yellow, orange, white.

BEFORE BLOWPIPE, ETC.—On charcoal fuses to a globule which on cooling does not retain its globular form but crystallizes, showing plane faces. In reducing flame yields white coat at a distance and yellow coat nearer the assay, and a brittle globule of lead. In closed tube with magnesium ribbon yielding a phosphide which, moistened with water, evolves phosphine. With salt of phosphorus saturated with copper oxide yields an azure blue flame. Soluble in nitric acid, and from the solution ammonium molybdate throws down a yellow precipitate.

SIMILAR SPECIES.—Differs from other lead minerals in fusing to a crystalline globule without reduction.

REMARKS.—Probably formed from galenite. Occurs with other lead minerals. Found at Phoenixville, Pa., Davidson county, N. C., Lenox, Me., and many other localities.
MIMETITE.

Composition. — 3Pb₂(AsO₄)₂ + PbCl₂ or PbCl₂(AsO₄)₂ (PbO 74.9, As₂O₅ 25.4, Cl 2.39 per cent.), often with some replacement by P or Ca.

General Description. — Pale yellow to brown hexagonal prisms or globular groups of crystals. Sometimes incrusting.

Physical Characters. — Translucent. Lustre, resinous. Color, yellow, brown or white. Streak, white. H., 3.5. Sp. Gr., 7.0 to 7.25, lower when Ca is present.

Before Blowpipe, Etc. — On charcoal fuses easily and is reduced to metallic lead, coating the coal with white and yellow sublimes and yielding strong arsenical odor. Phosphorus, if present, and chlorine may be detected as in pyromorphite.

CERUSSITE. — White Lead Ore.

Composition. — PbCO₃, (PbO, 83.5; CO₂, 16.5 per cent.). Often carries silver.

General Description. — Very brittle, white or colorless orthorhombic crystals; silky, milk-white masses of interlaced fibres; granular, translucent, gray masses and compact or earthy, opaque masses of yellow, brown, etc., colors.

Crystallization. — Orthorhombic, \( a : b : c = 0.610 : 1 : 0.723 \), \( \alpha = 117° 14' \); \( 0 \) \( 1 - \alpha = 144° 8' \); \( O \) \( 2 - \alpha = 124° 40' \); \( 1 \) \( 1 = 130° \). Twin crystals very frequent, the twinning plane being prismatic.


Lustre, adamantine, pearly, Transparent or translucent.

sometimes silky.

Streak, white.

Tenacity, very brittle.

Color, white, gray, colorless or colored by impurities.

Cleavages, parallel to prism and brachy dome 2-7.
LEAD AND BISMUTH MINERALS.

BEFORE BLOWPIPE, ETC.—On charcoal, decrepitates, fuses and gives a yellow coating, and finally a metallic globule. In closed tube, turns yellow, then dark, and on cooling is yellow. Effervesces in acids, but with hydrochloric or sulphuric acid leaves a white residue.

SIMILAR SPECIES.—Distinguished from anglesite by effervescence in acids and by frequent occurrence of twinned crystals. Has higher specific gravity than most carbonates.

REMARKS.—Cerussite is derived from galenaite by the action of water containing carbon dioxide. It may also be produced from anglesite by action of a solution of calcium carbonate.

USES.—It is smelted for lead and silver, and a process exists for the direct manufacture of white lead from cerussite.

PHOSGENITE.

COMPOSITION.—\( \text{Pb}_2 \text{Cl}_2 \text{CO}_3 \), \((\text{PbO}, 81.9; \text{Cl}, 13.0; \text{CO}_3, 8.1 \text{ per cent.})\).

GENERAL DESCRIPTION.—Large and small tetragonal crystals, usually prismatic and colorless; sometimes gray and translucent.


BEFORE BLOWPIPE, ETC.—Fuses easily to a yellow globule. On charcoal, is reduced to metal and forms chiefly a white coating of lead chloride. Soluble in nitric acid with effervescence.

CROCOITE.

COMPOSITION.—\( \text{PbCrO}_4 \), \((\text{PbO}, 68.9; \text{CrO}_3, 31.1 \text{ per cent.})\).

GENERAL DESCRIPTION.—Bright hyacinth-red mineral, usually in monoclinic prismatic crystals, but also granular and columnar. The color is like that of potassium dichromate.


BEFORE BLOWPIPE, ETC.—In closed tube, decrepitates violently, becomes dark, but recovers color on cooling. Fuses very easily, and is reduced to metallic lead with deflagration, the coal being coated with a yellow sublimate. With boric or S.Pb, forms yellow glasses, which are bright green when cold. Soluble in nitric acid to a yellow solution. Fused with KHSO_4 on platinum, yields a dark-violet mass, red on solidifying and greenish-white when cold which distinguishes it from vanadinite.

VANADINITE.

COMPOSITION.—\( 3\text{Pb}_2(\text{VO}_4)_2 \cdot \text{PbCl}_2 \) or \( \text{Pb}_2\text{Cl}(\text{VO}_4)_3 \), \((\text{PbO}, 78.7; \text{V}_2\text{O}_5, 19.4; \text{Cl}, 2.5 \text{ per cent.})\), often with P or As replacing V.
GENERAL DESCRIPTION. — Sharp, distinct, hexagonal prisms, usually small, and sometimes hollow; of bright-red, yellow and brown colors. Also in parallel groups and globular masses of crystals, as in pyromorphite and mimetite. \( \varepsilon = 0.712 \).


Lustre, resinous on Opaque or translucent.

Streak, white to pale Tenacity, brittle.

Yellow.

Color, deep red, bright red, yellow or brown.

Before Blowpipe, Etc.—Fuses easily on charcoal to a black mass, yielding a yellow sublimate in the reducing flame. The residue gives deep-green bead, with salt of phosphorus in the reducing flame. With strong nitric acid the substance becomes deep red, then dissolves to a yellow solution. Fused with KHSO\(_4\), yields a clear yellow, then a red, and finally yellow when cold.

Uses.—It is the source of vanadium, for vanadium black; for vanadium salts, which are used as a mordant in the manufacture of the finest silks; for vanadium bronze and for vanadium ink.

DESCLOIZITE.

Composition. — \((\text{Pb,Zn})(\text{PbOH})_2\text{VO}_4\)  \((\text{PbO}, 53.4; \text{ZnO}, 19.7; \text{V}_2\text{O}_5, 22.7; \text{H}_2\text{O}, 3.2)\).

General Description.—Small purplish-red, brown or black crystals, forming a drusy surface or crust. Also fibrous, massive.

Physical Characters.—Transparent to nearly opaque. Lustre, greasy. Color, purplish red, brown or black. Streak, orange or brown. H., 3.5. Sp. gr., 5.9 to 6.2.

Before Blowpipe, Etc.—On charcoal, fuses to black mass, enclosing metal. In closed tube yields water. Vanadium reactions as in vanadinite.

WULFENITE.

Composition. — PbMoO\(_4\), sometimes containing Ca, Cr, V.

General Description. — Usually in thin, square, tabular crystals of yellow, orange or bright orange-red color and resinous lustre. Less frequently in granular masses or acute pyramidal crystals.

Crystallization. — Tetragonal, \( c = 1.577; O \land 1 = 114^\circ 9'; O \land 1-t = 122^\circ 23'\). Usually flattened parallel to base or with a very flat pyramid replacing the base.
LEAD AND BISMUTH MINERALS.

Lustre, resinous or adamantine.  Translucent.
Streak, white.  Tenacity, brittle.
Color, wax yellow, bright red, brown, rarely green.
Cleavage, pyramidal.

Before Blowpipe, Etc.—Fuses easily on charcoal, giving yellow coat and finally a metallic globule. In salt of phosphorus dissolves to a bead, which is bright green in R. F. In borax, yields a colorless bead in O. F., which is made brown to black in R. F. Partially soluble in strong hydrochloric acid to a green liquid. If the solution is greatly diluted and stirred up with tin, it becomes deep blue and finally brown. A similar test may be obtained either by boiling in porcelain with strong sulphuric acid and adding alcohol, or by fusing in platinum with KHSO₄, dissolving in water and boiling with tin or zinc.

Remarks.—Wulfenite occurs with other lead minerals, especially vanadinite and pyromorphite. It is found in many localities in New Mexico and Arizona; in the lead regions of Wisconsin and Missouri; at Phoenixville, Pa.; Inyo County, Cal.; Southampton, Mass., and many other places, always associated with other ores of lead.

STOLZITE.

Composition.—PbWO₄ (PbO, 49.0; WO₃, 51.0 per cent.).
General Description.—Very small, acute, tetragonal pyramids of gray or drab color.
Before Blowpipe, Etc.—Fuses on charcoal to pearly crystalline globule. With soda, yields yellow coating and a metallic globule. Soluble in nitric acid, with separation of a yellow powder. In salt of phosphorus, with the reducing flame, gives a deep-blue to green glass, which powdered and boiled with dilute hydrochloric acid and tin, yields a deep-blue solution.

THE BISMUTH MINERALS.

The minerals described are: Metal, Bismuth; Sulphides, Bismuthinite, Aikinite; Telluride, Tetradyxite. Bismuth is also found intimately mixed with other minerals, as with tin ore in Bolivia; cobalt ore in Saxony and gold-bearing magnetite in Queensland, Australia.

The principal source of bismuth is the native metal; it is, however, extracted from the other minerals, and to a considerable extent from the hearths and last products of oxidation of lead.
cupellation. The manufacture is practically all in Germany, and the quantity produced per year is small.

The uses of bismuth are chiefly dependent upon its property of forming easily fusible alloys with other metals, especially tin, lead, and cadmium. These alloys expand in cooling, and are therefore used in reproducing woodcuts, in making safety plugs for boilers, etc. The salts of bismuth have numerous uses in medicine and in the arts are used in calico printing, cosmetics, and in glass of high refractive power. Also used in giving lustre to porcelain.

Bismuth is obtained from the native metal by simply heating in a closed inclined vessel, the liquid metal flowing out. If the ore is sulphide or telluride it may be roasted and then treated as above, or may be fused in a crucible with carbonate of soda and metallic iron, the iron combining with the acid elements and the metallic bismuth being set free. When in the cupellation of lead ore bismuth is found to be present, it is recovered by saving the last products of oxidation and the hearth of the furnace, grinding these and treating them with hot strong hydrochloric acid. After settling and cooling the liquid is siphoned off and diluted with water, by which a precipitate of the oxychloride is produced, which is easily reduced to metallic bismuth by fusion with carbonate of soda.

BISMUTH.—Native Bismuth.

Composition.—Bi, often alloyed with As or impure from S or Te.

General Description.—A brittle silver-white mineral with a reddish tinge, usually disseminated through the gangue in branching lines or in isolated grains or lumps. Rarely in indistinct hexagonal crystals.


Lustre, metallic. Opaque.

Streak, silver white. Tenacity, sectile to brittle.

Color, reddish silver white.

Before Blowpipe, Etc.—On charcoal fuses easily and volatilizes completely, coating the charcoal with a yellow sublimate. With bismuth flux forms a chocolate brown and red coating which is best seen on plaster, and which is changed by action of ammonia fumes to red and orange. Soluble in strong nitric acid from which solution water will precipitate a white basic salt.
LEAD AND BISMUTH MINERALS.

SIMILAR SPECIES.—Bismuth is characterized by its silver streak, reddish tinge, and arborescent structure.

REMARKS.—Bismuth occurs in crystalline rocks and clay slate associated with ores of cobalt, nickel, silver, gold, lead and zinc, also with molybdenite, wolframite, scheelite. The native metal is not found in any quantity in the United States, although obtained at Monroe, Cl., in Colorado, and in South Carolina. The most celebrated foreign localities are Schneeberg in Saxony and other places both in Saxony and Bohemia. Found also at Copapo, Chili; in Bolivia, Sweden, Norway, and in South Australia.

USES.—It is a source of commercial bismuth and of salts of bismuth.

BISMUTHINITE.

COMPOSITION.—B₄Sb₃ (Bi 81.2, S 18.8 per cent.). May contain Cu or Fe.

GENERAL DESCRIPTION.—A lead gray mineral of metallic lustre usually occurring in foliated or fibrous masses, or in groups of long needle-like orthorhombic crystals.


BEFORE BLOWPIPE, ETC.—On charcoal yields some sulphur, fuses easily with spitting, and coats the coal with white and yellow sublimes. Yields the characteristic bismuth reactions with bismuth flux and with nitric acid as described under bismuth. With soda gives sulphur reaction.

AIKINITE.—Needle Ore.

COMPOSITION.—Bi₂Pb₂Cu₃S₁₀ (Bi 36.2, Pb 36, Cu 11, S 16.8 per cent.).

GENERAL DESCRIPTION.—Long embedded needle like crystals of dark gray color and metallic lustre. Also massive.


BEFORE BLOWPIPE, ETC.—Fuses on charcoal, yielding white and yellow sublimes. With bismuth flux on placer yields chrome yellow coat of lead, chocolate and red coat of bismuth, and intense green flame of copper. The residues from treatment on coal yield in borax or salt of phosphorus greenish blue beads which in the reducing flame usually become black and opaque.

Soluble in nitric acid with separation of sulphur and lead sulphate.

TETRADYMITE.

COMPOSITION.—Bi₂₉Te₂S₉₃ or BiTeS. Either an alloy or a telluride of bismuth.

GENERAL DESCRIPTION.—Very soft, flexible, foliated masses of steel-gray color and bright metallic lustre, or small indistinct rhombohedral crystals. Will mark paper like graphite.


BEFORE BLOWPIPE, ETC.—On charcoal fuses easily and is completely volatilized, yielding a white fusible sublimate, followed by a yellow sublimate. The flame during fusion is colored blue. The white sublimate if placed on porcelain and moistened with concentrated sulphuric acid becomes rose colored. If dropped into boiling concentrated sulphuric acid a deep violet color is produced.
CHAPTER XXII.

ARSENIC, ANTIMONY, URANIUM AND MOLYBDENUM MINERALS.

THE ARSENIC MINERALS.

The minerals described are: Metal, Arsenic; Sulphides, Orpiment, Realgar; Oxide, Arsenolite.

The principal sources of metallic arsenic and white arsenic are not the above mentioned minerals, but the arsenides and arsenosulphides of iron, cobalt and copper, and the fumes given off from arsenical tin ores, etc., in which the distinct minerals can less definitely be recognized.

Metallic arsenic is ordinarily produced by sublimation from a mixture of the oxide and charcoal, but may be produced by sublimation at a high heat directly from arsenopyrite out of contact with air. Its uses are few, but it forms a constituent of some useful alloys, shot metal being the chief.

The intensely poisonous oxide known commonly as arsenic or white arsenic, is produced in large quantities by the roasting of arsenopyrite and other arsenical ores and as a by-product in the preparation of tin, silver, nickel, cobalt, etc. It is used in dyeing, in medicine, in sheep washing, in calico printing, as a preservative for timber and for natural history specimens, in the manufacture of fly paper, rat poisons, etc., and in glass manufacture.

Paris green is an arsenate of copper extensively used as an insecticide.

ARSENIC.—Native Arsenic.

Composition.—As, generally with some Sb and sometimes with Bi or a little Co, Ni, Fe, Ag or Au.

General Description.—A tin-white metal, tarnishing almost black. Usually granular, massive, with reniform surfaces. Can frequently be separated in concentric layers. Rarely found in needle-like crystals.

Physical Characters.—Opaque. Lustre, nearly metallic. Color, tin white, tarnishing nearly black. Streak, tin white. H., 3-5. Sp. gr., 5.63 to 5.73. Brittle. Granular fracture,
REALGAR.

Composition.—As₂S₃. (As, 70.1; S, 29.9 per cent).

General Description.—A soft, orange-red mineral, of resinous lustre, usually occurring in translucent, granular masses, but also compact and in transparent monoclinic crystals.

Physical Characters. H., 1.5 to 2. Sp. gr., 3.4 to 3.6.  
Lustre, resinous. Translucent to transparent.  
Streak, orange red. Tenacity, slightly sectile.  
Color, aurora red, becoming orange yellow on long exposure.

Before Blowpipe, Etc.—On charcoal, fuses easily, burns with a blue flame, yields white fumes, with garlic odor and also odor of sulphur dioxide and is volatilized completely. In closed tube yields red sublimate. Soluble in nitric acid, with separation of sulphur. Soluble also in potassium hydroxide from which hydrochloric acid precipitates yellow flakes.

Remarks.—Realgar is found with orpiment, arsenolite, galenite, argentite, etc., and is formed both by sublimation and by deposition from water. Realgar is obtained mainly from abroad, notably from Hungary and the island of Bomeo. Deposits are known in Utah, California and Wyoming.

Uses.—The artificial sublimate is used in fireworks and for signalling, in the form of “white Indian fire.” It also is used as a pigment.

ORPIMENT.

Composition.—As₂S₃. (As, 61; S, 39 per cent).

General Description.—Lemon-yellow, foliated masses, which cleave into thin, pearly, flexible scales, and also granular masses like yolk of hard-boiled eggs. Less frequently as reniform crusts and imperfect orthorhombic crystals.

Physical Characters. H., 1.5 to 2. Sp. gr., 3.4 to 3.6.  
Lustre, resinous or pearly. Translucent to nearly opaque.  
Streak, lemon yellow. Tenacity, slightly sectile.  
Color, lemon yellow. Cleavage, in plates or leaves.
Before Blowpipe, Etc.—As for realgar, except that the sublimate in closed tube is yellow.

Remarks.—Probably generally formed by sublimation, but is also deposited from hot water, and formed by alteration of realgar in air and sunlight. It occurs with realgar, arsenic, arsenolite, etc. Obtained mainly from several Hungarian localities, from Borneo, and from Kurdistan, Turkey. Found in powder at Edenville, N. Y., and massive in Wyoming, Utah and Nevada.

Uses.—The artificial material is used in dyeing to reduce indigo, and in tanning, as a constituent with potash and lime, to remove hair from skins.

Arsenolite.

Composition.—$\text{As}_2\text{O}_3$. (As, 75.8 per cent.).

General Description.—Minute white, hair-like crystals or yellowish or white crust upon arsenical ores. Very rarely as distinct octahedral crystals. Sweetish taste.

Physical Characters.—Transparent to opaque. Lustre, vitreous or silky. Color, white to yellowish. Streak, white. H., 1.5. Sp. gr., 3.7 to 3.72. Taste, sweetish astringent.


The Antimony Minerals.

The minerals described are: Metal, Antimony; Sulphides, Stibnite, Kermesite; Oxides, Valentinite, Senarmontite. Lead ores also frequently contain antimony.

The only commercially important antimony mineral is the sulphide, which is used to a slight extent as sulphide in vulcanizing rubber, and in safety matches, percussion caps, fireworks, etc., but chiefly important as a source of the metal. In 1892 this country produced about 500 tons* of metallic antimony, and used about four times that quantity, chiefly in preparing type and stereotype metal and other alloys. France and Japan are at present the chief producers.

In smelting, the ore is heated and the melted sulphide drained off. The sulphide may then be roasted, forming the oxide, which is easily reduced by fusion with charcoal, or more frequently the sulphide is mixed with wrought-iron scraps and salt, placed in a crucible and fused. The iron combines with the sulphur and the metallic antimony settles to the bottom.

* The Mineral Industry, 1892, p. 27.
ARSENIC, ANTIMONY, ETC., MINERALS.

The metal produced by either method is usually refined by smelting with sodium carbonate and a little antimony sulphide followed by two fusions with sodium carbonate alone.

ANTIMONY.—Native Antimony.

COMPOSITION.—Sb, sometimes with As, Fe or Ag.

GENERAL DESCRIPTION.—A very brittle, tin-white metal, usually massive, with fine, granular, steel-like texture or lamellar or radiated. Very rarely in rhombohedral crystals or complex groups.


BEFORE BLOWPIPE, ETC.—Fuses very easily, colors the flame pale green, gives copious white fumes, which continue to form as a thick cloud after cessation of blast, and often yield a crust of needle-like crystals.

STIBNITE.—Gray Antimony.

COMPOSITION.—Sb₂S₃ (Sb 71.8, S 28.2 per cent.). Sometimes contains silver or gold.

GENERAL DESCRIPTION.—A lead-gray mineral of bright metallic lustre, occurring in imperfectly crystallized masses, with columnar or bladed structure; less frequently in distinct, prismatic, orthorhombic crystals or confusedly interlaced bunches of needle-like crystals; also in granular to compact masses.

**Fig. 222.**

**Fig. 223.**

I, i-1, and ½. I, i-1 and ½.

CRYSTALLIZATION.—Orthorhombic, \( a:b:c = 0.993:1:1.018 \). \( I \wedge I = 90° 26' \). \( I \wedge I \) (macro), = 109° 12'. \( I \wedge I \) (brachy), = 108° 35½'. Prismatic forms, often bent and curved or in divergent groups. The vertical planes are striated longitudinally.

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Lustre, metallic. Opaque.

Streak, lead gray. Tenacity, brittle to sectile.

Color, lead gray, often with black or iridescent tarnish.

Cleavage, easy, parallel to brachy pinacoid, yielding slightly flexible, blade-like strips.

Before Blowpipe, Etc.—On charcoal, fuses very easily, yielding the same dense sublimate as antimony. The odor of sulphur dioxide may also be noticed. On charcoal, with soda, yields sulphur test. In closed tube fuses easily, yields a little sulphur and a dark sublimate which is brownish red when cold.

Soluble completely in strong boiling hydrochloric acid, with evolution of H₂S, with precipitation of white basic salt on addition of water and after dilution an orange precipitate on addition of H₂S. Strong nitric acid decomposes stibnite into white Sb₂O₅ and S. Strong hot solution of KOH colors stibnite yellow and partially dissolves it. From the solution hydrochloric acid will throw down an orange precipitate.

Similar Species.—Differs from galenite in cleavage, and from all sulphides by ease of fusion and cloud-like fumes.

Remarks.—Stibnite occurs in veins with other antimony minerals formed from it, also with cinnabar, sphalerite, siderite, etc. Large deposits of stibnite occur at Lovelocks, Bernier and Austin, Nevada; at Kingston, Idaho; at San Emidio, California; in Arkansas, in Utah, in Nova Scotia and in New South Wales. The most celebrated deposit, however, is that in Shikoku, Japan, from which the very finest crystals and groups are obtained.

Uses.—It is the chief source of antimony and its artificial pigment and pharmaceutical preparations. In the natural state it is used in safety matches and percussion caps, in fireworks, in rubber goods and in refining gold.

Kermesite.—Red Antimony.

Composition.—Sb₃S⁴O or 2Sb₂S₃Sb₂O₅ (Sb 75.0, S 20.0, O 5.0 per cent.).

General Description.—Fine hair-like tufts of radiating fibres and needle-like crystals, of a deep cherry-red color and almost metallic lustre.


Before Blowpipe, Etc.—As for stibnite.

Remarks.—Kermesite results from partial oxidation of stibnite. Extensive deposits exist at Perusa, Tuscany.
ARSenic, AntimonY, etc., Minerals.

SEnarmontite.

Composition.—$\text{Sb}_2\text{O}_3$. (Sb, 83.3 per cent.).

General Description.—Colorless to gray octahedral crystals and granular masses.

Physical Characters.—Transparent to translucent. Luster, resinous. Color, colorless or gray. Streak, white. H., 2 to 3.5. Sp. gr., 5.22 to 5.30.

Before Blowpipe, etc.—Fuses easily, coating the charcoal with white oxide. In R. F. is reduced, but again oxidizes and coats the coal, coloring the flame green. Soluble in hydrochloric acid.

Remarks.—Formed by oxidation and decomposition of stibnite and other ores of antimony.

VALENTINITE.

Composition.—$\text{Sb}_2\text{O}_3$. (Sb, 83.3 per cent.).

General Description.—Small white flat crystals (orthorhombic) or fan-shaped groups of a somewhat silky lustre and white or gray color. Also in spheroidal masses with radiated lamellar structure.


Before Blowpipe, etc.—As for senarmontite.

THE URANIum MINERALS.

The minerals described are: Uranate, UrAniNite; Phosphates, Autunite, TorberNite.

The metal uranium has no economic uses, although a possible use is suggested by the fact that a small percentage of uranium is said to increase the elasticity and hardness of steel.

A few tons of the chloride, nitrate and sulphate of uranium are used yearly in coloring glass yellow with a greenish reflex, and in coloring porcelain orange or black. A small amount is used in photography.

URANINITE.—Pitch Blende.

Composition.—A uranate of $\text{UO}_2$, Pb, etc., and may contain Ca, N, Th, Zr, Fe, Cu, Bi, etc.

General Description.—A black massive mineral of botryoidal or granular structure and pitch-like appearance. Rarely in small isometric crystals.


Lustre, pitch-like, submetallic. Opaque.

Streak, gray, olive green, dark brown. Tenacity, brittle.

Color, some shade of black.

Before Blowpipe, etc.—Infusible or very slightly fused on
edges, sometimes coloring the flame green from copper. On charcoal with soda may yield reaction for lead, arsenic and sulphur. In borax yields a green bead made enamel black by flaming. Soluble in nitric acid to a yellow liquid from which ammonia throws down a bright yellow precipitate.

Similar Species.—The appearance and streak are frequently sufficient distinctions. The bead tests are characteristic.

Remarks.—Uraninite occurs both in granitic rocks and in metallic veins. It is frequently associated with minerals resulting from its decomposition and with metallic ores. It is mined at Joachimstal, Bohemia, from whence the principal supply is obtained. It occurs in Jefferson and Gilpin counties, Colorado, having been mined at Central City and is found also in some quantity in Mitchell county, N. C., at Marietta, S. C., in Texas, and in the Black Hills of South Dakota.

Uses.—Uraninite is the chief source of the uranium salts used in painting on porcelain and in the manufacture of a fluorescent glass of yellowish-green color.

Autunite.—Lime Uranite.

Composition.—Ca(UO₄)(PO₄)₂ + H₂O. (UO₂ 61.7, CaO 6.1, P₂O₅ 15.5, H₂O 15.7 per cent.).

General Description.—Little square (I 4 1 a 90° 43') orthorhombic plates of bright yellow color and pearly luster, or in micaceous aggregates.


Before Blowpipe, Etc.—On charcoal fuses with inumescence to a black crystalline globule. With salt of phosphorus or borax in the reducing flame yields a green bead. Dissolves in nitric acid to a yellow solution.

Torbernite.—Copper Uranite.

Composition.—Cu(UO₄)(PO₄)₂ + H₂O. (UO₂ 61.2, CuO 8.4, P₂O₅ 15.1, H₂O 15.2 per cent.).

General Description.—Thin square, tetragonal plates of bright green color and pearly luster. Sometimes in pyramids or micaceous aggregates.


Before Blowpipe, Etc.—Fuses easily to a black mass and colors the flame green. In borax yields a green glass in O. F., which becomes opaque red in R. F. Soluble in nitric acid to a yellowish green solution.

The Molybdenum Minerals.

The minerals described are: Sulphide, Molybdenite; Oxide, Molybdite. Besides these molybdenum occurs as the acid constituent of Wulfenite elsewhere described.
The metal has no commercial use. Its chief important compounds are molybdic acid used to impart blue color to pottery and in dyeing silks and woolens, and ammonium molybdate, a useful chemical reagent.

**Molybdenite.**

**Composition.**—MoS₂, (Mo 60.0, S 40.0 per cent.).

**General Description.**—Thin graphite-like scales or foliated masses of metallic lustre and bluish gray color, easily separated into flexible non-elastic scales. Sometimes in tabular hexagonal forms and fine granular masses. Soft, unctuous and marks paper.

**Physical Characters.** H₄, 1 to 1.5. Sp. gr., 4.6 to 4.9.

- **Lustre,** metallic.
- **Streak,** greenish.*
- **Color,** bluish lead gray.
- **Opaque.**
- **Tenacity,** sectile to malleable.
- **Cleavage,** basal.

**Before Blowpipe, Etc.**—In forceps infusible, but at high heat colors the flame yellowish green. On charcoal gives sulphurous odor and slight sublimate, yellow hot, white cold, and deep blue when flashed with the reducing flame. Soluble in strong nitric acid and during solution on platinum it is luminous. With sulphuric acid yields a blue solution. In salt of phosphorus and borax yields characteristic molybdenum reactions.

**Similar Species.**—Differs from graphite in streak and blowpipe reactions. May usually be distinguished by its lighter bluish gray color.

**Remarks.**—Occurs usually in crystalline rocks, and is not readily altered. It is found in many American localities, but is not mined. Wastmoreland, N. H., Blue Hill Bay, Maine, and Pitkin, Colorado, have probably the largest American deposits.

**Uses.**—It is the source of the molybdenum salts which are important chiefly in analytical work.

**Molybdite.**

**Composition.**—MoO₃, (Mo 66.7 per cent.).

**General Description.**—An earthy yellow powder or, rarely, tufts and hair-like crystals of yellowish white color.

**Physical Characters.**—Opaque to translucent. Lustre, dull or silky. Color, yellow or yellowish white. Streak, straw yellow. H₄, 1 to 2. Sp. gr., 4.49 to 4.5.

**Before Blowpipe, Etc.**—On charcoal fuses, yielding crystals yellow hot, white cold, and made deep blue by the reducing flame. In borax and salt of phosphorus gives characteristic molybdenum reactions.

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* Best seen on glazed porcelain.
CHAPTER XXIII.
THE COPPER MINERALS.

The minerals described are: Metal, Copper; Sulphides, Chalcoyte, Bornite, Chalcopryrite; Sulphurscudies, Enargite, Tennantite; Sulphoantimonides, Tetrahedrite; Oxides, Cuprite, Tenorite; Oxchloride, Atacamite; Sulphates, Chalcantite, Brochantite; Phosphate, Libethenite; Arsenate, Olivenite, Carbonates, Malachite, Azurite; Silicates, Chrysocolla, Diopside. In addition to these the iron sulphides often carry copper which is extracted after burning for sulphuric acid.

The great copper minerals are chalcopyrite, native copper, and cuprite, though with the exception of two or three, all the others above mentioned are sufficiently plentiful to be considered as ores. The world's product* of copper in 1891 was 275,589 tons, of which this country produced 127,722 tons, chiefly from the mines of Montana, Michigan and Arizona.

The method of extraction of the copper is dependent upon the nature of the ore, and may roughly be classed under three headings:

- Treatment of native copper.
- Treatment of oxidized ores.
- Treatment of sulphides.

A great many processes exist or have existed, but these for a general brief discussion may be reduced to a small number of type processes of which the others are variations due to local conditions or constituents of the ore.

Treatment of Native Copper.

Native copper occurs in enormous quantities in Michigan, and the deposits mined average less than two per cent of copper, although occasionally enormous masses of the metal are found. The rock is crushed by steam stamps and the copper separated in part from

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* Mineral Industries, 1892, pp. 107 et seq.
the rock by the action of water and the use of jigs, tables, and other concentrating apparatus. The concentrated material is then melted in a large reverberatory furnace with limestone and slags from previous operations. The new slag thus formed contains the remaining rock and is removed, leaving behind copper, which after a period of reduction by charcoal and stirring is cast into ingots.

**Treatment of Oxidized Ores.**

The oxidized ores in Arizona which average over ten per cent of copper, are smelted in blast-furnaces with coke and the necessary flux to make a slag with the associated gangue. The result is an impure metal called black copper, which is later refined.

**Treatment of Sulphides.**

The treatment of sulphides is quite varied, depending chiefly on the presence or absence of arsenic, the richness of the ore and the local conditions. The ores always contain iron, copper and sulphur, and may contain arsenic, antimony, silver, gold, etc. All the smelting processes depend on the facts that at high temperatures copper has a greater affinity for sulphur than iron has, and iron a stronger affinity than copper for oxygen. So that if such an ore is subjected to oxidation by roasting, oxides result; but in the subsequent fusion, if enough sulphur has been left, the copper will form a fusible sulphide, and the oxidized iron will unite with the gangue and the flux to form a slag.

By regulating the roasting, the sulphur contents may be brought to any desired percentage. This may be just sufficient to satisfy the copper or to satisfy also a great deal of the iron producing a low-grade sulphide (matte), which, by re-roasting and refusion, is enriched. The low-grade matte means a smaller loss of copper in the slags, and is often of service in assisting the removal of arsenic and antimony.

When the matte has reached the required percentage of copper, it is roasted as free from sulphur as possible, and being now essentially an oxide, it may be smelted for copper either in a shaft-furnace, much as the oxidized ores are, or, when silver or gold is present, in a reverberatory furnace.

In a more recent method the ores are roasted and fused, producing a matte containing over fifty per cent of copper. This matte, while liquid, is run into a sort of Bessemer converter, and
a blast turned on, by which the sulphur, arsenic and antimony are driven off, the iron oxidized and converted into slag, and black copper obtained.

All copper needs refining, and this may be accomplished simply by remelting and oxidation, or, for electrical purposes, the crude copper, in bars, may be suspended in a bath of copper sulphate, slightly acid, and connected with the positive pole of a dynamo; the crude copper will dissolve, pure copper will accumulate at the negative pole, and the impurities, which may be in part gold and silver, will be deposited at the bottom of the bath as mud. Electrolytic copper may also be made from mattes.

The great uses of copper are in electrical work and in alloys with zinc and tin, such as brass, yellow metal, bronze, bell metal, gun metal, German silver, etc.

COPPER.

Composition.—Cu, often containing Ag, sometimes Hg or Bi.

General Description.—A soft, red, malleable metal, with a red streak. Usually in sheets or disseminated particles varying from small grains to enormous masses several hundred tons in weight. Also in threads and wire and in distorted crystals and groups of crystals.

Crystallization.—Isometric, tetrahexahedrons, cubes, dodecahedrons, etc. Often in complex groups or elongated forms or with cavernous faces. Crystals usually irregularly distorted.

Physical Characters. H., 2.5 to 3. Sp. gr., 8.8 to 8.9.

Lustre, metallic. Opaque.

Streak, copper red. Tenacity, malleable and ductile.

Color, copper red, tarnishing nearly black.

Before Blowpipe, Etc.—Fuses easily to a malleable globule, often coated with a black oxide. In beads, becomes in O. F. green when hot; blue, cold, and in R. F. opaque red. Soluble in nitric acid, with evolution of a brown gas, to a green solution, which will deposit copper on iron or steel. The solution becomes deep azure blue on addition of ammonia.

Similar Species.—Resembles niccolite and tarnished silver, differs in copper-red streak.

Remarks.—Occurs with native silver and ores of copper, and by oxidation may
form cuprite or melaconite or the carbonates. In Michigan it occurs in trap or
conglomerate. It is especially apt to occur near dikes of igneous rocks. The
great locality of the world for native copper, and the only locality still yielding this
mineral in large quantities, is the Lake Superior region of Northern Michigan, and
although the territory here covered is many square miles in extent, the Calumet and
Heca mine yields the major part of all that is produced. Although native copper is
also found in Arizona, California, and, to a limited extent, in other American locali-
ties, it is never mined for itself alone, nor does it constitute a large part of the copper
ore present. The Coro-Coro mines, in Bolivia, are now producing some copper from
the native metal.

Uses.—It is an important source of the copper of commerce.

CHALCOCITE.—Copper Glaunce.

Composition.—Cu₂S, (Cu 79.8, S 20.2 per cent.).

General Description.—Black granular or compact masses,
with metallic lustre or sometimes nodules or pseudomorphic after
wood. Often coated with the green carbonate, malachite. Also
in crystals.

Crystallization.—Orthorhombic. \( a : b : c = 0.582 : 1 : 0.970 \),
\( \alpha = 110° 35' \). \( \beta = 117° 24' \). Tabular forms, pseudo-
hexagonal or frequently twinned, making star-like groups.

Physical Characters. H., 2.5 to 3. Sp. gr., 5.5 to 5.8.

Lustre, metallic.

Streak, lead gray.

Color, blackish lead gray, with dull-black tarnish.

Before Blowpipe, etc.—On charcoal, fuses to a globule, yield-
ing sulphur dioxide. With soda, yields a copper button and a
strong sulphur reaction. Colors flame emerald green, or if moist-
ened with hydrochloric acid, it colors the flame azure blue. In
borax or salt of phosphorus, yields copper beads. Soluble in nitric
acid, leaving a residue of sulphur.

Similar Species.—It is more brittle than argentite, and differs
from bornite in not becoming magnetic on fusion.

Remarks.—Chalcocite occurs with other copper minerals and with hematite,
galenite and cassiterite. Is found at Butte, Montana, and other American localities of
less importance. Fine crystals are obtained from Cornwall, England.

Uses.—It is an ore of copper.

BORNITE.—Purple Copper Ore. Horse Flesh Ore.

Composition.—\( \text{Cu}_2\text{FeS}_4 \), (Cu 53.5, Fe 16.4, S 28.1 per cent.), but
often contains admixed chalcocite.
GENERAL DESCRIPTION.—On fresh fracture, bornite is of a peculiar red-brown color and metallic lustre. It tarnishes to deep blue and purple tints, often variegated. Usually massive, sometimes small cubes or other isometric forms.

Lustre, metallic. Opaque.
Streak, grayish black. Tenacity, brittle.
Color, dark copper red, brownish or violet blue, often varied.

Before Blowpipe, Etc.—Blackens, becomes red on cooling, and finally fuses to a brittle, magnetic globule and evolves sulphur dioxide fumes. In oxidizing flame with borax or salt of phosphorus, gives green bead when hot, greenish blue when cold, the bead is opaque red in the reducing flame. Soluble in nitric acid, with separation of sulphur.

Remarks.—On account of its high percentage of copper, it is especially valuable as an ore of copper when found in quantity. A large portion of the ore of many of the Chilian mines consists of bornite, and it has been found in quantity in the Montana copper regions. Also found at Bristol, Conn.; Acton, Canada; in Mexico, in Peru and other copper regions.

Uses.—It is an important ore of copper.

CHALCOPYRITE.—Copper Pyrites. Yellow Copper Ore.

Composition.—CuFeS₂ (Cu 34.5, Fe 30.5, S 35.0 per cent.), with mechanically intermixed pyrite at times.

General Description.—A bright brassy yellow mineral of metallic lustre, often with iridescent tarnish resembling that of bornite. Usually massive. Sometimes in tetragonal hemi forms.

Crystallization.—Tetragonal, \( c = 0.983 \). \( O \perp 1 = 125^\circ 40' \). \( 1 \perp 1 = 70^\circ 7\frac{3}{4}' \). Angles and forms closely resembling hemi forms of isometric system.
Physical Characters. H., 3.5 to 4. Sp. gr., 4.1 to 4.3.
Lustre, metallic.
Streak, greenish black.
Color, bright brass yellow, often tarnished in blue, purple and black hues.

Before Blowpipe, Etc.—On charcoal fuses with scintillation to a brittle magnetic globule. With soda yields metallic malleable red button and sulphur test. In closed tube decrepitates, becomes dark and iridescent and may give deposit of sulphur. Flame and bead reaction like bornite. Soluble in nitric acid with separation of sulphur, and from the solution ammonia throws down a brown precipitate, and leaves the liquid deep blue in color.

Similar Species.—Chalcopyrite is softer and darker in color than pyrite, and differs from gold in black streak and brittleness.

Remarks.—Chalcopyrite is probably formed in a manner similar to the formation of pyrite which is its frequent associate. Its most prominent associated minerals are the metallic sulphides and copper ores, many of which have been formed by its alteration. It sometimes contains gold or silver. It is a very widely distributed mineral and the major part of all the copper produced is made from it. Prominent mines are in the Butte, Montana, region; and in Strafford and Ely, Vermont. Also produced in large quantities at Falun in Sweden; Rio Tinto, Spain; Sudbury, Canada; and many other important localities.

Uses.—It is the great ore of copper.

ENARGITE.

Composition.—Cu₂AsS₄. (Cu, 48.3, As 19.1, S 32.6 per cent.). Sometimes with Cu replaced in part by Zn or Fe and As by Sb.

General Description.—A black brittle mineral of metallic lustre, and occurring usually columnar or granular but sometimes in orthorhombic crystals.

Crystallization.—Orthorhombic \( a:b:c = 0.871:1:0.835 \). \( L \perp L = 97^\circ 53' \).

Lustre, metallic.
Streak, blackish gray.
Color, black or blackish gray.
Before Blowpipe, Etc.—On charcoal fuses, yields white fumes with garlic odor. With soda yields malleable copper and a reaction for sulphur. In closed tube decrepitates, yields sulphur sublimate, then fuses and yields red sublimate of arsenic sulphide. Soluble in nitric acid.

Remarks.—Enargite occurs with other copper minerals, especially arsenates derived from its alteration. It is found mainly in the mountains of Chili and Peru. Also at Butte, Montana; Gilpin county, Colorado; in South Carolina, Utah and California.

Uses.—It is an ore of copper, and has been extensively mined.

Tennantite.

Composition.—Cu₃As₂S₈ grading into tetrahedrite by replacement of As by Sb.

General Description.—A black metallic mineral best known in isometric crystals but occurring massive in the Utah mines.


Before Blowpipe, Etc.—On coal fuses easily with intumescence and evolves white fumes with garlic odor. Frequently fuses to a magnetic globule due to the presence of iron. In closed tube decrepitates slightly. With soda yields malleable red button and sulphur reaction. Soluble in nitric acid.

Tetrahedrite.—Gray Copper Ore.

Composition.—Cu₃Sb₂S₇. Cu often partially replaced by Fe, Zn, Pb, Hg, Ag, and the Sb by As.

General Description.—A fine grained, dark gray mineral of metallic lustre. Less frequently in crystals, which are either the isometric tetrahedron or other hemihedral forms. The crystals are sometimes coated with chalcopyrite.

Fig. 227. Fig. 228. Fig. 229.

Physical Characters. H., 2 to 4.5. Sp. gr., 4.5 to 5.1.

Lustre, metallic.

Streak, black or reddish brown.

Opaque.

Tenacity, brittle.

Color, light steel to dark lead gray or iron black.
THE COPPER MINERALS.

BEFORE BLOWPIPE, ETC.—On charcoal fuses easily to a globule which may be slightly magnetic. Evolves heavy white fumes with sometimes garlic odor. The roasted residue gives bead and flame reactions for copper. Soluble in nitric acid to a green solution with white residue.

VARIETIES—Varieties based upon the replacing metal as mercuric, argentiferous, platiniferous, bismuthiferous, etc., are given special names as Freibergite, Schwartsite, Rionite, etc.

SIMILAR SPECIES.—The crystals are characteristic. The fine grained fracture in conjunction with the color is often sufficient to distinguish it. It is softer than arsenopyrite and the metallic cobalt ores, and does not generally yield a strongly magnetic residue on heating. Bournonite and chalcocite are softer, and finally the blowpipe reactions are distinctive.

REMARKS.—Ocurs with the sulphides of lead, silver, copper, etc., especially in Humbolt County, Nevada, and numerous localities in Colorado. Also in Mexico, Bolivia, Chili, and in many parts of Europe.

USES.—It is sometimes worked for silver and also for copper.

CUPRITE.—Red Oxide of Copper, Ruby Copper Ore.

COMPOSITION.—Cu₂O, (Cu 88.8 per cent.). Sometimes intermixed with limonite.

GENERAL DESCRIPTION.—Fine grained, very dark red or blood-red masses, also impure brownish red and earthy brick-red material. Sometimes in small deep red to crimson transparent cubes and octahedrons or as hair-like crystals.

LUSTRE, adamantine or dull. TRANSPARENT to opaque.
STREAK, brownish red. TENACITY, brittle.
COLOR, crimson, scarlet, vermilion, or brownish red.
Before Blowpipe, Etc.—On charcoal blackens and fuses easily to a malleable red button. Flame and bead tests give the color for copper. Soluble in nitric acid to a green solution. Soluble also in strong hydrochloric acid to a brown solution which diluted with water yields a white precipitate.

Similar Species.—It is softer than hematite and harder than cinnabar or proustite, and differs from them all by yielding an emerald-green flame and a malleable red metal on heating.

Remarks.—It is formed by oxidation of sulphides of the metal, and is found near the surface associated with limonite, quartz, and copper minerals. It changes to the black oxide and to the carbonates and silicate. In the United States it is especially abundant in the Arizona copper region. Also found in the Lake Superior region, and is abundant in Chili, Peru and Bolivia in association with the other copper ores.

Uses.—It is an important ore of copper.

Tenorite.—Melanite, Black Oxide of Copper.

Composition.—$\text{CuO}$, (Cu 79.85 per cent.).

General Description.—Dull black earthy masses, black powder and shining black scales.


Before Blowpipe, Etc.—Inferior, otherwise like cuprite.

Remarks.—Occurs in fissures in the lava of Vesuvius, as a black coat on chalcopyrite and as dull black masses with chrysocolla.

Atacamite.

Composition.—$\text{Cu(OH)}_2\text{Cl}$, (Cu 59.45, Cl 16.64 per cent.).

General Description.—Confused aggregates of crystals of bright or dark-green color. Also granular or compact massive, or as a crust. Rarely in slender orthorhombic prisms.

Physical Characters.—Translucent to transparent. Lustre, adamantine to vitreous. Color, bright green, emerald green, blackish green. Streak, apple green. H., 3 to 3.5. Sp. gr., 3.73 to 3.77.

Before Blowpipe, Etc.—On charcoal, fuses to a copper red, malleable button, and colors the flame a beautiful and persistent blue without the aid of hydrochloric acid. In closed tube yields water and a gray sublimate. Soluble in acids to a green solution.

Chalcantite.—Blue Vitriol.

Composition.—$\text{CuSO}_4 \cdot 5\text{H}_2\text{O}$, (CuO 31.8, SO$_4$ 32.1, H$_2$O 36.1 per cent.).

General Description.—A blue, glassy mineral, with a disagreeable metallic taste. It occurs usually as an incrustation, with fibrous, stalactitic or botryoidal structure; but sometimes in flat triclinic crystals.

THE COPPER MINERALS.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses, coloring flame green and leaving metallic copper. In closed tube yields water and sulphur dioxide and leaves a white powder. Easily soluble in water to a blue solution.

REMARKS.—It is produced by oxidation of the sulphides, especially chalcopyrite. Copper is sometimes saved by precipitation from mine waters containing chalcanthite.

BROCHANTITE.

COMPOSITION.—Cu₄(OH)₂SO₄·2Cu(OH)₂. (CuO 70.34, SO₄ 17.71, H₂O 11.95 per cent.).

GENERAL DESCRIPTION.—Velvety, emerald-green crusts of fine needle crystals and as botryoidal masses.


BEFORE BLOWPIPE, ETC.—On charcoal turns black, colors the flame emerald green and leaves malleable red button. Insoluble in water, but soluble in acids. In closed tube yields water.

LIBETHENITE.

COMPOSITION.—Cu₄(OH)₂PO₄. (CuO 65.4, P₂O₅ 29.8, H₂O 3.8 per cent.).

GENERAL DESCRIPTION.—A dark, olive-green mineral, usually in druses of small almost octahedral crystals and more rarely compact.

CRYSSTALLIZATION.—Orthorhombic, a : b : c = 0.702, 1 : 1 = 93° 53′. 1 = 1 to 1 = 109° 53′.


BEFORE BLOWPIPE, ETC.—Fuses easily to a brown or reddish globule, coloring the flame green, and yields metallic copper. Fused with lead yields a crystalline bead and metallic copper. In closed tube yields water and turns black. Soluble in nitric acid.

OLIVENITE.

COMPOSITION.—Ca₂(OH)₂SO₄. (CaO 56.1, As₂O₅ 40.7, H₂O 3.2 per cent.).

GENERAL DESCRIPTION.—Needle-like crystals of dark olive-green, also nodules and fibrous or velvety masses of light-green to gray or brown color.

CRYSSTALLIZATION.—Orthorhombic, a : b : c = 0.673, 1 : 1 = 93° 34′. 1 = 1 to 1 = 109° 56′.


BEFORE BLOWPIPE, ETC.—On charcoal, fuses, deflagrates, colors the flame bluish green and gives odor of garlic. Residue is a brown, brittle, somewhat crystalline button. In closed tube, yields water. Soluble in nitric acid.
MALACHITE.—Green Carbonate of Copper.

Composition.—$\text{Cu}_2(\text{OH})_2\text{CO}_3$; ($\text{CuO}$ 71.9, $\text{CO}_2$ 19.9, $\text{H}_2\text{O}$ 8.2 per cent.)

General Description.—Bright-green masses and crusts, often with a delicate, silky fibrous structure or banded in lighter and darker shades of green. Sometimes stalactitic. Also in dull-green, earthy masses, and rarely in small, slender, monoclinic crystals. Frequently coating other copper minerals or filling their crevices and seams.

Physical Characters. H., 3.5 to 4. Sp. gr., 3.9 to 4.03.

Lustre, silky, adamantine or dull. Translucent to opaque.

Streak, pale green.

Tenacity, brittle.

Color, bright emerald to grass green or nearly black.

Before Blowpipe, Etc.—On charcoal, decompounds, blackens, fuses, and colors the flame green, leaving a globule of metallic copper. In closed tube, blackens and yields water and carbon dioxide. Soluble in acids, with effervescence.

Similar Species.—Distinguished by color and effervescence with acids.

Remarks.—Malachite is formed by action of carbonated waters on other copper minerals. It is found chiefly with these or pseudomorphous after them, especially after copper and azurite. Immense deposits occur at Bisbee, Arizona, and other localities in the same region. Also in large deposits in Siberia, Chili and Australia. In smaller quantities it is found in the vicinity of all copper ores.

Uses.—Is an ore of copper, and like marble is polished for ornamental articles, table-tops, etc.

AZURITE.—Blue Carbonate of Copper.

Composition.—$\text{Cu}_3(\text{OH})_2(\text{CO}_3)_2$; ($\text{CuO}$ 69.2, $\text{CO}_2$ 25.6, $\text{H}_2\text{O}$ 5.2 per cent.).

General Description.—A dark-blue mineral occurring in fine, glassy monoclinic crystals and groups. Also massive, with some-
times velvety appearance or earthy and light-colored. Also frequently as an incrustation on other ores or distributed through their cracks and crevices.

**Crystallization.**—Monoclinic $\beta = 87^\circ 36'$. $I \wedge l = 99^\circ 19'$. $O : I - T = 135^\circ 14'$. Forms very numerous and complex.

**Physical Characters.** H., 3.5 to 4. Sp. gr., 3.77 to 3.83.
- **Lustre,** vitreous.
- **Streak,** blue.
- **Color,** dark blue to azure blue.

**Before Blowpipe, Etc.**—As for malachite.

**Remarks.**—Origin, associates and localities are the same as for malachite.

**Uses.**—As an ore of copper and a rather unsatisfactory blue paint.

**Chrysocolla.**

**Composition.**—CuSiO$_3$ + 2H$_2$O. Often very impure (CuO 45.2, SiO$_2$ 34.3, H$_2$O 20.5 per cent.).

**General Description.**—Green to blue incrustations and seams often opal-like in texture, or sometimes, from impurities, resembling a kaolin colored by copper. Also brown, resembling limonite, and in dull green earthy masses. Never found in crystals.

**Physical Characters.** H., 2 to 4. Sp. gr., 2 to 2.3.
- **Lustre,** vitreous, dull.
- **Streak,** white.
- **Color,** green to light blue, brown when ferriferous.

**Before Blowpipe, Etc.**—In forceps or on charcoal is infusible, but turns black, then brown and colors the flame emerald green. In bead, reacts for copper. With soda, yields malleable copper. In closed tube, yields water. Decomposed by hydrochloric acid, leaving a residue of silica. Boiled with KOH, yields a blue solution, from which excess of NH$_4$Cl precipitates flocculent H$_2$SiO$_4$.

**Similar Species.**—It is softer than turquoise or opal and does not effervesce like malachite.

**Remarks.**—Chrysocolla occurs with other copper minerals, especially near the tops of veins. It is probably formed by the action of hot solutions of alkaline silicates on other copper ores. Found at Clifton, Arizona; Hartville, Wyoming, and in most of the prominent copper-bearing regions.
USES.—As an ore of copper and an imitation turquoise.

**DIOPTASE.**

**COMPOSITION.**—$\text{H}_2\text{CaSiO}_4$, (CaO 50.4, SiO$_2$ 38.2, H$_2$O 11.4 per cent.).

**GENERAL DESCRIPTION.**—Glassy, emerald-green crystals and druses of indistinct crystals. Also found massive.

**CRYSTALLIZATION.**—Hexagonal, $\delta = 0.534$. $R \wedge R = 125^\circ 55'$. $2 \wedge 2 = 95^\circ 26\frac{1}{2}'$. Commonly prismatic, with rhombohedral terminations.


**BEFORE BLOWPIPE, ETC.**—Decrepitates, blackens, colors the flame emerald green, but is infusible. In closed tube, blackens and yields water. Gelsatinizes with acids.
CHAPTER XXIV.

MERCURY AND SILVER MINERALS.

THE MERCURY MINERALS.

The minerals described are: Metal, Mercury; Sulphide, Cinnabar; Chloride, Calomel.

The only ore is cinnabar with which the native metal sometimes occurs in small quantities. The ore is usually low grade, that mined in 1889 in this country yielding* only an average of about one per cent. of mercury. The world's product of mercury in 1891 was about 35,000 tons,† of which the United States produced about one-fourth.

Mercury is obtained from cinnabar by heating the larger lumps in a shaft-furnace, resembling a continuous lime kiln, with three exterior fire places. A little fuel is also mixed with the ore. The heat decomposes the sulphide, forming fumes of sulphur dioxide and mercury. These fumes are carried off through large iron pipes to condensers where the mercury is liquified. The finer ore is heated in a vertical shaft containing a series of inclined shelves down which the ore slips whenever any is drawn off at the bottom. The fumes go to the condensers already mentioned.

Mercury is extensively used in certain processes for the extraction of gold and silver from their ores and in the manufacture of vermilion. Minor uses are in barometers, thermometers, silvering mirrors, and in medicine.

MERCURY.

Composition.—Hg, with sometimes a little silver.

General Description.—A tin white liquid with metallic lustre. Usually found in little globules scattered in the gangue, or in cavities with cinnabar or calomel.


Before Blowpipe, Etc.—Entirely volatile. In crucible or closed tube may be collected in small globules. Soluble in nitric acid.

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* Bulletin 10 of the 11th Census, United States.
† Mineral Industries, 1892, pp. 407 et seq.
CINNABAR.—Natural Vermillion.

**Composition.**—HgS, (Hg 86.2 per cent.).

**General Description.**—Very heavy, bright vermilion to brownish red masses of granular texture; more rarely small transparent rhombohedral crystals, or bright scarlet powder, or earthy red mass. Sometimes nearly black from organic matter.

**Physical Characters.**  H., 2 to 2.5.  Sp. gr., 8 to 8.2.

- Lustre, adamantine to dull.  Opaque to transparent.
- Streak, scarlet.  Tenacity, brittle to sectile.
- Color, cochineal red, scarlet, reddish brown, blackish.

**Before Blowpipe, Etc.**—Completely volatilized without fusion if pure. With soda gives sulphur reaction. In closed tube yields black sublimate, which becomes red when rubbed; if soda is used a metallic mirror is obtained instead of the black sublimate, and by rubbing with a splinter of wood globules of mercury may be collected. If cinnabar powder is moistened with hydrochloric acid and rubbed on bright copper the coin is coated with mercury. Soluble in aqua regia.

**Similar Species.**—Cinnabar is softer and heavier than hematite, cuprite, and rutile. It has more decided red streak than crocoite and realgar, and differs from proustite in density and blowpipe reactions.

**Remarks.**—Cinnabar occurs in slate rocks and shales, and sometimes in granite or porphyry associated with sulphides of iron, copper, antimony, and arsenic, and with native gold. Its chief localities are Idria, Southern Austria; Almaden, Spain; Huancafelica, Peru; Kweichow, China; Ekaterinoslav, Russia, and at several places in Lake, San Benito, Naja, and Santa Clara counties, California.

**Uses.**—It is the only important ore of mercury. The artificial cinnabar is the important pigment vermilion.

CALOMEL.—Horn Mercury.

**Composition.**—HgCl₂, (Hg 84.9 per cent.).

**General Description.**—A gray or brown translucent mineral of the consistency of horn. Usually found as a coating in cavities with or near cinnabar. Sometimes in well-developed tetragonal forms $a = 1.723$.


**Before Blowpipe, Etc.**—Volatilizes without fusion, yielding a white coating. In closed tube with soda forms a metallic mirror.
THE SILVER MINERALS.

The minerals described are: Metal, Silver, Amalgam; Sulphtides, Tellurides, etc., Argentite, Hessite, Proustite, Pyrrargyrite, Stephanite, Polybasite; Haloids, Cerargyrite, Bromyr-ite, Emolite, Iodyrite.

Generally speaking ordinary silver ores contain less than one per cent. of the silver compounds distributed through various earthy and metallic minerals, and only in occasional rich specimens do they show the true nature of the silver-bearing substance. Frequently the ore will contain less than twenty ounces of silver per ton.

In 1892 nearly $55,000,000 of silver was* extracted in this country alone, being about 40 per cent. of the product of the world.

A steadily increasing proportion of the world's output of silver is obtained from ores of other metals which contain it, especially the ores of lead and copper. In many cases also the silver minerals are smelted with these ores, and the silver later separated from the metallic lead or copper product.

In some instances the silver is extracted from the ore by wet processes or by treatment with mercury.

The extraction of silver by reduction with lead-ores in a water-jacket furnace, and the subsequent treatment has been referred to under lead, p. 179.

When the silver is obtained as a constituent of a copper matte, it may be recovered by several processes. The best known of these is the so-called Ziervogel process, in which the ground matte, containing iron, copper, and silver, and possibly gold, as sulphides, is roasted at a gradually increasing temperature until most of the sulphur is gone. It is then reground very fine and carefully reroasted, until by tests it is found to have reached a stage in which the iron and copper are oxides and the silver is a sulphate. The material is then treated with hot water, which dissolves out the silver sulphate and the solution is run over copper plates which throw down the silver as metal.

Several processes for extracting silver by the use of mercury exist, the principle in every case being that mercury will reduce certain

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* Mineral Industries, 1892, pp. 171 et seq.
compounds of silver to metal and unite with the silver, or if mercury is present and some other substance, as iron or copper, reduces the ore to silver, the mercury will collect it.

The details of amalgamation are in transforming the silver to a condition in which the mercury can act—for instance, forming chlorides by roasting with salt—and in the method of reduction.

In pan amalgamation, so called, the finely-crushed ore, chloridized when necessary, and mixed to a pulp with water, is charged into a tub-like vessel, with an iron bottom and wooden sides. In this tub or pan there revolves a stirrer, with arms shaped to throw the pulp to the sides, from which it rolls back to the centre. Attached to the arms are grinding shoes, which can be lowered so as to rub on the iron bottom or be raised free from it. The practice will differ in detail, but generally the pulp will be kept hot by steam, and no mercury will be added until the grinding is completed. During the grinding the metallic iron of the bottom and the shoes reduces the silver compound; although chemicals, such as salt, copper sulphate, potassium cyanide, etc., are sometimes added to assist. After the grinding the mercury is added, and the stirring continued until the mercury has collected all the silver. The mass is then run into a larger tub, diluted, the mercury amalgam separated, and, by subsequent distillation, the silver recovered from the mercury.

**SILVER.**—Native Silver.

**Composition.**—Ag, sometimes alloyed with Au, Cu, Pt, Hg, Sb, Bi.

**General Description.**—A silver-white, malleable metal, occurring in masses, scales, and twisted wire-like filaments, penetrating the gangue or flattened upon its surface. Sometimes in isometric crystals, usually elongated, needle-like forms, or arborescent, from the union of distorted forms which branch from one direction parallel to others.

**Physical Characters.**
- H., 2.5 to 3.
- Sp. gr., 10.1 to 11.1.
- Lustre, metallic.
- Opaque.
- Streak, silver white.
- Tenacity, malleable.
- Color, silver white, tarnishing brown to nearly black.

**Before Blowpipe, Etc.**—On charcoal, fuses to a white metallic globule. Soluble in nitric or sulphuric acid, but from these it is
precipitated as a white curd-like precipitate by hydrochloric acid or salt. The precipitate darkens on exposure to light.

Similar Species.—When tarnished, resembles copper or bismuth, but is distinguished by its silver-white streak from the former and by non-volatilization from the latter.

Remarks.—Silver may have been formed by the reduction of its ores, as it occurs pseudomorphous after them. It is also changed to sulphides by contact with soluble sulphides, and into the chloride by salt water. Its associates are the other silver minerals, and galena, pyrite, stibnite, tetrahedrite, etc.

The most celebrated mines where native silver is obtained are those of Kongsberg, in Norway, and Huantaya, Peru. Occurs also in Northern Mexico, in the Michigan copper region, in numerous Colorado localities, at Butte, Montana; in Idaho; Arizona, and in smaller quantity in other silver-producing regions.

Amalgam.

Composition.—$Ag_2Hg$ to $AgHg$.

General Description.—A brittle, silver-white mineral of bright metallic lustre, which occurs in imbedded grains and indistinct isometric crystals.


Before Blowpipe, etc.—On charcoal, partially volatilized, leaving malleable silver. In closed tube, yields mercury mirror. Soluble in nitric acid.

Argentite.—Silver Glance.

Composition.—$Ag_2S$, ($Ag$ 87.1 per cent.).

General Description.—A soft black mineral, of metallic lustre, which cuts like wax and occurs as masses, disseminated grains, or incrusting. Also as isometric crystals, usually modified cubes and grouped in arborescent shapes.

![Fig. 238](image)

![Fig. 239](image)


Lustre, metallic.

Streak, lead gray.

Color, lead gray to black or blackish gray.
BEFORE BLOWPIPE, ETC.—On charcoal, swells, fuses, yields fumes of sulphur dioxide, and finally malleable silver. Soluble in nitric acid, with separation of sulphur.

SIMILAR SPECIES.—Differs from other soft black minerals in cutting like wax and in yielding malleable silver on heating. Differs from cerargyrite in solubility in nitric acid.

REMARKS.—Occurs sparingly with other silver minerals as pure material, but is probably the compound of silver so frequently included in galena, sphalerite, etc. Large amounts of argentite have been obtained in Nevada, especially from the Comstock lode and the Austin mines. Also in Arizona. It is a common ore in Mexico, Chili, Peru and Bolivia.

USES.—It is an ore of silver.

HESSITE.—Petzite.

COMPOSITION.—\((Ag,\text{Au})_2Te\), grading from hessite, \(Ag,Te\) (Ag 63 per cent.) to petzite, in which there is 20 to 25 per cent. of gold.

GENERAL DESCRIPTION.—Fine-grained, gray, massive mineral, of metallic lustre. Also coarse granular, and in small, indistinct, isometric crystals.

Physical Characters. H., 2 to 2.5. Sp. Gr., 8.3 to 8.6.
LUSTRE, metallic. OPAQUE.
STREAK, black. TENACITY, slightly sectile.
COLOR, between steel gray and lead gray.

BEFORE BLOWPIPE, ETC.—On charcoal, fuses to a black globule, with white silver points on its surface. If powdered and dropped into boiling concentrated sulphuric acid, the acid is colored an intense purple.

PROUSTITE.—Light Ruby Silver.

COMPOSITION.—\(Ag_3AsS_2\), (Ag 65.4, As 15.2, S 19.4 per cent.). Sometimes containing a little antimony.

GENERAL DESCRIPTION.—A scarlet vermillion mineral, either translucent or transparent, with a scarlet streak. Usually occurs disseminated through the gangue or as a stain or crust. Rarely in small hexagonal crystals.

CRYSTALLIZATION.—Hexagonal, \(c = 0.804\), usually in acute rhombohedral or scalenohedral forms.
Physical Characters. H., 2 to 2.5. Sp. gr., 5.37 to 5.64.

Lustre, adamantine brilliant. Translucent to transparent.

Streak, scarlet. Tenacity, brittle.

Color, scarlet vermilion.

Before Blowpipe, Etc.—On charcoal, fuses, yields sulphurous and garlic odors and malleable silver. In closed tube, fuses and yields slight red sublimate, yellow when cold. Decomposed by nitric acid, leaving a white residue. In powder, is turned black by potassium hydroxide solution, and partially dissolved on boiling. Hydrochloric acid precipitates from this a lemon yellow arsenic sulphide.

Similar Species.—Differs from pyrargyrite in scarlet streak, and from cuprite and cinnabar by garlic odor when heated.

Remarks.—Occurs with other silver minerals, and is mined as an ore of silver. Most abundant in the United States at Poor Man’s Lode, Idaho; Austin, Nevada, and in Gunnison County, Colorado, at the Ruby silver district; in large quantities at Guanajuato, Mexico; at Chañareillo, Chili, and other South American localities. Noted European localities are Andreasberg, Freiberg, and Joachimsthal in the Harz.

Pyrargyrite.—Dark Ruby Silver.

Composition.—Ag₃Sb₂, (Ag 59.9, Sb 22.3, S 17.8 per cent.). Often with small amounts of arsenic.

General Description.—A nearly black mineral, which is deep red by transmitted light and has a purplish-red streak. Usually occurs massive or disseminated, or in thin films, sometimes in crystals.

Crystallization.—Hexagonal, c = 0.789. Prismatic crystals, with rhombohedral or scalenohedral terminations, which are not alike at the opposite ends (hemimorphic).

Physical Characters. H., 2.5. Sp. gr., 5.77 to 5.86.

Lustre, metallic, adamantine. Translucent to opaque.

Streak, purplish red. Tenacity, brittle.

Color, black or nearly so, but purple red by transmitted light.

Before Blowpipe, Etc.—On charcoal, fuses easily, spirits, evolves dense white fumes and leaves malleable silver. A white sublimate forms. In closed tube, yields black sublimate, red when cold. Soluble in nitric acid, with separation of sulphur and antimony trioxide. In powder, is turned black by a solution
of potassium hydroxide, and on boiling it is decomposed; the solution deposits an orange precipitate on addition of hydrochloric acid.

**Similar Species.**—The streak is purplish red differing from the scarlet of proustite. The streak and silver reaction distinguish it from cuprite, cinnabar and realgar.

**Remarks.**—Occurs with other silver minerals and with arsenic, arsenopyrite, tetrahedrite, galenite, etc. Localities same as for proustite, with which it is usually associated.

**Uses.**—It is an important ore of silver.

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**Stephanite.**—Brittle Silver Ore.

**Composition.**—Ag₅SbS₄. (Ag 68.5, Sb 15.2, S 16.3 per cent.).

**General Description.**—Fine-grained, iron-black mineral, with metallic lustre, often disseminated through the gangue. Sometimes in short six-sided prismatic crystals. It is soft, but brittle.

**Crystallization.**—Orthorhombic, 
\[ a : b : c = 0.629 : 1 : 0.685 \]
\[ \alpha \wedge \beta = 115^\circ 39'. \]
\[ \gamma \wedge \beta = 125^\circ 7^{1/2}'. \]
\[ \gamma \wedge \alpha = 130^\circ 16'(macro), 96^\circ 8'(brachy). \]

Crystals usually pseudo-hexagonal.

**Physical Characters.**
- **H.** 2 to 2.5.
- **Sp. gr.** 6.2 to 6.3.
- **Lustre, metallic.** Opaque.
- **Streak and Color.** Black. Brittle.

**Before Blowpipe, Etc.**—On charcoal, fuses easily, yielding white fumes and coat and odor of sulphur dioxide, finally leaves malleable silver. Soluble in nitric acid, with residue of sulphur and antimony trioxide. With potassium hydroxide, reacts like pyrargyrite.

**Similar Species.**—It is more brittle than argentite and softer than tetrahedrite.

**Remarks.**—Occurs with other silver ores. It is of common occurrence in the Nevada silver mines, and also at Guanajuato, Mexico, and at Chañarcillo, Chili. Found also in the mines of Idaho and in those of Saxony, Bohemia and Hungary.
POLYBASITE.

Composition.—(Ag Cu)₃SbS₆, often with some Sb replaced by As.

General Description.—A soft, iron-black mineral, of metallic lustre, best known in six-sided tabular prisms, with bevelled edges. In thin splinters it is cherry red by transmitted light. Orthorhombic.


Before Blowpipe, etc.—Fuses with spiring. Gives off odor of garlic sometimes, but always yields heavy white fumes and odor of sulphur dioxide, and leaves malleable button, which in beads reacts for copper, or, if dissolved in nitric acid, will yield a flocculent white precipitate on addition of hydrochloric acid. In closed tube, fuses very easily, but yields no sublimate. Soluble in nitric acid.

CERARGYRITE.—Horn Silver.

Composition.—AgCl. (Ag 73.3 per cent.).

General Description.—A soft, grayish-green to violet crust or coating of the consistency and lustre of horn or wax. Rarely in cubic crystals.

Physical Characters. H., 1 to 1.5. Sp. gr., 5 to 5.5.

Lustre, waxy, resinous. Translucent.

Streak, shining white. Tenacity, very sectile.

Color, pearl gray or greenish, darkens on exposure to light, becoming violet, brown or black.

Before Blowpipe, etc.—Fuses very easily, yields acrid fumes and a globule of silver. Rubbed on a moistened surface of zinc or iron, it swells, blackens and the surface is silvered, and the mineral is reduced to spongy metallic silver. In matrass, with acid potassium sulphate, yields a globule, yellow hot, white cold, and made violet or gray by sunlight. Insoluble in acids, soluble in ammonia. On coal, with oxide of copper, yields azure-blue flame.

Similar Species.—Bromyrite, embolite and iodiyrite are most easily distinguished by tests with acid potassium sulphate. It differs from argentite in color and insolubility in nitric acid.

Remarks.—Occurs usually near the top of veins, and is probably precipitated from silver-bearing solutions by chlorides in surface waters. In the United States its most celebrated localities have been Poor Man's Lode, Horn Silver and certain Idaho mines and the mines at Austin, Nevada. Found also in proportionally large quantities in many of the Mexican and Chiliian mines.

Uses.—It is a very important ore of silver.
BROMYRITE.—Bromargyrite.

Composition.—AgBr. (Ag 57.4 per cent.).

General Description.—Like cerargyrite, except that the color is bright yellow to grass green or olive green. H, 2 to 3. Sp. gr., 5.8 to 6. Usually found in small concretions and little altered by exposure.

Before Blowpipe, etc.—Like cerargyrite, except that in contact with acid potassium sulphate a little bromine vapor is evolved, coloring the fluid salt yellow, and the fused bromyrite sinks as a dark red, transparent globule, which, on cooling, becomes opaque and deep yellow, and when exposed to sunlight becomes dark green.

EMBOLITE.

Composition.—Ag(Cl.Br). Isomorphous mixtures of the chloride and bromide.

General Description.—Intermediate between cerargyrite and embolite. Color, green to yellow, darkening on exposure. H, 1 to 1.5. Sp. gr., 5.31 to 5.81.

Before Blowpipe, etc.—The acid potassium sulphate fusion is like that of cerargyrite or that of bromyrite, as the bromine is small in amount or plentiful.

IODYRITE.—Iodargyrite.

Composition.—AgI. (Ag 48.1 54 per cent.).

General Description.—A yellow or yellowish-green, wax-like mineral, occurring massive or in thin flexible scales or in hexagonal crystals.


Before Blowpipe, etc.—Fuses very easily, spreads out and gives pungent odor. In closed tube, fuses and becomes deep orange in color, but cools yellow. With oxide of copper, colors flame intense green. In contact with acid potassium sulphate, yields violet vapor and deep-red globules, which is yellow when cold and not changed by exposure to sunlight.
CHAPTER XXV.

GOLD, PLATINUM AND IRIDIUM MINERALS.

THE GOLD MINERALS.

The minerals described are: Metal, Gold; Telluride, Sylvanite. Aside from vein and placer deposits of native gold the metal is obtained to a very considerable extent from the minerals pyrite, arsenopyrite or pyrrhotite, and from other sulphides or tellurides. In Colorado, for instance, the gold occurs chiefly in pyrite.

In 1892 there was produced* in the United States approximately $33,000,000 worth of gold, which was about one-fourth of the world's production.

A large proportion of the world's gold is found in superficial deposits called placers, which are beds of sand, gravel or boulders accumulated from the erosion of higher rocks containing gold veins. In working shallow placers the dirt is thrown into a wooden trough several hundred feet long, through which a stream of water is flowing. At the bottom of the trough or "sluice" are placed cross-bars or blocks of wood, or sometimes a pavement of flat stones set on edge is constructed. Near the head of the sluice mercury is added at a regular rate, and this encountering the gold unites with it, and the heavy gold and heavy amalgam are caught in the interstices of the wood or stone pavement, while the lighter dirt, etc., are washed away.

At intervals the stream is stopped, the bars or blocks removed and the amalgam collected. By heating in a retort the mercury is distilled from the gold.

Deep placers are sometimes treated by what is called hydraulic mining, which differs from the preceding chiefly in the magnitude of the work and the fact that the water is used in great volume and at heavy pressure, not simply to carry the material down the sluice but also to tear down and wash away the placer. Usually this is preceded by driving a tunnel into the bottom of the placer and exploding heavy charges of powder to loosen the gravel bank.

* Mineral Industries, 1892, p. 171.
Gold that is found in place is usually in quartz veins associated with sulphides, especially pyrite. It is extracted by finely crushing the vein rock and collecting the gold by mercury or copper plates coated with mercury. The vein material is usually stamped in a mortar by blows of several pestles, usually five, raised successively bycams and dropped. Generally water and mercury are in the mortar, and as the material becomes sufficiently fine the water carries it through a screen over a series of amalgamated plates which catch most of the gold. From time to time the amalgam is scraped off of the plates and collected from the mortar and retorted.

Gold bearing pyrite is usually stamped as described, but the residues which still carry some gold are frequently concentrated, roasted, and chlorinated. That is, the roasted oré is subjected to the action of nascent chlorine and the gold is converted into a chloride soluble in water. The chlorine may be generated by a mixture of salt, pyrolusite and sulphuric acid, or by a mixture of sulphuric acid and chloride of lime.

After dissolving out the chloride of gold with water the gold may be precipitated as metal by ferrous sulphate or as sulphide by sulphuretted hydrogen; in the latter case the precipitate is pressed, dried, roasted, and finally fused.

GOLD.

Composition.—Au, usually alloyed with Ag, and sometimes Cu, Bi, Rh, or Pd.

General Description.—A soft malleable metal with color and streak varying from golden yellow to yellowish white according to the silver contents. It is found in nuggets, grains, or scales, usually so disseminated as to be apparent only on assay. It is found occasionally in isometric crystals, usually united in branching forms and passing into wire-like, net-like, and dendritic shapes. Also occurs as a constituent of many sulphides, as pyrite, sphalerite, galenite, pyrrhotite, arsenopyrite, etc.

Physical Characters.  H., 2.5 to 3.  Sp. gr., 15.6 to 19.3.

Lustre, metallic.  Opaque.

Streak, like color.  Tenacity, malleable.

Color, golden yellow to nearly silver white.

Before Blowpipe, Etc.—On charcoal fuses to a bright yellow
GOLD, PLATINUM AND IRIDIUM MINERALS.

button insoluble except in aqua regia. Any silver present will separate from the solution as a white curd-like precipitate. If the solution is evaporated to a thick syrup and diluted with water and heated with stannous chloride it becomes purple, and a purple precipitate settles.

SIMILAR SPECIES.—Chalcopyrite, pyrite, and scales of yellow mica are mistaken for gold, but differ entirely in specific gravity, streak, brittleness, and solubility in acids.

REMARKS.—Occurs in infinitesimal amount in practically all rocks and soil, and even when in paying quantities is commonly only revealed by an assay. The solvent action of superheated water collects and redeposits the gold in more concentrated state, usually in quartz veins associated with or contained in pyrite, arsenopyrite, chalcopyrite, galena, pyrrhotite, magnetite, hematite, bismuth, tellurium minerals, etc. It is practically unchangeable, but the wearing away of the containing rocks and the sorting and transportation of the fragments with the solution of the solvent portions results in the formation of gold-bearing gravels, river beds, etc.

The four largest gold producing States are California, Colorado, South Dakota and Montana. Besides these American localities the mines of Victoria and New South Wales, Australia, those on the eastern coast of South Africa, and the Siberian mines are the largest gold producers. Many other countries yield smaller amounts.

USES.—The chief uses are for coinage and jewelry.

SYLVANITE.—Graphic Tellurium.

COMPOSITION.—\((\text{Au,Ag})\text{T}_{\text{e}}\). Au about 25 per cent.

GENERAL DESCRIPTION.—A soft silver-white or light gray mineral of metallic lustre, usually found in flat plate-like monoclinic crystals, which are joined in branching groups resembling Hebrew letters. Also in bladed and granular masses.

PHYSICAL CHARACTERS.—Opaque. Lustre, metallic. Color, silver white or steel gray, inclining to yellow. Streak like color. H., 1.5 to 2. Sp. gr., 7.9 to 8.3. Very sectile.

BEFORE BLOWPIPE, ETC.—On charcoal fuses to a gray globule, yields a white sublimate which disappears in reducing flame, coloring the flame green. After long heating a light yellow bead of metal is obtained, which is soluble in aqua regia with a curd-like white precipitate. In open tube yields a white sublimate which melts to clear transparent drops. If powdered and dropped into boiling concentrated sulphuric acid the acid is colored intense purple. Soluble in nitric acid.

THE PLATINUM AND IRIDIUM MINERALS.

The minerals described are Platinum and Iridosmine.

Purified platinum is largely used in incandescent lamps and laboratory apparatus and to a limited extent in jewelry. In Russia it was formerly used in coinage.

The greater portion of the metal is obtained by washing placer
deposits in the Ural mountains, and only a little is obtained from other localities. Russia produced nearly five tons in 1891.®

Platinum, as it occurs in nature, is always alloyed with iron and other metals, from which it must be separated before it possesses the peculiar properties which make it valuable. The native mineral is first treated with dilute aqua regia, which dissolves out any iron, gold or copper. Then concentrated aqua regia is added to the residue, and the platinum and a small amount of iridium are brought into solution. After evaporation of the excess of acid, these are precipitated by ammonium chloride, the ammonium-platinic chloride being formed and also a small amount of the iridium salt. This precipitate, on being heated, leaves the metal, which consists almost wholly of platinum, but also carries a small amount of iridium. The metals can be further separated, but for many purposes this alloy is preferable to the pure platinum.

The mineral iridosamine, which occurs only in small grains, is used for pointing gold pens, and, by fusion with phosphorus, is converted into a phosphide of iridium, which is used for pointing tools and stylographic pens, and for draw-plates for gold and silver wire.

The phosphide, by heating in a bed of lime, is changed to pure iridium, which, alloyed with platinum, is used for the standards of weights and measures.

A process of iridium plating also exists.

PLATINUM.—Native Platinum.

COMPOSITION.—Pt(Fe), usually with small quantities of Rh, Ir, Pd, Os, Cu, and nearly always with Fe even as high as one-sixth of the whole.

GENERAL DESCRIPTION.—A malleable, steel-gray to white metal, occurring in small grains and nuggets in alluvial sands. Very rarely in small cubes.

Physical Characters.  

Lustre, metallic.  

Streak, steel gray.  

Color, light steel gray.  

H., 4 to 4.5.  

Sp. gr., 14 to 19.  

Opaque.  

Tenacity, malleable.  

Often magnetic.

GOLD, PLATINUM AND IRIDIUM MINERALS.

BEFORE BLOWPIPE, ETC.—Infusible and unaffected by fluxes or any single acid. Soluble in aqua regia.

SIMILAR SPECIES.—Heavier than silver and not soluble in nitric acid.

REMARKS.—Found in alluvial deposits with other refractory minerals, as gold, iridium, chromite, corundum, zircon, diamond, etc. Is said to occur in syenite and is sometimes found included in masses of chromite or of serpentine. By far the larger part of the platinum of commerce is obtained from placer deposits in the Ural mountains; Borneo, Brasil, and the United States of Colombia also produce small amounts. It has been identified in many of the gold regions of the United States, but only in small quantities, and the quantity annually produced is insignificant.

IRIDOSMINE.

COMPOSITION.—(Ir, Os), sometimes with Rh, Pt, etc.

GENERAL DESCRIPTION.—A tin-white or gray, metallic mineral, very hard and heavy, and occurring in irregular, flattened grains and hexagonal plates.


CHAPTER XXVI.

POTASSIUM, SODIUM AND AMMONIUM MINERALS.

THE POTASSIUM MINERALS.

The minerals described are: Chloride, Sylvite; Sulphates, Aphthitalite, Kalinite; Nitrate, Nitre. In addition to these, potassium is a constituent of many silicates, among which orthoclase is prominent, and of kainite, MgSO₄KCl ÷ 3H₂O. It is also found in solution in many brines.

The natural potash salts, especially the chlorides, are obtained in large amounts from two or three deposits in Germany.* The nitrate is mined in India, and occurs in small amounts elsewhere. Potassium bromide is extracted from the mother liquor of certain brines. The chief important uses are in the form of the nitrate in gunpowder and as the chloride or sulphate in fertilizers. The element is essential to plant growth and is liable to exhaustion in soils.

SYLVITE.

Composition.—KCl, (K 52.4 per cent.).

General Description.—Colorless, transparent cubes or white masses, which look like common salt and have somewhat similar taste. Absorbs moisture and becomes damp.


Before Blowpipe, Etc.—Fuses very readily, coloring flame violet. If added to a salt of phosphorus and copper oxide bead, the flame is colored azure blue. Soluble in water and acids.

APHTHITALITE.

Composition.—(K₂Na₄)₂SO₄.

General Description.—Thin, white, hexagonal plates or white crusts and masses on lava or with other potassium and sodium minerals. Not altered by exposure.

* The German Verkaufsyndicate der Kaliwerke, who control all the Stasfurt mines, give, in their World's Fair Pamphlet, as sold in 1892, Carnallit 756,750, Kieserit 5782, Schoenit 40,689, Kainit 345,024, Sylvinit 32,669, metric tons. These are the production figures of the crude mineral.
POTASSIUM, SODIUM, ETC., MINERALS.

Physical Characters.—Transparent to opaque. Luster, vitreous. Color, white or bluish to greenish. Streak, white. H., 3 to 3.5. Sp. gr., 2.63 to 2.65. Taste, salt and bitter.

Before Blowpipe, Etc.—Fuses easily and quietly, coloring the flame violet. After fusion on coal in reducing flame, the mass will stain bright silver. Soluble in water.

KALINITE.—Potash Alum.

Composition.—KAl(SO₄)₂ + 12H₂O. (K₂O 9.9, Al₂O₃ 10.8, SO₄ 33.8, H₂O 45.5 per cent.).

General Description.—A white efflorescence on argillaceous minerals, usually fibrous, or as mealy crusts, or compact.

Physical Characters. H., 2.5. Sp. gr., 1.75.
Lustre, vitreous. Transparent or translucent.
Streak, white. Tenacity, brittle.
Color, white. Taste, astringent.

Before Blowpipe, Etc.—On heating, becomes liquid, yields water, and finally swells to a white, spongy, easily-powdered mass, which is insinible, but colors the flame violet. With cobalt solution, becomes deep blue on heating. Soluble in water.

NITRE.—Saltpetre.

Composition.—KNO₃. (K₂O 46.5, N₂O₃ 53.5 per cent.).

General Description.—White crusts, needle-like, orthorhombic crystals and silky tufts, occurring in limestone caverns or as incrustations upon the earth’s surface or on walls, rocks, etc. Not altered by exposure.

Lustre, vitreous. Translucent.
Streak, white. Tenacity, brittle.
Color, colorless, white, gray. Taste, salty and cooling.

Before Blowpipe, Etc.—On charcoal fuses easily, deflagrates violently like gunpowder, colors the flame violet. Soluble in water.

Remarks.—Formed in certain soils by the action of a ferment, especially after rains. Although found in small quantity in many of the so-called alkali lands of our Western
States, it is not utilized. Deposits in Ceylon and India are worked, and refined nitre produced, but almost all of the commercial product is made from sodium nitrate and potassium chloride.

**THE SODIUM MINERALS.**

The minerals described are: Chloride, Halite; Sulphates, Thenardite, Glauberite, Mirabilite; Carbonate, Trona; Nitrate, Soda Nitre, besides which sodium is an important constituent in certain silicates.

The most important of these minerals are halite, soda-nitre and trona.

Halite is common salt. It occurs in various localities in beds varying from a few feet to over three thousand feet in thickness. It occurs also in nearly all water, from infinitesimal quantities to strong brines, and it occurs as incrustations on high planes in dry regions. The salt deposits are mined and the brines are pumped up and evaporated by the heat of the sun or by artificial heat. In this country 1,622,000 tons were reported* as produced in 1892.

The amount used is enormous; for instance, over 1,000,000 tons per year are converted into sodium and chlorine compounds.

Soda Nitre is found in enormous quantities at Tarapaca, Chili; nearly a million tons a year are exported. It is used in the manufacture of nitre for gunpowder, in the production of nitric acid, but chiefly for fertilizing purposes. It is also the source of most of the iodine as the mother liquors after refining may contain twenty per cent. of sodium iodate.

Trona.—Carbonates of sodium, mixed carbonates, and bicarbonates occur plentifully in the alkali deserts of the West with sulphates and chlorides. The pools and lakes into which these districts drain contain large amounts of these salts, and by evaporating the water to the required degree of concentration, crystals of soda are deposited, which are refined by subsequent operations.

**HALITE.—Rock Salt, Common Salt.**

**Composition.**—NaCl, (Na 60.6 per cent.), usually impure.

**General Description.**—Essentially colorless to white and vitreous, but from iron is frequently brown to red. It occurs in cubic crystals, often with cavernous faces and in masses, with cubical cleavage, and also compact granular and coarse fibrous.

* Mineral Industry, 1892, p. 419.
POTASSIUM, SODIUM, ETC., MINERALS.

In dry countries it occurs as a fibrous efflorescence. It is liable to absorb moisture and becomes damp, especially when containing calcium or magnesium chlorides. It is known by its taste.

**Physical Characters.** H., 2.5. Sp. gr., 2.4 to 2.6. Translucent to transparent.
- Lustre, vitreous.
- Streak, white.
- Color, white, colorless, yellow, brown, deep blue.
- Taste, salt.

**Before Blowpipe, Etc.**—Decrepitates violently, fuses very easily and colors the flame yellow and may be volatilized. Easily soluble in cold water.

**Similar Species.**—The taste distinguishes it from all other minerals.

**Remarks.**—Halite occurs with rocks of all ages in beds of great thickness. These are formed by the gradual and complete evaporation of bodies of water into which the salt has been brought in small increments by inflowing streams. Vast lakes and seas of salt water exist in different parts of the world as well as many salt springs.

Innumerable immense deposits of salt are known and worked in almost every civilized country. In the United States we have many deposits. Hundreds of square miles of central and western New York are underlaid by strata of salt varying from a few feet to one or two hundred feet in thickness. Immense amounts of salt are also produced in the Saginaw district of Michigan. At Petite Anse, La., salt is found of such purity and so near the surface that it is simply blasted out and crushed to make it ready for the table. The supply seems to be inexhaustible. In the southeastern part of Nevada a large mountain consists mainly of salt. Many other States also produce this substance, notably, Kansas, West Virginia, Ohio, and California.

The associates are other minerals produced in the same manner, as gypsum, anhydride and various soluble chlorides, bromides and sulphates.

**Uses.**—Halite is the source of all the salt of commerce and of most of the sodium and sodium compounds. It is used to glaze pottery, and in many chemical and metallurgical processes.
THENARDITE.

Composition.—Na₂SO₄, (Na₂O 56.3 per cent.).
General Description.—White or brownish orthorhombic crystals in salt beds, either acute pyramids or short tabular prisms with rough faces. Also massive and as an efflorescence or incrustation in alkali lands.
Before Blowpipe, Etc.—On charcoal fuses to a mass which will stain bright silver. Colors flame yellow. Soluble in water.

GLAUBERITE.

Composition.—Na₂SO₄, CaSO₄, (Na₂O 22.3, CaO 20.1, SO₄ 57.6 per cent.).
General Description.—Tabular monoclinic crystals of pale yellow, green, or red color, occurring in beds of rock salt, also in lamellar masses. On long exposure it absorbs moisture and falls to powder.
Physical Characters.—Translucent. Lustre, vitreous. Color, colorless, yellow, gray or red. Streak, white. H., 2.5 to 3. Sp. gr., 2.7 to 2.8. Taste, bitter and slightly salt.
Before Blowpipe, Etc.—On charcoal decompounds, whitens, colors flame yellow, fuses to a bead, clear hot, opaque cold, which when moistened will stain bright silver. Partially soluble in water, falling to powder.

MIRABILITE.—Glauber Salt.

Composition.—Na₂SO₄ · 10H₂O, (Na₂O 19.3, SO₄ 21.8, H₂O 55.9 per cent.).
General Description.—Translucent, white, fibrous crusts or monoclinic crystals, closely resembling those of pyroxene in form and angle. On exposure loses water and falls to powder.
Before Blowpipe, Etc.—On charcoal fuses, colors the flame yellow and leaves a mass which will stain bright silver. In closed tube yields much water. Easily soluble in water.

SODA NITRE.—Chili Saltpetre.

Composition.—NaNO₃, (Na₂O 36.5, N₂O₅ 63.5 per cent.).
General Description.—Rather sectile granular masses or crusts of white color, occurring in enormous beds and as an efflorescence. Rarely found as rhombohedral crystals of the forms of calcite. On exposure crumbles to powder.

Physical Characters. H., 1.5 to 2. Sp. gr., 2.24 to 2.29. Transparent.
Lustre, vitreous. Tenacity, brittle.
Streak, white.
Color, colorless, white or yellowish. Taste, cooling and salty.

Before Blowpipe, Etc.—On charcoal defflagrates less violently
than nitre and becomes liquid. Colors the flame yellow. Very
easily soluble in water.

Remarks.—It is associated with salt, gypsum, and many soluble salts. There is
only one producing locality, the celebrated nitrate fields of northern Chili. These fields,
however, form one of the greatest sources of wealth to that nation. Smaller deposits
exist in Nevada, New Mexico, and California. Large deposits are reported in the
United States of Colombia.

Uses.—It is used in manufacture of nitre and nitric acid in large
amounts, and also in fertilizers. It frequently contains sodium
iodate and is the chief source of the iodine of commerce.

Trona.—Uraro.

Composition.—Na₂CO₃·NaHCO₃·2H₂O, (Na₂O 41.2, CO₂ 38.9, H₂O 19.9.).

General Description.—Beds and thin crusts of white glimmering material, often
fibrous and occasionally in monoclinic crystals. It is not altered in dry air.

Physical Characters.—Translucent. Lustre, vitreous, glimmering. Color, white,

Before Blowpipe, Etc.—Fuses easily, coloring flame yellow. In closed tube
yields water and carbon dioxide. Easily soluble in water. Effervesces vigorously
in cold dilute acids.

The Ammonium Minerals.

The minerals described are: Chloride, Sal Ammoniac; Sul-
phate, Mascagnite.

The hypothetical compound radical ammonium, has never been
separated from its compounds. Its occurrence in nature is rare,
and its minerals while of great theoretical interest do not occur in
commercial quantities. Its compounds, many of which are of
great importance in the arts, are obtained by the dry distillation
of organic matter, and notably of bituminous coal in the process
of gas manufacture, from coke ovens, from the dry distillation of
bones and from the gases of blast furnaces using coal as fuel.

SAL AMMONIAC.

Composition.—NH₄Cl, (NH₄ 33.7, Cl 66.3 per cent.).

Physical Characters.—Transparent to translucent. Lustre, vitreous. Color,
colorless, white, yellowish. Streak, white. H., 1.5 to 2. Sp. gr., 1.53. Taste,
pungent, salt. Cleavage, parallel to octahedron.

Before Blowpipe, Etc.—Sublimes, without fusion, a white fumes. With soda
or quicklime, gives odor of ammonia. Easily soluble in water.

Remarks.—Occurs near volcanoes, burning coal-beds and in guano deposits.
Artificially, it is a by-product from gas-works.
MASCAGNITE.

Composition.—\((\text{NH}_4)_2\text{SO}_4\), \((\text{NH}_4)_2\text{O}~39.4, \text{SO}_4~60.6\) per cent.

General Description.—Yellowish, mealy incrustations on lava or in guano. Rarely in orthorhombic crystals.

Physical Characters.—Translucent. Lustre, dull or vitreous. Color, lemon-yellow, yellowish or gray. Streak, white. H, 2 to 2.5. Sp. gr., 1.76 to 1.77. Taste, pungent and bitter.

Before Blowpipe, etc.—Sublimes without fusion. With soda or quicklime, yields odor of ammonia. Easily soluble in water.

Remarks.—Occurs on lava or guano or near burning coal-beds. It is artificially made from the ammoniacal liquors of gas-works, coke-ovens, and blast furnaces and to a less extent is a by product from the manufacture of boric acid in Tuscany,
CHAPTER XXVII.

BARIUM AND STRONTIUM MINERALS.

THE BARIUM MINERALS.

The minerals described are: Sulphate, Barite; Carbonates, Witherite, Barytocalcite, and the metal occurs also in a few silicates.

In the elementary state barium is unimportant. It may be prepared by the electrolysis of its chloride. The only important mineral compound is the sulphate, which is used as an adulterant in paint. The mineral is crushed coarsely, treated with sulphuric acid to remove impurities, washed, pulverized and either mixed with white lead or used for giving weight and glaze to paper. Nearly 30,000 tons were mined in this country in 1892. The carbonate is used in sugar refining.

BARITE.—Heavy Spar.

Composition.—BaSO₄. (BaO 65.7, SO₃ 34.3 per cent.), sometimes with some strontia, silica, clay, etc.

General Description.—A heavy white or light-colored mineral, vitreous in lustre. It occurs in orthorhombic crystals, which are frequently united by their broader sides in crested divergent groups, and varying insensibly from this to masses made up of curved or straight lamellæ and cleavable into rhombic plates. It occurs also granular, fibrous, earthy, stalactitic and nodular.

**Fig. 243.**

1, 0 and \( \frac{3}{4} - 1 \).

**Fig. 245.**

1 and 0.

**Fig. 244.**

\( \frac{3}{4} - 1, 1 - b \) and 0.
DESRIPTIVE MINERALOGY.

CRYSTALLIZATION.—Orthorhombic, \( a : b : c = 0.815 : 1 : 1.314 \).
\( I \wedge I = 101^\circ 37\frac{1}{2}^\prime; O \wedge i - t = 127^\circ 17^\prime; O \wedge \frac{1}{3} - t = 141^\circ 8\frac{1}{2}^\prime. \)
Usually tabular or prismatic. Often united.

Physical Characters. H., 2.5 to 3.5. Sp. gr., 4.3 to 4.6.
Lustre, vitreous and pearly. Transparent to opaque.
Streak, white. Tenacity, brittle.
Color, white or light shades of yellow, brown, red or blue.
Cleavage, basal and prismatic (101° 37′ being prism angle).

Before Blowpipe, Etc.—In forceps, decrepitates and fuses;
coloring the flame yellowish-green and leaving an alkaline residue. With soda, on charcoal, gives sulphur reaction. Insoluble in acids.

Similar Species.—Distinguished among non-metallic minerals by its high specific gravity, insolubility and green flame.

Remarks.—Usually found with metallic ores, especially of lead, copper, iron, silver, manganese and cobalt. The important American localities producing barite are in the States of Missouri and Virginia. Tennessee, Connecticut, Kentucky and Illinois also have extensive deposits. Some barite is also imported from abroad, Germany and Hungary both having important mines.

Uses.—The white variety is ground and used as an adulterant of white lead and for weighting paper. Colored varieties are sometimes used in ornamental slabs, vases, etc.

WITHERITE.

Composition.—\( \text{BaCO}_3 \) (BaO 77.7, CO₂ 22.3 per cent).

General Description.—Heavy white or gray translucent masses of vitreous lustre, sometimes with cavities of indistinct crystals or of globular or botryoidal groups. Also granular, columnar and in six-sided crystals resembling quartz.

Fig. 246. Fig. 247.

Crystallization.—Orthorhombic. \( a : b : c = 0.693 : 1 : 0.730. \)
\( I \wedge I = 117^\circ 48^\prime. \) Crystals complex, repeated twins, with usually deep, horizontal striations on the faces.
BARJUM AND STRONTIUM MINERALS.


Before Blowpipe, Etc.—Fuses rather easily, coloring flame yellowish-green and becoming alkaline.  Soluble in dilute hydrochloric acid, with effervescence, and less rapidly soluble in strong acid.

Similar Species.—Distinguished by its weight, effervescence with acids and green flame.

Remarks.—Occurs in veins with lead ores or with ores of silver or barite, and is probably deposited from solution in water containing carbonic acid.  Witherite is not mined in the United States, although small deposits occur near Lexington, Ky., and on the north shore of Lake Superior.  The most productive mines are at Fallowfield in England.

Uses.—As an adulterant of white lead and in refining beet-sugar molasses.

BARYTCALCITE.

Composition.—BaCa(CO₃)₂, (BaO 54.5, CaO 18.9, CO₂ 29.6 per cent.), with traces of manganese.

General Description.—Occurs massive and in attached monoclinic crystals, usually of a yellowish-white color.


Before Blowpipe, Etc.—Fuses with difficulty to a bluish-green mass; colors the flame yellowish-green.  Soluble in dilute acids, with effervescence.

THE STRONTIUM MINERALS.

The minerals described are: Sulphate, Celestite; Carbonate, Strontianite.

The strontium minerals are chiefly of use as precipitants of sugar from the molasses residues of the beet sugar industry, and in the manufacture of the nitrate for use in red fire of fireworks.

CELESTITE.

Composition—SrSO₄, (SrO 56.4, SO₄ 43.6 per cent.).

General Description.—A white translucent mineral, often with a faint bluish tinge.  Occurs in tabular to prismatic orthorhombic crystals, fibrous and cleavable masses, and rarely granular.  It is notably heavy, and has a general resemblance to barite.
Crystallization.—Orthorhombic, $a : b : c = 0.779 : 1 : 1.280$. $I \perp I = 104^\circ 10'$. $O \perp I = 128^\circ$. $O \perp \frac{1}{2} I = 140^\circ 35'$.

Physical Characters. H., 3 to 3.5. Sp. gr., 3.05 to 3.07.

Lustre, vitreous or pearly. Transparent, nearly opaque.

Streak, white. Tenacity, brittle.

Color, white colorless, pale blue or reddish.

Cleavage.—Basal and prismatic, yielding rhombic plates in which the rhomb angles are $104^\circ 10'$ and $75^\circ 50'$.

Before Blowpipe, Etc.—Fuses easily to a white pearly glass and colors the flame crimson. Usually decrepitates and becomes alkaline. With soda on charcoal gives sulphur reaction. Insoluble in acids.

Similar Species.—Distinguished from barite by its red flame and from other minerals by its high specific gravity, insolubility and red flame.

Remarks.—Celestite occurs frequently in cavities in limestone, marl or sandstone or with beds of gypsum or in volcanic regions with sulphur, gypsum, etc. The island of Sicily contains the most celebrated deposits of this mineral, and is the chief producing locality. In the United States deposits occur on Strontian and N. Bass Island, Lake Erie, at Bell's Mills, Pa., at Chaumont Bay, Lockport, and other places in western New York. In Kansas, Texas, West Virginia and Tennessee, also at Kingston, Canada.

Uses.—It is a source of strontium nitrate used to make crimson color in fireworks.

STRONTIANITE.

Composition.—SrCO$_3$. (SrO 70.1, CO$_3$ 29.9 per cent.).

General Description.—Usually found as yellowish-white or greenish-white masses made of radiating imperfect needle crystals and spear-shaped crystals, very like those of aragonite. Also
BARIJUM AND STRONTIUM MINERALS.

fibrous or granular and only rarely in distinct orthorhombic crystals, sometimes of considerable size.

Physical Characters.  H., 3 to 3.5  Sp. gr., 3.68 to 3.72.

Lustre, vitreous.  Translucent.
Streak, white.  Tenacity, brittle.
Color, pale yellowish or greenish-white, also green, gray and colorless.

Before Blowpipe, Etc.—In forceps swells, sprouts, colors the flame crimson, fuses on the edges and becoming alkaline. Soluble in cold dilute acids with effervescence.

Similar Species.—Diffs from calcite and aragonite in fusibility, higher specific gravity and purer red flame. The flame and effervescence distinguish it from all other minerals.

Remarks.—Strontianite is found in the United States chiefly in the State of New York, especially at Schoharie, Muscalongs Lake, Chaumont Bay, Theresa and Clinton. Strontianite used in the German beet sugar industry is largely obtained from Westphalia.

Uses.—It is the chief source of the strontium salts used in fireworks, and is also converted into the hydroxide and used to precipitate sugar from molasses as a strontium compound from which crystalline sugar can later be obtained.
CHAPTER XXVIII.
CALCIUM AND MAGNESIUM MINERALS.

THE CALCIUM MINERALS.

The minerals described are: Fluoride; Fluorite; Sulphates, Anhydrite, Gypsum; Phosphate, Apatite; Arsenate, Pharmaco-
lite; Carbonates, Aragonite, Calcite, Dolomite, Ankerite; Tungstate, Scheelite.

The commercially important compounds of calcium are the carbonates, calcite and dolomite; the sulphate, gypsum; the phos-
phate, apatite; and to a more limited extent the fluoride, fluorite; and the tungstate, scheelite.

The limestone and marble industries are of enormous extent and value, the production of limestone exceeding in value even that of granite. In 1889 there was produced in this country:*

Marble, 3,320,213 cubic feet.
Limestone for building, 92,289,896 cubic feet.
Limestone for furnace flux, 3,894,337 tons.
Limestone for burning, 478,082 tons.
Lime in addition to above, 18,474,568 barrels.
Limestone for roads, 46,491,622 cubic feet.
Limestone for other purposes, 27,228,887 cubic feet.

In addition to uses above enumerated must be given lithographic stone and limestone used for hydraulic cements. In 1892† 7,607,-067 barrels of hydraulic cement were produced in the United States.

Something like 250,000 tons of gypsum are mined yearly in this country, of which about one-third is burned to produce plaster-
of-paris, and nearly one-half is simply ground and used as land plaster.

Apatite and phosphate rock are used in enormous quantities for the manufacture of soluble phosphates for fertilizers. Florida and South Carolina produced about 650,000 tons of phosphate rock‡ in

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† Mineral Industry, 1892, p. 54.
‡ Ibid., p. 370.
CALCIUM AND MAGNESIUM MINERALS.

1892. The phosphoric acid is rendered available for the use of plants by treating the rock with sulphuric acid.

Fluorite has an increasing use as a flux in melting iron and other metallurgical operations. It is also used in producing opalescent glass and enamels and in the manufacture of hydro-fluoric acid. In 1892* 9000 tons were mined in Illinois.

FLUORITE.—Fluor Spar.

COMPOSITION.—CaF₂. (Ca 51.1, F 48.9 per cent.).

GENERAL DESCRIPTION.—Usually found in glassy transparent cubes or cleavable masses of some decided yellow, green, purple or violet color. Less frequently granular or fibrous. Massive varieties are often banded in zigzag strips of different colors. The cleavage is very easy, parallel to the octahedron, and therefore polyhedrons, with angles of 70° 31′, and 109° 28′ are easily obtained.

CRYSTALLIZATION.—Isometric. Usually cubes with or without modifying planes. The cube faces are often striated parallel to the edges, giving the appearance of a very flat tetrahedron. Rarely found in octahedrons, sometimes formed by the grouping of small cubes in parallel positions.


Lustre, vitreous. Transparent to nearly opaque.

Streak, white. Tenacity, brittle.

Color, wine-yellow, green, violet, blue, colorless, brown, black.

Cleavage, octahedral.

BEFORE BLOWPIPE, ETC.—In closed tube at a low heat becomes

phosphorescent. In forceps fuses to a white opaque glass and colors the flame red. Soluble in hydrochloric acid. Heated with acid potassium sulphate or sulphuric acid, fumes are set free which corrode glass.

**Similar Species.**—Recognized by cleavage and crystals and by the etching test. When cut it may resemble aqua marine, yellow topaz, etc., but is distinguished by softness.

**Remarks.**—Fluorite may have been deposited from solution in carbonated waters. It is usually found in veins as the gangue of metallic ores, especially lead, silver, copper, and tin. Sometimes found in beds. This mineral is mined in large quantities at Rosiclare, Illinois. Found in smaller amounts in Jefferson and Boulder counties, Colo.; at McComb and other places in western New York. In many localities throughout New England, also in New Jersey, Arizona, Virginia, California and other States.

**Uses.**—It is used as a flux in smelting ores; also in the manufacture of opalescent glass, hydrofluoric acid, enamel for cooking utensils, and the brighter colored varieties are cut into vases, figures or imitation gems. Used in small amounts as a constituent of the bath used in the electrolytic production of aluminium.

**Anhydrite.**

**Composition.**—CaSO₄. (CaO 41.2, SO₃ 58.8 per cent.).

**General Description.**—Granular, marble-like or sugar-like in texture, or as fibrous and lamellar masses of white, gray, bluish or reddish color. Cleavage in three directions at right angles. Rarely in orthorhombic crystals.

**Physical Characters.**

- H., 3 to 3.5.
- Sp. gr., 2.9 to 2.98.
- Lustre, vitreous or pearly.
- Streak, white.
- Color, white, gray, bluish, brick-red. Cleavages at right angles.

**Before Blowpipe, Etc.**—Fuses to a white enamel and colors the flame red. With soda yields a sulphur reaction. Soluble slowly in acids.

**Similar Species.**—Differs from gypsum in being harder and not yielding decided test for water. Does not effervescence in acids like marble. Cleavage pseudo-cubic.

**Remarks.**—Anhydrite occurs with rock salt, limestone, or with gypsum, from which it may have been formed by heat. It changes to gypsum by hydration, often with swelling or efflorescence. The chief American locality is at Hillsboro, New
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Brunswick. Also abundant in Nova Scotia. Found in smaller quantity at Lockport, N. Y., in eastern Pennsylvania and in Tennessee.

Uses.—A siliceous variety is cut and polished for ornamental work. Its tendency to swell prevents its use in building.

GYPSUM.—Selenite, Alabaster.

Composition.—CaSO₄ + 2 H₂O, (CaO 32-3, H₂O 20-9, SO₄ 46-6 per cent.).

General Description.—Soft colorless white or slightly tinted masses, which may be granular or compact, or may be translucent and silky, fibrous or transparent and cleavable into plates and strips. Also in transparent cleavable monoclinic crystals.

Crystallization.—Monoclinic. \( \beta = 80^\circ 42' \), \( \alpha : \beta : \gamma = 0.690 : 1 : 0.412 \). \( I \perp I = 111^\circ 30' \). \( I \perp I = 133^\circ 40' \). \( I \perp I = 143^\circ 48' \). \( O \perp I = 168^\circ 31' \). Usually simple or in arrow head twins or radiating groups.

Physical Characters. H., 1-5 to 2. Sp. gr., 2.31 to 2.33.

Lustre, pearly, silky, vitreous. Transparent to opaque.

Streak, white. Tenacity, brittle, laminae flexible.

Color, white, colorless, gray, red, yellow, brown.

Cleavage easy parallel to clinohumite, orthohumite and positive unit ortho dome. The cleavage fragments are rhombic plates with angles 66° and 114°. Other less prominent cleavages also exist.

Before Blowpipe, Etc.—When heated quickly becomes white and opaque and fuses to an alkaline globule, coloring the flame.
yellowish-red. In closed tube yields water. Soluble in hydrochloric acid. The powdered dehydrated mineral when mixed with water will form a compact mass. Gives sulphur reaction.

**Varieties.**

* Selenite.—Crystals or transparent cleavable masses.
* Satin Spar.—Fine translucent fibrous varieties with sheen of silk.
* Alabaster.—Compact and fine grained, suitable for carving.
* Rock Gypsum.—Scaly, granular or dull colored and compact.

**Similar Species.**—Talc, brucite, mica, calcite, heulandite, stilbite. It is softer than all but talc, lacks the greasy feeling of talc and is further characterized by quiet solubility, cleavages and calcium flame.

**Remarks**—Gypsum occurs in large beds with limestones, marls, and clays, and in volcanic regions with sulphur. It is frequently formed by the action of the sulphuric acid from decomposing sulphides, upon calcarous minerals. It is also formed by the dehydration of anhydrite, by the evaporation of lakes and seas and by the action, in volcanic regions, of sulphurous vapors on limestone.

The largest producing locality in the United States is in the region of Alabaster, Michigan. Other producing localities are Ottawa county, Ohio, Smith and Washington counties, Virginia, Webster county, Iowa, and many places in central and western New York. Deposits of gypsum in quantity are also known at Scottsboro, Ala., Calcasieu, La., Rayston’s Bluff, Ark. Also in Texas, Colorado, Kansas, Montana, Utah and most of the other States and Territories. Large quantities are annually imported from New Brunswick and Nova Scotia. Celebrated deposits also occur in Spain and Sicily.

**Uses.**—When burned and ground it is called plaster-of-Paris. In this state if mixed with water, it becomes hard and sets, is used for the production of casts, moulds, cements, washes and the hard finish on inside walls of houses.

Land plaster is ground gypsum, and is used on soils. Minor uses are: Satin spar for cheap jewelry, selenite in optical work and alabaster in carving.

**APATITE.**—Asparagus Stone. Phosphate Rock.

**Composition.**—Ca₅(Cl,F)(PO₄)₃.

**General Description.**—Large and small hexagonal prisms, usually of green or red color, but sometimes violet, white or yellow. Also in compact varieties which are commonly dull-gray or white, rock-like masses or nodules not unlike common limestone.
Crystallization.—Hexagonal. $c = 0.733$. $a \wedge l = 142^\circ 16'$. $O \wedge l = 139^\circ 42'$. Usually prismatic. Sometimes also tabular and pyramidal.


Before Blowpipe, Etc.—Fuses with difficulty on sharp edges and colors the flame yellowish-red, or, if moistened with concentrated sulphuric acid, colors the flame momentarily bluish-green. Easily soluble in hydrochloric acid.

If to ammonium molybdate in nitric acid solution a few drops of a nitric acid solution of apatite be added, a bright-yellow precipitate will be thrown down on heating. In the chlorine variety silver nitrate will produce a curdy white precipitate in the nitric acid solution.

Varieties.—Certain mineral deposits are essentially of the same composition as crystalline apatite.
Phosphorite.—Concretionary masses, with fibrous or scaly structure. $H = 4.5$.

Ostronite.—Compact, earthy, impure material, of white or gray color. $H$, 1 to 2.

Phosphate Rock or Nodules.—The former in place of original deposition, the latter chiefly in river beds. Massive, gray, white, brown or black. $H$, 2 to 5.

Guano.—Granular to sponge-like and compact material, of gray to brown color. Sometimes with lamellar structure.

Similar Species.—Green crystals, differ from beryl in lustre, hardness and solubility. Red crystals differ from willemite in not gelatinizing or yielding zinc.

Remarks.—Occurs in granites, limestones, tin veins, beds of iron ore, etc., frequently as inclusions in other minerals, and is of both igneous and secondary origin. The most productive American localities for the pure mineral are in Ontario and Quebec, Canada; Ottawa County, Quebec, having several productive mines. Other deposits, but smaller in extent, occur at Bolton, Mass.; Crown Point, N. Y., and Hardstown, N. J. Immense deposits of the phosphate rock, so largely used in fertilizers, occur in eastern South Carolina and in Florida; in the latter case underlying a wide belt of country and extending through several counties in the central part of the State.

Uses.—The massive varieties and some crystalline deposits furnish most of the phosphates for fertilizers. It is converted into soluble phosphates by treatment with sulphuric acid, in which state it is available as plant food. Apatite is also used in the manufacture of phosphorus.

Pharmacolite.

Composition.—$\text{CaH}_2\text{AsO}_4\cdot 2\text{H}_2\text{O}$. ($\text{CaO} \ 52.9$, $\text{As}_2\text{O}_3 \ 53.3$, $\text{H}_2\text{O} \ 20.8$ per cent.).

General Description.—White or pink silky fibres or powder, and rarely small monoclinic crystals.

Physical Characters.—Translucent to opaque. Lustre, silky, dull. Color, white or tinged red by erythrite. Streak, white. $H$, 2 to 2.5. Sp. gr., 2.64 to 2.73.

Before Blowpipe, Etc.—Fuses to a white or bluish enamel and colors the flame light blue. On charcoal, yields garlic odor. In closed tube, yields water. Easily soluble in acids.

Remarks.—Occurs with arsenical ores, especially smaltite, arsenopyrite and pyromorphite.

Aragonite.—Flos Ferri.

Composition.—$\text{CaCO}_3$. ($\text{CaO} \ 56.0$, $\text{CO}_2 \ 44.0$ per cent.).

General Description.—This form of calcium carbonate is found in orthorhombic crystals, which are frequently pseudo-
hexagonal from twinning, and as groups of acutely terminated needle crystals, which grade into fine fibres. It also occurs stalactitic, incrusting and in pure white groups of interlacing, coral-like stems. The prevailing tint is white, but it is occasionally violet or pale green.

![Fig. 261. Fig. 292.](image)

**Crystallization.**—Orthorhombic. \( \alpha : \beta : \gamma = 0.622 : 1 : 0.721 \).

\( I \times I = 116^\circ 12' \). \( O \times 1 - 7 = 144^\circ 13^{1/2}' \). Frequently twinned by contact of prismatic faces, producing sometimes hexagonal shapes.

**Physical Characters.** H., 3.5 to 4. Sp. gr., 2.93 to 2.95.

Lustre, vitreous. Translucent or transparent.

Streak, white. Tenacity, brittle.

Color, white, violet, yellow, pale green.

Cleavage.—Parallel to brachy pinacoid, prism, and brachy dome.

**Before Blowpipe, Etc.—**Infusible, colors flame red. In closed tube decrepitates, loses weight and falls to pieces. With hydrochloric acid, dissolves with rapid effervescence.

**Similar Species.**—Needle crystals differ from those of natrolite in the terminations. Strontianite and witherite have higher specific gravity and are fusible. Calcite differs in form and cleaves in three directions with equal ease yielding diadral angles of 105° 3', whereas aragonite cleaves: 1. Easily parallel to the brachy pinacoid, yielding plates. 2. Indistinctly parallel to prism, yielding angle of 116° 12'. 3. Very indistinctly parallel to a brachy dome.

**Remarks.** Aragonite is largely deposited from carbonated water solution principally in rock cavities and mineral veins. It is found with gypsum and in beds of serpentine and with iron ores as fos ferr, the cornolidal variety.

It can be changed into calcite by heat, and the difference between it and calcite is supposed to be that the calcite is deposited from cold solution and aragonite from hot
solution. It is not of common occurrence, but is found at Sulphur Creek and Colton, California, also in Solano County, Cal.; in Lockport and Edenville, N. Y.; in Madison County, N. Y.; Haddam, Ct.; Warsaw, Ill., etc.

**CALCITE.—Calc spar, Limestone, Marble, Iceland Spar, Etc.**

**Composition.**—\( \text{CaCO}_3 \), (CaO 56.0, CO\(_2\) 44.0 per cent).

**General Description.**—Yellowish white to white or colorless, more or less transparent crystals, usually rhombohedrons or scalenohedrons. Massive with easy cleavage or coarse to fine-grained, stalactitic, and occasionally fibrous, lamellar or pulverulent.

**Crystallization.**—Hexagonal. \( c = 0.834 \). \( R \cap R = 105^\circ 57' \).

\( -2 \cap -2 = 78^\circ 51' \). \( -\frac{1}{2} \cap -\frac{1}{2} = 134^\circ 57' \). \( 4 \cap 4 = 65^\circ 50' \).

Scalenohedra, \* \( 3 - \frac{3}{3} \cap 3 - \frac{3}{3} \), \( X = 104^\circ 38' \), \( Y = 144^\circ 24' \), \( Z = 132^\circ 56' \). Occurs in several hundred forms, of which these are commonest. Basal plane often rough. Frequently twinned, the base and rhombohedron \(-\frac{1}{2}\) being the usual twinning planes.

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* See page 69.
CALCIUM AND MAGNESIUM MINERALS.

Lustre, vitreous to dull.  Transparent to opaque.
Streak, white.  Tenacity, brittle.
Color, yellow, white, colorless, or pale shades of red, green, blue, etc.
Cleavage, parallel to the rhombohedron, therefore yielding dihedral angles of 105° 5′ and 74° 55′.

Before Blowpipe, Etc.—Infusible.  Becomes opaque and alkaline and colors flame red.  Soluble readily in cold dilute acids, with vigorous effervescence.

Varieties.—The following are the most prominent varieties:
Iceland Spar.—Colorless, transparent crystals and masses.
Dog Tooth Spar.—Scalenohedral crystals, supposed to resemble canine teeth in shape.
Fontainebleau Sandstone.—Crystals containing up to 60 per cent. of sand.
Satin Spar.—Fibrous, with silky lustre.
Argentine.—Foliated, pearly masses.
Marble.—Coarse to fine granular masses, crystalline.
Limestone.—Dull, compact material, not composed of crystalline grains.
Chalk.—Soft, dull-white, earthy masses.
Calcareous Marl.—Soft, earthy and intermixed with clay.
Stalactites.—Icicle-like cylinders and cones, formed by partial evaporation of dripping water.
Stalagmite.—The material forming under the drip on the floor of the cavern.
Travertine, Onyx.—Deposits from springs or rivers, in banded layers.

Other names, such as Hydraulic Limestone, Lithographic Limestone, Rock Meal, Plumbocalcite, Sparrita, etc., are of minor importance, and are chiefly based on color, use, locality, etc., and do not generally indicate important structural or chemical differences.

Similar Species.—The distinctions from aragonite have been given under that mineral.  Dolomite differs in slow partial solution in cold dilute acids, instead of rapid and complete effervescence.

Remarks.—Calcite is very widely distributed.  It is derived, in great part, from
fossil remains, shells, corals, etc., but also, in considerable part, by the decomposition of calcium silicates by hot carbonated waters, and possibly, in a degree, by the action of heat on aragonite. The carbonated waters deposit aragonite or calcite, according to the temperature of the solution. In the production of marble Vermont is far ahead of any other State, and the centre of the industry is situated at Rutland. Georgia and Tennessee also produce large quantities, especially of a beautiful, coarse, granular structure. Alabama, California, New York, Pennsylvania and Massachusetts also have large deposits, some of which are worked. Crystallized calcite occurs throughout the world in all limestone regions. In the United States these localities are innumerable and transparent varieties are common. Bossie, N. Y.; Warren, Ill., and Llano and Lampasas Counties, Texas, may be especially noteworthy. Fine stalactites occur in the caves of Virginia, Kentucky and New York. Deposits from thermal springs are common in the Yellowstone Park, and similar deposits occurring in San Luis Obispo County, California, are cut and polished, yielding slabs of onyx marble of extreme beauty.

Uses.—Limestone and marble are important building stones, and the latter is also used for statuary, ornaments, interior work, tombstones, etc. Limestone, again, is used for making quicklime and as a flux in smelting siliceous ore, in glass-making, in many chemical processes, in hydraulic cement, as a lithographic stone etc. Iceland spar is used in optical apparatus for polarizing light.

DOLOMITE.—Pearl Spar, Magnesian Limestone.

Composition.—(Ca.Mg)CO₃ or CaMg(CO₃)₂. (CaO 30.4, MgO 21.7, CO₂ 47.8 per cent.), but the proportion of magnesium to calcium varies, and iron and manganese also occur.

General Description.—White, massive marble, with coarse to fine grain. Gray, white and bluish, compact limestone and small, white, pink or yellow, rhombohedral crystals with curved edges.

Crystallization.—Hexagonal. \( c = 0.832 \), \( a \times R = 106° 15' \). Usually in rhombohedrons, and frequently the form is built of small individuals in only approximately parallel position, so that the resultant composite form seems to have curved faces.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.8 to 2.9.

Lustre, vitreous or pearly. Translucent to opaque.

Streak, white. Tenacity, brittle.

Color, white, pink, greenish-gray, brown or black.

Cleavage. Rhombohedral. Angles, 106° 15' and 73° 45'.
CALCIUM AND MAGNESIUM MINERALS.

BEFORE BLOWPIPE, ETC.—Infusible, colors flame yellowish-red and becomes alkaline. With cobalt solution, becomes pink. Fragments are very slightly attacked by cold dilute acid. The powdered mineral is sometimes attacked vigorously by cold dilute acid, but sometimes is not. On heating there is a vigorous effervescence.

SIMILAR SPECIES.—Differs from calcite in effervescence, color with cobalt solution and frequent curvature of rhombohedral planes. It differs from siderite and ankerite in not becoming magnetic on heating.

REMARKS.—Dolomite is frequently the chief constituent of whole mountain ranges and may have formed: 1. From a solution of the mixed carbonates of calcium and magnesium in carbonated waters. 2. From calcite by infiltration of waters containing magnesium carbonate. 3. By solution of part of calcium carbonate of a magnesian limestone in preference to the less soluble magnesian carbonate, thus increasing the proportion of the latter. Many of the marbles of Vermont, Georgia and Tennessee contain magnesium, and frequently enough to be classed under dolomite. Crystals are common in many localities, especially in the zinc region of Missouri, in many places in the limestone region of Western New York, in the gorge at Niagara, at Glen Falls and Brewster, N. Y., at Stony Point, N. C.; Roxbury, Vt., and elsewhere.

USES.—The same as for calcite. The dolomite limestone and marble are less soluble than the calcite varieties, and are to that extent, preferable for construction. It is also used for making epsom salts.

ANKERITE.

COMPOSITION.—(Ca,Mg,Fe)CO₃ sometimes containing manganese.

GENERAL DESCRIPTION.—Gray to brown rhombohedral crystals like those of siderite, also cleavable and granular masses and compact.

PHYSICAL CHARACTER.—Translucent to opaque. Luster, vitreous to pearly. Color, gray, yellow or brown. Streaks, white or nearly so. H., 3.5 to 4. Sp. gr., 2.95 to 3.1. Brittle. Cleavage, rhombohedral. \( R \times R = 106° 12' \).

BEFORE BLOWPIPE, ETC.—Infusible, darkens and becomes magnetic. Soluble in acids with effervescence.

SCHEELITE.

COMPOSITION.—CaWO₄. (CaO 19.4, WO₃ 80.6 per cent.), sometimes with replacement by molybdenum.

GENERAL DESCRIPTION.—Heavy brownish white or white masses and square pyramids. Also drusy crusts of yellow or brown crystals.
Crystallography.—Tetragonal. \( c = 1.536 \). \( \theta \wedge 1 = 114^\circ 43' \). \( \theta \wedge 1-2 = 123^\circ 4' \). Second order pyramid most prominent, basal plane usually rough.

Physical Characters. H., 4.5 to 5. Sp. gr., 5.4 to 6.1.

Lustre, adamantine. Transparent to opaque.

Streak, white. Tenacity, brittle.

Color, pale yellow, gray, brown, white or green.

Cleavage, distinct parallel to first order pyramid, indistinct parallel to second order pyramid.

Before Blowpipe, Etc.—Fusible with difficulty on sharp edges. In salt of phosphorus forms a clear bead which in the reducing flame becomes deep blue, and if the bead is powdered and dissolved in dilute hydrochloric acid it yields a deep blue solution, especially on addition of metallic tin. Scheelite is soluble in hydrochloric or nitric acid, leaving a yellow residue.

Similar Species.—Distinguished among non-metallic minerals by its weight and behavior in salt of phosphorus.

Remarks.—Scheelite occurs in crystalline rocks, and usually with cassiterite, wolframite, topaz, fluorite, molybdenite, and in quartz. It changes into wolframite, and also forms from wolframite. The mineral is by no means common, but is found at Monroe and Trumbull, Conn.; Flowe mine, S. C., in Nevada, Idaho, and Colorado. Also in large crystals at Malta, Quebec.

Uses.—Scheelite is used as a source of tungsten, which has important properties when used in the manufacture of ferro-tungsten and tungsten steel. Other applications are in the manufacture of
tungstic acid, from which a yellow pigment is obtained, and tungstate of soda, which renders fabrics almost incombustible.

THE MAGNESIUM MINERALS.

The minerals described are: Hydroxide, Brucite; Sulphate, Epsomite; Carbonate, Magnesite; Aluminate, Spinel. Magnesia is also the principal base in several important silicates and occurs in many others, and in the carbonate dolomite.

The carbonate, magnesite, is not rare, over 30,000 tons having been produced in 1892, and the hydroxide and sulphate also occur in considerable quantities.

Magnesite is used as a lining and flux in the basic processes for steel, and is the favorite source of carbon dioxide in seltzer and soda water manufacture, as the treatment with sulphuric acid leaves a soluble residue of crude epsom salts.

The metal magnesium prepared by fusing together the double chloride of potassium and magnesium, fluorite and metallic sodium, and purified by distillation out of contact with air is now made in some quantity in the shape of ribbon and as coarse grains. It is used in flash lights to produce a vivid light for photographing in absence of sunlight, and as a reducing agent in the preparation of some of the rarer elements.

BRUCITE.

COMPOSITION.—Mg(OH)₂, (MgO 69.0, H₂O 31.0 per cent).

GENERAL DESCRIPTION.—White or gray translucent foliated masses with pearly or wax-like lustre. Also fibrous and in tabular hexagonal crystals.

Physical Characters. H., 2.5. Sp. gr., 2.38 to 2.4.

Lustre, pearly or wax-like. Translucent.

Streak, white. Tenacity, sectile and flexible.

Color, white, bluish, greenish. Cleavage, basal.

Before Blowpipe, Etc.—Infusible, becomes alkaline, and with cobalt solution becomes pink. Yields water in closed tube. Soluble in hydrochloric acid.

Similar Species.—Harder and more soluble than foliated talc or gypsum, and quite infusible.
DESCRIPTION MINERALOGY.

REMARKS.—Brucite is usually found in serpentine or limestone with magnesite or hydromagnesite. On exposure it becomes coated with a white powder, and is sometimes changed to serpentine or hydromagnesite. Its most prominent American locality is at Texas, Pa., also at Fritz Island in the same State; at Brewster, N. Y., and Hoboken, N. J.

EPSOMITE.—Epsom Salt.

COMPOSITION.—\( \text{MgSO}_4 + 7 \text{H}_2\text{O} \) \( (\text{MgO} 16\% , \text{SO}_4 32\% , \text{H}_2\text{O} 51\% \text{ per cent.}) \).

GENERAL DESCRIPTION.—A delicate white fibrous efflorescence or earthy white crust with a characteristic bitter taste. Also common in solution in mineral water. Occasionally in orthorhombic needle crystals.

PHYSICAL CHARACTERS.—Transparent or translucent. Lustre, vitreous or dull. Color and streak, white. H., 2 to 2.5. Sp. gr., 1.75. Taste, bitter and salty.

BEFORE BLOWPIPE, ETC.—Fuses at first, but becomes fusible after the water of crystallization has been driven off. With cobalt solution becomes pink. In closed tube yields acid water. Easily soluble in water.

REMARKS.—Epsomite is formed by action of the sulphuric acid of decomposing sulphides, upon such magnesian minerals as serpentine and magnesite.

MAGNESITE.

COMPOSITION.—\( \text{MgCO}_3 \) \( (\text{MgO} 47\% , \text{CO}_2 52\% \text{ per cent.}) \), with sometimes iron or manganese replacing part of the magnesium.

GENERAL DESCRIPTION.—White chalk-like lumps and veins in serpentine. Rarely fibrous or in rhombohedral crystals closely agreeing with dolomite in form and angle. \( \theta = 0.811 \). \( R \times R = 107^\circ 24' \).

Physical Characters. H., 3.5 to 4.5. Sp. gr., 3 to 3.12.

LUSTRE, dull, vitreous or silky, OPAQUE to translucent.

STREAK, white. TENACITY, brittle.

COLOR, white, yellow, brown. FRACTURE, conchoidal.

BEFORE BLOWPIPE, ETC.—Infusible, becomes alkaline. With cobalt solution becomes pink. Soluble with effervescence in warm hydrochloric acid, but does not effervesce in cold dilute acid. No decided precipitate is produced by addition of sulphuric acid, whereas heavy precipitates form with solutions of calcite and dolomite.

SIMILAR SPECIES.—Differs from dolomite and calcite in not yielding the calcium flame.

REMARKS.—Usually formed with serpentine by action of carbonated waters on eruptive magnesian rocks, such as olivine (chrysotile), or when the decomposition is carried farther the results are magnesite and quartz. As the former is the more common decomposition, magnesite usually occurs with serpentine and also with other magnesian minerals, such as talc, brucite, dolomite, etc.
CALCIUM AND MAGNESIUM MINERALS.

Found at Bolton and Sutton, Province of Quebec, at Texas, Pa., Barre Hill, Md., and at several localities in California and Massachusetts.

Uses.—It is used in the lining of converters in the basic process for steel, and for lining kilns in the manufacture of sulphuric acid and for other purposes where a non-conducting and refractory material is required. It also is used in obtaining carbon dioxide for soda water, the residue being converted into epsom salts. Epsom salts, magnesia, and magnesia alba are also made from magnesite.

SPINEL.—Balas Ruby.

Composition.—MgAlO₃, (MgO 28.2, Al₂O₃ 71.8 per cent.). Iron, manganese and chromium are sometimes found.

General Description.—Usually in octahedral, simple or twinned crystals, which cannot be scratched by steel or quartz and vary in color according to composition. Also in rolled pebbles and loose crystals.

Physical Characters. H., 8. Sp. gr., 3.5 to 4.5.
Lustre, vitreous. Transparent to opaque.
Streak, white. Tenacity, brittle.
Color, red, green, blue, black, brown, yellow.
Cleavage, octahedral.

Before Blowpipe, Etc.—Infusible, often changing color, the red variety becomes green, then nearly colorless, finally red. In powder is turned blue by cobalt solution. Insoluble in hydrochloric or nitric acid, but somewhat soluble in sulphuric acid.

Varieties.—
Balas Ruby or Ruby Spinel (Magnesia Spinel).—Clear red or reddish, often transparent. Sp. gr., 3.5 to 3.5.
Ceylonite (Iron Magnesia Spinel).—Dark-green, brown, black, usually opaque.

Picotite (Chrome Spinel).—Yellowish to greenish-brown, translucent.

Similar species.—Characterized by octahedral crystals and by hardness.

Remarks.—Occurs in limestone, serpentine, gneiss, etc., associated with corundum, chondrodite, brucite, etc., and sometimes changed to talc, muscovite or serpentine. Gem specimens have been obtained at Hamburg, N. J.; San Luis Obispo, Cal., and Orange County, N. Y. The crystals also occur in many localities in North Carolina, Massachusetts and near the New York and New Jersey line. Especially abundant in Ceylon and Burmah.

Uses.—Transparent varieties are used as gems.
CHAPTER XXIX.

ALUMINUM MINERALS.

The minerals described are: Fluorite, Cryolite; Oxides and Hydroxides, Corundum, Bauxite, Diaspore, Gibbsite; Sulphates, Alunogen, Aluminit, Alunite. Phosphates, Turquoise, Wavellite, Lazulite. Aluminum is also prominent in many silicates.

The minerals of aluminum, aside from the clays, have important commercial applications, which may be roughly classified as: I. Ores of Aluminum. II. Abrasive materials. III. Gems.

Ores of Aluminum.

Metallic aluminum, formerly prepared only by reduction of the chloride by the metal sodium, is now made in relatively large quantities by electrolysis. In 1892 there was produced in this country nearly 150 tons of the metal, which sold as low as 50 cents per pound.

Only bauxite and gibbsite are at present used as ores, bauxite being preferred simply on account of cheapness, as gibbsite is not found in quantity, whereas over 11,000 tons of bauxite were mined in the U. S. in 1892. Corundum has too high a value as abrasive material, and the abundant clays and silicates contain a much smaller percentage of aluminum, and before using, need to be decomposed and freed from silica. It is stated that kaolin is being used at Trotha, Germany.

The ore is heated with sodium carbonate only to low redness, in order to produce sodium aluminate without rendering the silica, or iron soluble. On dissolving out the sodium aluminate with water and passing carbon dioxide through the solution, aluminum hydroxide is formed, which yields the oxide when heated. By this mode of procedure most of the iron and silicon is separated, which would otherwise be reduced by the current and alloyed with the aluminum.

The electric processes may be divided into two groups, those which produce aluminum alloys and those which produce pure
aluminum. In the first group the oxide is reduced by passing the current from a dynamo through a mixture of aluminum oxide, carbon and some metal, usually copper. The oxide is reduced, the aluminum unites at once with the metal present, and is protected by it from oxidation, which would otherwise again take place at the high heat to which it is subjected. The alloys prepared in this way are extensively used, especially the alloy with copper, which is the basis of aluminum bronze, containing as much as 10 per cent of aluminum. It is extremely tough, and is extensively applied in machinery, especially mine machinery, engine castings, etc.

For the production of the pure metal the oxide or sulphide may be decomposed by electrolysis in some bath, which protects the metal from contact with oxygen. The Hall process consists in the electrolysis of the oxide in a fused bath of cryolite or the mixed fluorides of sodium and aluminum. The process is carried on in iron tanks, the bottom and sides of which are thickly lined with carbon. The tanks serve as the negative electrodes and are filled with the cryolite flux, to which a little fluorite is added. The positive electrodes are carbon cylinders, which dip into the electrolyte.

The cylinders are first lowered until they touch the bottom of the tank, and the ground cryolite is melted as a result of the poor contact. The cylinders are then raised, and the current thenceforth passes through the melted liquid. The alumina is now added, and is immediately dissolved by the flux and decomposed by the current. The metal settles at the bottom of the bath, while the oxygen combines with the carbon of the anode and escapes as carbon dioxide. The metal is dipped out by cast-iron ladles, alumina is again added from time to time, and thus the operation is continuous.

The aluminum thus produced is a white metal, with a bluish tint—a good conductor of heat and electricity, malleable and ductile and not easily tarnished. It is used in the manufacture of scientific apparatus where lightness, strength and non-corrosiveness are desirable, also, to a small extent, in making cooking utensils; and in Germany, for making army equipments and shells for cartridges. It has a considerable use in the manufacture of fancy articles and in ornamental work, and in steel, copper and zinc castings a fraction of 1 per cent. of aluminum is added to the
melted metal to prevent blow-holes. Aluminum is especially
sonorous and is now used in the Austrian army for drums, and
the substitution of aluminum for brass in the other band instru-
ments is being tried.

**Cryolite.** To the amount of about 10,000 tons per year is imported
into the United States from Greenland, its only important locality,
and is used in making sodium carbonate, alum and calcium fluoride.
A small amount of cryolite is used as a flux in the manufacture of
aluminum as above described.

**Abrasive Materials.**
Corundum to the amount of about 2000 tons per year is mined
in the South, and a somewhat larger amount of emery is imported
for use in grinding and polishing.

**Gems.**
Rubies and sapphires, which are varieties of corundum, turquoise
and chrysoberyl are all found of sufficient beauty to be classed as
gems or precious stones. In this country sapphires have been
found in Montana, but their status in the gem market is not yet
very well defined. A considerable amount of turquoise of a mark-
etable grade has been mined in New Mexico.

**Cryolite.—Eisstein.**

**Composition.**—AlNa₃F₆. (Al 12.8, Na 32.8, F 54.4 per cent.).

**General Description.**—Soft, translucent, snow-white to color-
less masses, resembling spermaceti or white wax in appearance.
Occasionally with groups of triclinic crystals so slightly inclined
as to closely approach cubes and cubic octahedrons in angle and
form.

**Physical Characters.** H., 2.5. Sp. gr., 2.95 to 3.
Lustre, vitreous or wax-like. Translucent or transparent.
Streak, white. Tenacity, brittle.
Color.—Colorless, white, brown.
Cleavage.—Basal and prismatic, angles near 90°.

**Before Blowpipe, etc.**—Fuses very easily, with strong yellow
coloration of the flame, to a clear globule, opaque when cold.
With cobalt solution, becomes deep blue. In closed tube, yields
acid fumes, which attack and etch the glass. Soluble in acid
without effervescence.
SIMILAR SPECIES.—Characterized by its easy fusibility, and fumes which attack glass.

REMARKS.—Found at Ivigtut, Greenland, as a large bed in a granite vein, and contains, scattered through it, crystals of siderite, quartz, chalcopyrite and galenite. This is the only locality where cryolite is produced in commercial quantities, but here the supply seems inexhaustible. Small amounts have been found at Mlask, Urals, and in the United States at Pike’s Peak, Colorado.

USES.—It is used in the manufacture of sodium carbonate, and aluminum hydroxide, and is made into alum. The by-product, calcium fluoride, is sold to smelters and glass manufacturers. Cryolite is also used as a flux or bath in the manufacture of aluminum.

CORUNDUM.—Sapphire, Ruby, Emery.

COMPOSITION.—Al₂O₃. (Al 52.9, O 47.1 per cent.).

GENERAL DESCRIPTION.—With the exception of the diamond, the hardest of all minerals. Occurs in three great varieties, which are most conveniently described separately.

Sapphire or Ruby.— Transparent to translucent, sometimes in crystals and of fine colors—blues, reds, greens, yellows, etc.

Adamantine Spar or Corundum.— Coarse crystals or masses, with nearly rectangular cleavage, or granular, slightly translucent, and usually in some blue, gray, brown or black color.

Emery.—Opaque, granular corundum, intimately mixed with hematite or magnetite, usually dark-gray or black in color.

FIG. 274. FIG. 275.

CRYSTALLIZATION.—Hexagonal. \( c = 1.353 \). Acute pyramids and truncated, barrel-shaped forms. Often rough and rounded by alteration and attrition.
ALUMINUM MINERALS.

Lustre, vitreous or adamantine. Transparent to opaque.
Streak, white.
Tenacity, brittle to tough.
Color, blue, red, green, yellow, black, brown or white.
Cleavage, rhombohedral, angle of 86° 4′.

Before Blowpipe, Etc.—Infusible and unaltered, alone or with soda, or sometimes improved in color. Becomes blue with cobalt solution at high heat. Insoluble in acids and only slowly soluble in borax or salt of phosphorus.

Remarks.—Occurs in granular limestone, granite, gneiss and other crystalline rocks and in the gravel of river-beds. It is usually associated with chloritic minerals, rarely with quartz, and is frequently found altered, and many alteration products occur, as spinel, feldspar, mica, tourmaline, cyanite, fahlore, etc. The American localities producing corundum or emery are: Rabun County, Ga.; Macon, Clay and Jackson Counties, N. C.; Westchester County, N. Y.; Chester County, Pa., and Chester, Mass. Fair-sized rubies and sapphires have been obtained near Helena, Montana, and at several localities in North Carolina. The finest rubies are obtained from Upper Burma and Ceylon.

Uses.—Sapphire and ruby, when clear and transparent, are valuable gems, the ruby sometimes being more highly valued than the same weight of diamond. The various colors have different names; Blue, sapphire; red, ruby; yellow, oriental topaz; green, oriental emerald; purple, oriental amethyst. Adamantine spar and emery are the most important abrasive materials, and thousands of tons are used in grinding and polishing. Corundum can be used in the electric smelting processes for aluminum, but its price makes this unprofitable.

BAUXITE.

Composition.—Al₂O(OH)₃, with usually part of the Al replaced by Fe.

General Description.—Disseminated, rounded grains, oolitic and sponge-like to clay-like masses. Also fine-grained, compact. Usually white, or, if ferruginous, will be yellow, brown or red.

Physical Characters. H., 1 to 3. Sp. gr., 2.4 to 2.5.
Lustre, dull or earthy. Opaque.
Streak, like color.
Tenacity, brittle.
Color, white, red, yellow, brown or black.

Before Blowpipe, Etc.—Infusible. Becomes deep blue with
cobalt solution, and may become magnetic in reducing flame. In
closed tube yields water at high heat. Soluble with difficulty in
hydrochloric acid.

REMARKS.—Bauxite may have been deposited from solution in hot alkaline waters
or may have resulted from alteration of corundum. It is usually found with clay or
kaolin associated with other aluminum minerals. Large deposits exist at Beaux,
France, Lake Wochein, Carniola, and in Antrim, Ireland. In the United States it is
mined at Linwood, Ga., and Piedmont, Ala. The production at these two places is
extensive, and numerous large deposits occur throughout several counties in this
region near the State boundaries. Immense amounts of the mineral are also found
in Saline and Palaski Counties, Arkansas.

USES.—Is the chief source of aluminum, and is also used in
the linings of basic converters, Siemens-Martin furnaces, etc., and
in the manufacture of alum.

DIASPHERE.

COMPOSITION.—$\text{Al}_2\text{O}_3\cdot\text{H}_2\text{O}$.

GENERAL DESCRIPTION.—Thin, flat, orthorhombic prisms, foliated masses and thin
scales. When pure, it is transparent and white or pinkish in color. When impure, it
is often brown.

PHYSICAL CHARACTER.—Transparent to nearly opaque. Lustre, pearly and vitreous.
Color, gray, white, pink, yellow, brown. Streak, white. H., 6.5 to 7. Sp. gr.,
3.3 to 3.5. Very brittle. Cleaves into plates.

BEFORE BLOWPIPE, ETC.—Infusible. Usually decomposes. With cobalt solution,
becomes deep blue. In closed tube, yields water at high heat. Insoluble in acids.

SIMILAR SPECIES.—Distinguished by its hardness, cleavage and decomposition.

REMARKS.—Occurs with corundum and its associates.

GIBBSITE.

COMPOSITION.—$\text{Al}_2\text{O}_3\cdot\text{H}_2\text{O}$.

GENERAL DESCRIPTION.—A white or nearly white mineral, usually occurring in small stalactites or thin mamillary crusts, with
smooth surface and sometimes fibrous internal structure. Rarely
in small six-sided monoclinic crystals. When breathed upon, it
has a strong clay-like odor.

PHYSICAL CHARACTER.—H., 2.5 to 3.5. Sp. Gr., 2.38.

LUSTRE, faint vitreous. TRANSLUCENT.

STREAK, white. TENACITY, brittle to tough.

COLOR, white, greenish, reddish, yellow. CLEAVAGE, basal.

BEFORE BLOWPIPE, ETC.—Infusible, exfoliates, glows and be-
comes white. With cobalt solution becomes deep blue. In
ALUMINUM MINERALS.

closed tube yields water. Soluble in hydrochloric or sulphuric acid.

Remarks.—If gibbsite could only be found in quantity it would be even more valuable than bauxite for the manufacture of aluminum. No large deposits, however, are known, and the mineral is not mined except when it occurs in comparatively small quantity with the bauxite of Georgia and Alabama. The mineral is found in even smaller quantity at Richmond and Lenox, Mass., and in Dutchess and Orange counties, N. Y. Foreign localities also are rare.

ALUNOGEN.

Composition.—Al[SO₄]₃ + 18 H₂O, (Al₂O₃ 15.3, SO₄ 36.0, H₂O 48.7 per cent.).

General Description.—A delicate fibrous crust of white or yellow color. Sometimes massive. Taste like alum.

Physical Characters.—Translucent. Lustre, vitreous or silky. Color, white yellowish or reddish. Streak, white. H., 1.5 to 2. Sp. gr., 1.6 to 1.8. Taste, like alum.

Before Blowpipe, Etc.—Melts in its own water of crystallization, but becomes infusible. It is colored deep blue by cobalt solution. In closed tube yields much acid water. Easily soluble in water.

Remarks.—Formed by action of sulphuric acid of decomposing sulphides upon aluminous shales. Also formed during volcanic action.

ALUMINITE.

Composition.—Al₂[OH]₂[SO₄]₆ (Al₂O₃ 29.6, SO₄ 23.3, H₂O 47.1 per cent.).

General Description.—Usually found in white rounded or irregular masses of chalk-like texture and peculiar harsh feeling.

Physical Characters.—Opaque. Lustre, dull or earthy. Color and streak, white. H., 1 to 2. Sp. gr., 1.66. Meets to the touch and adheres to the tongue.


Remarks.—Found in clay beds. Expense of transportation alone keeps aluminite from the list of aluminium ores. Quite extensive deposits occur near Silver City, New Mexico, also near Trinidad, Colo., and in others of the Western States.

ALUNITE.—Alum Stone.

Composition.—K[AlO₄]₃[SO₄]₂ + 3 H₂O, (Al₂O₃ 37.0, K₂O 11.4, SO₄ 38.6, H₂O 13 per cent.).

General Description.—Occurs fibrous and in tabular to nearly cubic rhombohedral crystals, or so intermixed with a siliceous material as to form a hard granular and nearly white rock.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.58 to 2.75.

Lustre, vitreous. Transparent to nearly opaque.

Streak, white. Tenacity, brittle.

Color, white, grayish or reddish.
Before Blowpipe, Etc.—Infusible and decrepitates. With cobalt solution becomes deep blue. With soda infusible, but the mass will stain silver. In closed tube yields water at a red heat. Imperfectly soluble in hydrochloric or sulphuric acid.

**Remarks.**—Formed by action of sulphur dioxide and steam upon anhydrite or allied rocks. Occurs at Tolfia, Italy, in Hungary and in Rosita Hills, Colorado.

**Uses.**—By roasting and lixiviation with water, alum is obtained, and the Tolfia rock is so treated for manufacture of Roman alum. The rock is also used for millstones.

**Turquoise.**

**Composition.**—Al₆(OH)₁₈PO₄·H₂O and always contains some copper which gives it color.

**General Description.**—Sky blue to green opaque nodules or veins, also in rolled masses.

**Physical Characters.** H., 6. Sp. gr., 2.6 to 2.83.

Lustre, dull or wax-like. Opaque or slightly translucent.

Streak, white or pale green. Tenacity, rather brittle.

Color, sky-blue to apple-green.

Before Blowpipe, Etc.—Infusible, becomes brown and colors the flame green. In salt of phosphorus yields bead greenish-blue when cold, which on charcoal in the reducing flame becomes opaque red. Soluble in hydrochloric acid, the solution becoming fine blue with ammonia. In a nitric acid solution of ammonium molybdate produces a yellow precipitate on boiling.

**Similar Species.**—It is harder than chrysocolla.

**Remarks.**—Turquoise is mined in the United States at Los Cerrillos in New Mexico, and fine material is obtained. Also in Grant county, New Mexico. Previous to the opening of these mines turquoise had been obtained almost altogether from the famous Persian locality and from Arabia. The mineral is also known to occur in Arizona, California, Colorado and Nevada.

**Uses.**—As a gem.

**Wavellite.**

**Composition.**—Al₆(OH)₁₈(PO₄)₄+9H₂O. (Al₆O₃ 38.0, P₂O₅ 35.2, H₂O 26.8 per cent.). F is sometimes present.

**General Description.**—Hemispherical masses which, when broken yield complete or partial circles with radiating crystals.
ALUMINUM MINERALS.

The component crystals are rarely large enough to be measured. Occasionally stalactitic. Color most frequently white, green or yellow.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.31 to 2.34. 
Lustre, vitreous. Translucent. 
Streak, white. Tenacity, brittle. 
Color, colorless, white, yellow, green, brown, blue, black.

Before Blowpipe, Etc.—Whitens, swells, and splits, but does not fuse. With cobalt solution becomes deep blue. In closed tube yields acid water. Soluble in hydrochloric acid. Ammonium molybdate produces a yellow precipitate from nitric acid solutions.

Remarks.—In the United States is most abundant at Magnet Cove, Ark., West Whiteland, Pa., and Silver Hill, N. C. It is without industrial use.

LAZULITE.

Composition.—(Mg, Fe,Ca)Al₆(PO₄)₂.
General Description.—Azure blue acute monoclinic pyramids and masses. Usually quite opaque.
Before Blowpipe, Etc.—Infusible, but becomes white, cracks and falls to pieces, coloring the flame bluish-green, especially when moistened with sulphuric acid. In closed tube yields water and turns white. Insoluble in acids. 
Remarks.—Occurs in veins in clay slate, quartzite, etc.

CHRYSOBERYL.

Composition.—Gl₃Al₃O₈ (GIO 19.8, Al₂O₃ 80.2 per cent.).
General Description.—Pale green or nearly yellow tabular crystals; thicker deep emerald-green crystals, which by transmitted light are a peculiar purplish red; and rolled pebbles looking like green bottle glass, but sometimes possessing a peculiar internal undulating opalescence. Very hard.

Crystallization.—Orthorhombic \(a : b : c\) = 0.470:1:0.580. \(\alpha \times \alpha = 120^\circ\ 39'\). \(\beta \times \beta\) = 98° 15'. (brachy) 86° 16'. Often flat plates or flat contact twins with feather-like striations on plane \(i = 7\).

\(i = \overline{X}, 2 = \overline{Y}, 1 = 1.\)
Physical Characters.  H., 8.5.  Sp. gr., 3.5 to 3.84.

Lustre, vitreous to greasy.  Translucent to transparent.
Streak, white.
Color, pale yellowish green to emerald green.
Before Blowpipe, Etc.—Infusible.  In powder, is turned blue by cobalt solution.  Insoluble in acids.
Varieties.—Alexandrite, the deep emerald-green variety, which is cumbeline red by transmitted light.
Cymophane or Cats Eye.—Yellowish-green and opalescent.

Remarks.—No fine gems have been found in the United States, although the mineral occurs sparingly in Stowe, Peru and Canton, Me., Greenfield, N. Y., Haddam, Conn.  The best gems are obtained from Ceylon, the Urals Mountains and Brazil.

Uses.—As a gem, especially the alexandrite and cat's eye.

MONAZITE.

Composition.—Ce,La,Dy)PO₄, but with notable quantities of thorium and silicon and frequently small amounts of cerium and ytterbium.

General Description.—Small, brown, resinous, monoclinal crystals, or yellow, translucent grains, disseminated or as sand.  Sometimes in angular masses.
Before Blowpipe, Etc.—Infusible, turns gray.  Slowly soluble in hydrochloric acid, leaving a white residue.  Solutions added to a nitric acid solution of ammonium molybdate produce a yellow precipitate.

Uses.—It is the chief source of the rare elements cerium, lanthanum, and didymium.
CHAPTER XXX.

BORON, SULPHUR, TELLURIUM, HYDROGEN AND CARBON MINERALS.

THE BORON MINERALS.

The minerals described are: *Boric Acid*, *Sassolite*, *Borates*, *Borax*, *Ulexite*, *Colemanite* (Priceite and Pandermite), *Boracite* (Stassfurtite). Boron is also a constituent of some common silicates, e.g., tourmaline and datolite.

Commercial borax is manufactured from all the different minerals mentioned, and has many important uses, based either on its power to unite with almost any oxide to form a fusible compound, or upon its antiseptic properties. It is used in welding, as basis of enamels on metal or porcelain, as a flux, as antiseptic in packing meat, in antiseptic powders and soaps, in washing, dyeing, etc.

Sassolite is obtained chiefly by condensing and evaporating the steam issuing from fumaroles in the mountains of Tuscany. Pandermite to the amount of about 8000 tons annually is obtained in Asia Minor. Boracite is from the mines at Stassfurt, Germany. In this country the borax minerals are obtained from the “marshes” of the so-called Great Basin, especially those marshes lying in Nevada and California. In San Bernardino County, Cal., the calcium borates are mined from a vein. In 1892 about 70,000 tons of borax were extracted in California and Nevada.

When the crude material is borax with other sodium and calcium salts, the borax is extracted by boiling in hot water, cooling and crystallizing. The calcium borates need to be first decomposed, usually by sulphuric acid or sulphurous fumes.

**SASSOLITE.**—Natural Boracic Acid.

**Composition.**—*H₄BO₃*, (B₂O₃ 56.4, H₂O 43.6 per cent.).

**General Description.**—Small white or yellowish scales, of pearly lustre, acid taste, and somewhat unctuous feel. Rarely stalactitic or in minute monoclinic crystals. Chiefly occurs in solution or vapor in volcanic regions.
Lustre, pearly.
Streak, white.
Color, white or yellowish.

Before Blowpipe, Etc.—Fuses easily with intumescence to a clear glass without color, but colors the flame yellowish-green. In closed tube, yields water. Soluble in water.

Remarks.—In the region of volcanoes sasso-lite is brought to the surface in the jets of steam, collects in the water from these jets, and, to some extent, forms also a crust more or less solid. The only productive locality is in Tuscany. It also forms a small proportion of the boron compounds at the California borax localities.

Uses.—It is an important source of borax.

BORAX.—Tinkal.

Composition.—Na₂B₄O₇·10H₂O, (B₂O₃ 36.6, Na₂O 16.2, H₂O 47.2 per cent.).

General Description.—A glistening, white or nearly white efflorescence or constituent of certain soils, but more frequently in solution in lakes, or as well-formed monoclinic crystals in the mud of these lakes. The crystals closely resemble those of pyroxene in form and angle.

Physical Characters. H., 2 to 2.5. Sp. gr., 1.69 to 1.72.
Lustre, vitreous to dull.
Streak, white.
Color, white, gray, bluish, greenish. Taste, alkaline.

Before Blowpipe, Etc.—Swells greatly and fuses to a clear glass. Colors flame yellow, and if mixed to a paste with a flux of acid potassium sulphate and powdered fluorite, and fused, it will color the flame bright green. In closed tube, swells, blackens, yields much water and a burnt odor. Soluble in water. If treated with a few drops of sulphuric acid, covered with alcohol, and the alcohol set on fire, a green flame is obtained.

Remarks.—Borax in the United States is produced from the deposits existing in both Nevada and California. The Nevada localities are mainly in Esmeralda County, while those of California are in Lake, Bernardino and Inyo Counties.

Uses.—In welding, soldering, soap-making, glass-making, glaz-
ing, as a flux in assaying, refining and testing metals, as a preservative, in medicine, and as chief ingredient of many washing powders and antiseptic preparations.

ULEXITE.—Boronatrocite.

Composition.—CaNaB₄O₉·8H₂O, (B₂O₃ 43.0, CaO 13.8, Na₂O 7.7, H₂O 35.5 per cent.).

General Description.—White, rounded masses (cotton-balls) of loosely-compacted, intertwined, silky fibres, which are easily pulverized between the fingers.


Lustre, silky. Translucent.

Color and Streak, white. Tenacity, brittle.

Before Blowpipe, Etc.—Fuses very easily, with intumescence to a clear glass. Colors flame intense yellow, and will yield green flame, as with borax. In closed tube yields water. Soluble in acids.

Remarks.—Occurs in dry lakes or on the banks surrounding partially dried lakes, with halite, gypsum, glauberite, borax, etc. Is probably formed by the action of soluble calcium salts on boric acid and borax in solution in the same waters. It is abundant in Esmeralda County, Nevada, and is also found in several of the California borax localities and in the gypsum beds of Nova Scotia. Large deposits also occur in the dry plains of the north of Chili.

Uses.—It is a source of part of the borax of commerce.

COLEMANITE.—Priceite, Pandermite.

Composition.—Ca₂B₄O₉·5H₂O, (B₂O₃ 50.9, CaO 27.2, H₂O 21.9 per cent.).

General Description.—There are three varieties essentially of the same composition and characters:

Colemanite.—Geodes of beautifully transparent colorless monoclinic crystals in the massive mineral.

Priceite.—Loosely compacted white chalky masses.

Pandermite.—Firm compact porcelain-like white masses.

Physical Characters.—Transparent to opaque. Lustre, vitreous to dull or white or colorless. Streak, white. H., 4 to 4.5. Sp. gr., 2.26 to 2.43. Brittle.

Before Blowpipe, Etc.—Fuses easily, coloring flame green. Insoluble in water, easily soluble in hydrochloric acid.

Remarks.—Priceite occurs in Curry County, Oregon, in layers between slate and stenite. Pandermite, in a bed beneath gypsum near Panderman on the Sea of Marmora, Colemanite at Inyo and San Bernardino Counties, Cal., with celestite and quartz.
BORACITE.—Stassfurtite.

**Composition.**—Mg₂Cl₂B₄O₈, (B₂O₃ 62.57, MgO 31.28, Cl 7.93 per cent.).

**General Description.**—Snow-white, rather soft masses (stassfurtite) and small hard glassy isometric crystals, usually colorless and embedded in gypsum.


Before Blowpipe, etc.—Fuses easily with intumesence, to a white glass and colors the flame yellowish green. In closed tube yields no water or but little. Soluble slowly in hydrochloric acid.

**Remark.**—Occurs in deposits of halite, gypsum, anhydrite, and especially in the immense beds of potash and magnesia salts at Stassfurt, Prussia.

THE SULPHUR AND TELLURIUM MINERALS.

The minerals described are: Sulphur and Tellurium; the principal sulphur minerals, however, are the sulphides and sulphates elsewhere described.

According to the estimate of W. H. Adams, the average annual consumption of sulphur in the world between 1867–1892 was 917,890 tons, of which 553,180 were obtained from pyrite, and 364,710 from native sulphur. Sulphur is also recovered in considerable quantities from the former waste products of gas works, Leblanc soda manufactories and other chemical works.

Nine-tenths of the world’s supply of native sulphur is obtained from the island of Sicily. In this country between 1000 and 2000 tons are obtained yearly from the Cove Creek mines, Utah.

Sulphur is extracted from the native mineral by simple fusion and consequent separation from the gangue. The common method in use in Sicily involves the burning of part of the sulphur to melt the remainder, causing heavy loss of the element.

The crude sulphur may be refined by sublimation.

Tellurium is included in this section on account of its close chemical relation to sulphur. It has no commercial importance.

SULPHUR.—Brimstone.

**Composition.**—S, sometimes with traces of tellurium, selenium, or arsenic. Often mixed with clay, bitumen, etc.

**General Description.**—Yellow, resinous, orthorhombic pyramids, usually translucent or transparent; also in crusts, stalactites,

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*Mineral Industry, 1892, p. 426.*
spherical shapes, and powder. Color usually pale-yellow to sulphur-yellow, but is sometimes brown or green.

**Fig. 280.**

CRystallization.—Orthorhombic. \[ \frac{a}{b} : c = 0.813 : 1 : 1.903. \]
\[ 1 \times 1 = 105^\circ 26'. \]
\[ 0 \times 1 - t = 117^\circ 43'. \]
Usually pyramidal, sometimes tabular.

**Physical Characters.** H., 1.5 to 2.5. Sp. gr., 2.05 to 2.09. Lustre, resinous. Transparent to translucent.
Streak, white or pale yellow. Tenacity, brittle.
Color, yellow, yellowish-orange, brown, or gray.
Cleavage, parallel to base, prism and pyramid, not perfect.

**Before Blowpipe, etc.**—Melts easily, then takes fire and burns with a blue flame and suffocating odor of sulphur dioxide. In closed tube melts and yields a fusible sublimate, brown hot, yellow cold, and if rubbed on a moistened silver coin the coin is blackened. Insoluble in acids.

**Remarks.**—Formed in large deposits by the decomposition of sulphides and sulphates, especially gypsum, which by water and decaying organic matter is reduced to the sulphides with subsequent production of hydrogen sulphide which on decomposition forms sulphur. Such deposits are usually with gypsum, celestite, or other sulphides and sulphates. Sulphur is also deposited from the steam in volcanic regions.

The great sulphur producing region of the world is the island of Sicily. Almost all of the sulphur used in the United States is imported from this locality. Smaller amounts are imported from Japan. Deposits are numerous in the United States, and have been developed at Cove Creek and Fresno, Utah, and Winnemucca, Nevada. Extensive deposits are also known in California, Louisiana, Wyoming and Texas. Less important occurrences are numerous.
USES.—Sulphur is used in immense quantities for the manufacture of sulphuric acid, gunpowder, matches, rubber goods, bleaching, medicines, etc. Large quantities of it, however, are recovered in various chemical and metallurgical operations as by-products.

TELLURIUM.

Composition.—Te with a little Se, S, Au, Ag, etc.

General Description.—A soft tin white mineral of metallic lustre occurring fine grained or in minute hexagonal prisms.


Before Blowpipe, Etc.—On charcoal fuses easily, volatilizes, coloring flame green and forming a white coat, which is made rose color by transferring to porcelain and moistening with sulphuric acid. Soluble in hydrochloric acid.

THE HYDROGEN MINERALS.

WATER.—Ice, Snow.

Composition.—H₂O, (H 11.1, O 88.9 per cent.).

General Description.—Ice or snow at or below 0° C. Water from 0° to 100° C. Steam above 100° C., or aqueous vapor at all ordinary temperatures. It is too well known to need description.

Crystallization.—Hexagonal c = 1.403 approximately. Usually star-like forms of great variety and beauty. In hail, crystals may resemble quartz.

Physical Characters. H. (ice), 1.5. Sp. gr. (ice), 0.91.

Lustre, vitreous. Transparent.

Streak, colorless. Tenacity, brittle.

Color, white or colorless, pale blue in thick layers.

Tasteless if pure.

Before Blowpipe, Etc.—Melts at 0° C. Under pressure of 760 mm. boils at 100° C. and is converted into steam.

Remarks.—Rarely pure, usually containing air, carbon dioxide, some of the salts of calcium, magnesium, sodium, potassium, etc., and even traces of the metals. When pure it is tasteless and a universal solvent.

THE CARBON MINERALS.

The definite minerals described are: Diamond and Graphite. In addition to these Coal, Asphaltum, Petroleum, Ozokerite and Amber are economically important carbon compounds which are on the border line of mineralogy, being without definite composition or crystalline form.
Carbon also exists in all organic matter, in all carbonates; in the carbon dioxide of the air; and in natural gas.

Diamonds have been found in this country, but practically, the production for the world is from the South African mines, with a limited amount from Brazil. Over two million carats were mined in Kimberley in 1893.

Graphite is mined in New York and Pennsylvania, and to a slight extent in other States. In 1892* about 600 tons of graphite were obtained by concentration of the ore in this country. The annual product of the world is over 5000 tons, chiefly from Austria and Ceylon.

The uses of graphite are numerous, the best known being, pencils, crucibles, stove polish, lubricants, paints for iron, foundry facings, etc.

Mineral coal is so well known that a description from a mineralogical standpoint would be of little use. Something like 150,000,000 tons are mined per year in this country, and about four times that in the world.

Asphaltum or mineral pitch is a mixture of different hydrocarbons, brown to black in color and grading between liquid and solid. Different names, such as elaterite, gilsonite, albertite, etc., have been given to varieties from different localities.

The chief locality for asphaltum is the famous pitch lake of the island of Trinidad, although deposits of asphalitic sandstone are mined in California, Utah, Kentucky, and other States in this country, and asphalitic limestones are mined in France and Switzerland. Over 160,000 tons were used in the United States in 1892, of which about two-thirds were imported.

The principal use is for street pavements, usually mixed with 70 to 80 per cent. of sharp sand, 5 to 15 per cent. of limestone, and a little coal tar residuum. It is also used as cement, roofing, and floor material, and for coating wood or metal to prevent decay or rust.

Asphaltum is also a constituent of some varnishes.

Petroleum is closely related to asphaltum, and may be regarded as including the liquid members of the series. In 1892 the wells of this country yielded 2,282,469 gallons of the crude oil, which

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*Mineral Industries, 1892.
was converted into naphtha, illuminating oils, lubricating oils and paraffine. It is obtained also in Canada, Russia, India and Burma.

Ozokerite or mineral wax is essentially a paraffin, colorless to white when pure, but oftener greenish or brown, and possessing all the properties of beeswax except its stickiness. It is found in Galicia, Hungary, and Utah, and is extensively used. In the crude state it serves as an insulator for electric wires. By distilling it yields a refined product, ceresine, used for candles, waxed paper and hydrofluoric acid bottles; a product with properties and appearance of vaseline, and a black residuum which in combination with india rubber constitutes the insulating material called okonite.

In 1890 over 6000 tons were mined in Hungary, and 175 tons in Utah.

Amber or succinite is a fossil resin found chiefly along the Prussian coast of the Baltic Sea. It is usually transparent and of a yellowish or brownish color. Its chief use is for jewelry and for mouth pieces for pipes.

DIAMOND.

COMPOSITION.—C.

GENERAL DESCRIPTION.—Transparent, rounded, isometric crystals with a peculiar adamantine lustre like oiled glass. Usually colorless or yellow, and with easy octahedral cleavage. Also translucent, rough, rounded crystalline aggregates and opaque crystalline or compact masses of gray to black color and no distinct cleavage. Especially characterized by a hardness exceeding that of any other known substance.

CRYSTALLIZATION.—Isometric, frequently octahedrons or hex-octahedrons, the latter with rounded faces. Often striated or with triangular depressions. Rarely cubical.
BORON, SULPHUR, CARBON, ETC. MINERALS.

Lustre, adamantine.  Transparent to opaque.
Streak, colorless.  Tenacity, brittle.
Color, colorless, yellow, rose, green, blue, gray, black.
Cleavage, octahedral.

Before Blowpipe, Etc.—Is slowly consumed, producing its equivalent of carbon dioxide. In powder it is burned by ordinary blowpipe flame. Insoluble in acids.

Varieties.—Carbonado or Black Diamond.—Opaque, dark-colored, and without cleavage. Sp. gr., 3.15 to 3.29.
Bort.—Translucent, non-cleavable, crystalline aggregates, often harder than the crystals and more tough. Sp. gr., 3.499 to 3.503. The name bort is also applied to fragments of crystals.

Remarks.—Origin not known. The diamond is found in alluvial deposits with other minerals, such as gold, platinum, zircon. The great South African localities, however, while in part alluvial or "river diggings," are chiefly confined to a limited area where they occur enclosed in a wall of carbonaceous shale surrounding a serpentine shale core, in which are found not only the diamonds, but garnets, zircon, magnetite, etc. Diamonds have also been found in quartzose conglomerates and with the so-called flexible sandstone "itacolumite."

Although diamonds have been found in isolated localities in the southern and western States no deposits, not even of an alluvial character, have been discovered in North America. By far the largest diamond deposit ever found occurs at Kimberley, South Africa, and immense quantities are mined here annually. Alluvial deposits which have become famous occur in Brazil, India, the Urals and Borneo.

Uses.—As a gem when transparent and without flaw; colorless stones and those of decided tints ranking superior to yellow or brownish stones. Smaller stones, especially the translucent and opaque crystals, are used in cutting machinery, diamond drills, saws, etc., on account of their great abrasive power. The dust is also used in polishing other diamonds.

GRAPHITE.—Plumbago, Black Lead.

Composition.—C. Sometimes with iron, sand, clay, etc.
General Description.—Disseminated flakes or scaly to compact masses, and more rarely six-sided plates. Soft, greasy and cold to the touch; black to very dark gray in color and usually metallic in lustre. When impure it is apt to be slaty or earthy.
Physical Characters.  H., 1 to 2.  Sp. gr., 2.09 to 2.25.  
Lustre, metallic to dull.  Opaque.  
Streak, dark-gray.  Tenacity, scales flexible,  
Color, black or dark gray.  slightly sectile.  
Cleavage, basal, cleaves into plates.  Unctuous, marks paper.

Before Blowpipe, Etc.—Infusible, but is gradually burned.  
May react, if impure, for water, iron and sulphur.  Insoluble in  
acids.  If a piece of graphite is brought into contact with a piece  
of zinc in a solution of copper sulphate, it is quickly copper-plated.  
Molybdenite under the same test is very slowly plated.  
Similar Species.—Differs from molybdenite in darker color,  
streak, flame test and salt of phosphorus bead, and as above men-  
tioned.  Micaceous hematite is harder and has a red streak.

Remarks.—Graphite probably results from alteration of embedded organic matter  
coal, peat, etc., by heat, destructive distillation and pressure.  It occurs disseminated  
in crystalline limestones and granites and in larger irregular masses.  Large deposits  
exist in Ceylon, Austria and Eastern Siberia.  Almost all the American output is  
obtained at Ticonderoga, N. Y.  Deposits at Southampton, Pa., and near Raleigh,  
N. C., have also produced graphite in commercial quantities.

Uses.—Graphite is used for refractory vessels, as crucibles, re-  
torts, stove polish, etc., for lead pencils, in electroplating, in electrical supplies, in casting moulds, as a finish, as a lubricant for machinery, as a paint for iron, etc., for coating metals, shot, gun-  
powder, etc.
CHAPTER XXXI.

SILICA AND THE SILICATES.

The minerals composed of silica alone and the silicates cannot conveniently be classified upon an economic basis, and we have, therefore, followed practically the order of Dana's "System of Mineralogy," Sixth Edition, believing that—in this country, at least—most collections of minerals will be arranged in this order for many years. The order herein followed is:

A.—Silica.

B.—Anhydrous Silicates:
   I. Disilicates and Polysilicates.
   II. Metasilicates.
   III. Orthosilicates.
   IV. Subsilicates.

C.—Hydrous Silicates:
   I. Zeolite Division.
   II. Mica Division.
   III. Serpentine and Talc Division.
   IV. Kaolin Division.

D.—Titanate Silicates.

ECONOMIC DISCUSSION.

Aside from the occasional occurrence of certain silicates in specimens suitable for gems, only a few of this greatest group of common minerals are of economic importance as distinct minerals. The great stone or quarry industry,* however, which represents in the United States a capital of nearly $100,000,000, and produced in 1889 material worth in the rough over $50,000,000, consists in the extraction of blocks of either carbonate of lime or magnesia or of silica and silicates. For instance, in 1889 the values of materials quarried in this country were:

* The facts and figures are essentially those of the Eleventh Census Report on Mineral Industries, pp. 395 to 666.
Granite, 314,464,095
Sandstone, 16,816,037
Bluestone, 1,689,506
Slate, 3,482,513
Limestone and Marble, 17,932,265

Granite, commercially speaking, includes a number of hard, durable rocks, such as granite proper, syenite, gneiss, basalt, diorite, andesite, etc., which are composed of silicates—usually three or more—and principally quartz, the feldspars and the micas, pyroxene and amphibole. It is used in enormous quantities in buildings, in paving blocks and in construction of bridges, dams, etc. In 1889, 62,287,156 cubic feet were quarried in the United States, of which 26,000,000 were used in building and 20,000,000 in paving blocks.

Sandstone is composed of grains, chiefly quartz, with sometimes a little feldspar, mica or other minerals, and classified as siliceous, ferruginous, calcareous or argillaceous, according to the nature of the cement which binds the grains together. Its use are the same as those of granite, but a larger proportion of the quantity quarried is used in building. In 1889, 71,171,054 cubic feet were quarried in the United States.

Bluestone is a very hard, durable, fine-grained sandstone, cemented together with siliceous material. It is used principally for flag and curb stone. In 1889, 5,126,340 cubic feet were quarried in the United States.

Slate is used chiefly as roofing material and for interior work.

Fibrous talc and compact talc, or soapstone, are extensively used, the former for grinding to "mineral pulp," used in paper manufacture, the latter for many purposes, usually because it is refractory, expands and contracts very little, retains heat well and is not attacked by acids. These properties make it valuable in furnaces, crucibles, baths, hearths, and cooking utensils. It is also used in cosmetics, refractory paints, and slate pencils.

In 1892 there were produced in this country 51,000 tons of fibrous talc and 19,000 tons of soapstone.

The micas, muscovite, phlogopite and biotite, have become of great importance as non-conductors in electrical apparatus, and are also used in stove and furnace doors. The larger sheets are cut and split to the desired size; the waste is, to some extent, built up into plates suitable for certain grades of electrical work, but the
greater part is ground to spangle wall paper. At present most of the sheet mica is imported from Canada.

Asbestos.—The minerals amphibole and serpentine, in their fibrous varieties, are known commercially as asbestos, and are extensively used as incombustible paper, cloth, boiler and steam-pipe covering, yarn or rope for packing valves. Very little is obtained in the United States—the large supply coming from Canada and Italy, is the fibrous serpentine, chrysotile.

Serpentine is, to some extent, mined and used as an ornamental stone, but is commercially classed with the marbles.

Feldspar is crushed in large quantities for admixture with kaolin in the manufacture of porcelain.

Quartz is also used in large amounts in the manufacture of sand-paper, porcelain, glass, in honestones, oilstones, etc., and its colored and chalcedonic varieties as precious or ornamental stones.

Infusorial Earth is calcined and made into water filters, polishing powders, soap filling and boiler covering.

Kaolinite and Clay.—Enormous and varied industries use as their raw material the beds of clay which result from the decomposition of the feldspars and other silicates. These beds are composed in part of some hydrous aluminum silicate such as kaolinite, but usually with intermixed quartz, mica, undecomposed feldspar, oxides and sulphides of iron. Their properties and uses depend chiefly upon their composition.

The industries include the manufacture of common brick, paving brick, fire-brick, and hydraulic cement, all varieties of earthenware, stoneware and porcelain, terra cotta, sewer pipes and drain tiles, and are carried on all over the country and the world.

The minerals beryl, garnet, topaz, tourmaline, spodumene, tittanite and chrysotile are sometimes found in specimens which are valuable as gems.

SILICA.

The minerals composed of silica (SiO₂) are Quartz, Tridimite and Opal.

Quartz.—Agate, Jasper, Chalcedony.

Composition.—SiO₂, (Si 46.7, O 53.3 per cent.).

General Description.—Usually a hard, brittle, vitreous substance more or less transparent, and occurring both massive and in
hexagonal crystals, and of all colors, but especially colorless, milky, white, amethyst, smoky and red. Also found in cavities, particularly as translucent, non-crystalline layers of gray, yellowish and bluish tints and with usually a mammillary, stalactitic or nodular structure. Also found as more or less opaque, non-crystallized material containing considerable amounts of iron, and alumina, and often highly colored, as red, brown, or yellow.

In rocks quartz rarely has definite shape, but apparently forms last and fills the interstices between the other minerals.

**Fig. 284.**  **Fig. 285.**  **Fig. 286.**  **Fig. 287.**

R and -1.  I, R, and 2 - 1.  I, R, -1, 2 - 2, and 6 -5.  I, R and -1.

**Crystallization.**—Hexagonal.  $c = 1.0999$.  $R \times R = 94^2 14'$.  $R \times -1 = 133^2 44'$.  $R \times I = 141^2 47'$.  $I \times 2 - 2 = 142^2 2'$. Usually prismatic, with both rhombohedrons, R and -1, terminating, the former usually larger and brighter. Prism faces are nearly always horizontally striated. Frequently in tapering forms. Faces very irregularly developed.

**Physical Characters.**  H., 7.  Sp. Gr., 2.6 to 2.66.

Lustre, vitreous to greasy.  Transparent to opaque.

Streak, white.  Tenacity, brittle to tough.

Color, colorless and all colors.

Cleavage, difficult, parallel to rhombohedron.

Before Blowpipe, Etc.—Infusible. With soda, fuses with marked effervescence to a clear or opaque bead, according to the proportions used. Insoluble in salt of phosphorus and slowly soluble in borax. Insoluble in all acids except hydrofluoric.
SILICA AND THE SILICATES.

Varieties.

A. Crystalline Varieties.—Vitreous in lustre, often transparent; occurring in isolated or grouped crystals or drusy surfaces or crystalline.

Rock Crystal.—Pure, colorless or nearly colorless quartz.

Amethyst.—Purple to violet and shading to white. Fracture shows lines like those of the palm of the hand. Color disappears on heating, and is probably due to a little manganese.

Rose Quartz.—Light-pink or rose-red, becoming paler on long exposure to light. Usually massive. Colored by titanium or manganese.

Yellow Quartz or False Topaz.—Light yellow.

Smoky Quartz.—Dark yellow to black. Smoky tint, due to some carbon compound.

Milky Quartz or Greasy Quartz.—Translucent. Usually massive. Common as a rock constituent.

Ferruginous Quartz.—Opaque, brown or red crystals, sometimes small and cemented like a sandstone.

Acenturine.—Spangled with scales of mica, hematite, or goethite.

Cat's Eye.—Opalescent, grayish-brown or green quartz with included parallel fibres of asbestos.

B. Chalcedonic Varieties.—With lustre like wax. Translucent. Not in crystals. Frequently nodular, mammillary, stalactitic or filling cavities.

Chalcedony.—Pale blue or gray varieties, uniform in tint.

Agate.—Strata or bands representing successive periods of deposition, and frequently of different tints or with irregularly mingled colors or visible colored inclusions constituting such sub-varieties as banded agate, clouded agate, moss agate, ruin or fortification agate, etc.

Carnelian or Sard.—Blood-red or brownish-red.

Onyx and Sardonyx.—Parallel layers of lighter and darker color, as white and black, white and red, etc. The layers are in planes.

Chrysoprase.—Apple-green.

Prase.—Dull leek-green.

Plasma, Heliotrope and Bloodstone. Bright to dark-green, spotted with white or red dots.

C. Jasper Varieties.—Opaque, dull in lustre, usually high in color, impure from clay and iron.
D. In addition to these, there are

**Flint.**—Smoky-gray to nearly black, translucent nodules, found in chalk-beds.

**Touchstone.**—Velvet-black and opaque, on which metal streaks are easily made and compared.

**Sandstones.**—Quartz grains cemented by silica, iron oxide, clay, calcium carbonate, etc.

**Quartzite,** compact quartz, granular or slaty in structure.

**Remarks.**—Quartz is chiefly found as an original constituent of such rocks as granites, gneiss, etc., formed by igneous or plutonic action, and also, to a very large extent, as a deposit from solution in water. Silicates are attacked by carbonated waters, forming carbonates of calcium, magnesium, sodium, etc., and leaving a residue of silica. This, in turn, is soluble in hot solutions of these same carbonates, and is dissolved, transported, and, by evaporation and cooling, is redeposited, filling seams, cavities, veins, etc. Quartz is the most common of all solid minerals, and occurs with almost all other species and in almost all localities.

**Uses.**—Aside from the uses of the quartz rocks in building, etc., large quantities of quartz are used in the manufacture of sandpaper, glass, porcelain and as an acid flux in smelting. The chalcedonic varieties—agate, onyx, etc.—are often polished and used as ornaments, and so also are some of the jaspers. Rock crystal is used in cheap jewelry, and is cut for spectacles and for some forms of optical apparatus. The colored crystalline varieties are often cut in cheap jewelry, and the amethyst, when of a particular dark purple, is highly valued as a gem.

**TRIDYMITE.**

**Composition.**—$\text{SiO}_2$.

**General Description.**—Small colorless, six sided plates. Often in wedge-shaped groups of three (trillings), which are sometimes octahedral in appearance.


**Before Blowpipe, etc.**—Like quartz, but soluble in boiling sodium carbonate.

**Remarks.**—Occurs in cavities in volcanic rocks, such as trachyte or andesite.

**OPAL.**

**Composition.**—$\text{SiO}_2 \cdot n\text{H}_2\text{O}$, ($n\text{H}_2\text{O}, 5$ to $12$ per cent.).

**General Description.**—Transparent to translucent veins and masses, usually of milky-white or red color and frequently showing blue, green, red, etc., internal reflections (opalescence). This grades into less translucent and opaque masses, with no play of color and somewhat resembling chalcedony, but without the wax-
like lustre. Other varieties are transparent, like melted glass, and opaque and earthy.


Before Blowpipe, Etc.—Infusible. Becomes opaque and yields more or less water. Soluble in hydrofluoric acid more easily than quartz and soluble in caustic alkalies.

Varieties.
Precious Opal.—Milky-blue, yellow or white translucent material with fine internal reflections, attributed to thin curved lamellae, which have been cracked, bent and broken during solidification.

Fire Opal.—Reddish or brown in color and with reflections having the appearance of fire.

Common or Semi-Opal.—Translucent to opaque, with greasy lustre and of all colors, but without opalescence. Most frequently yellow or brown.

Wood Opal.—Petrified wood, the petrifying material being opal.

Opal Jasper.—Like ordinary jasper, but with resinous lustre.

Hyalite.—Colorless transparent masses resembling drops of melted glass or of gum arabic.

Geyserite, Silicious Sinter.—Loose, porous rock of opal silica deposited from hot water. Opaque, brittle and often in stalactitic or other imitative shapes.

Florite or Pearl Sinter.—Pearly, translucent material found in volcanic tufa and near hot springs.

Tripolite or Infausorial Earth.—Massive, chalk-like or clay-like material composed of the remains of diatoms.

Similar Species.—Softer than quartz and soluble in caustic alkalies. May also yield noticeable water in a closed tube. Rarely confused with any other mineral.

Remarks.—Occurs in fissures in igneous rocks or imbedded in limestone, clay-beds, etc. Fine precious opals are found at Gem City, Washington; at Opaline, Idaho; also in Latoka County, Idaho, and Morrow County, Washington. Queretaro and Zimapán, Mexico, also yield good gems. Other famous localities are Cservenitzza, Hungary; Bula Creek, Queensland, and Wilcannia, New South Wales. Deposits of infusorial earth occur at Dankirk, Md.; Richmond, Va.; Virginia City,
BEFORE BLOWPIPE, ETC.—Fuses in thin splinters to a semi-transparent glass and colors flame violet. Insoluble in acids.

VARIETIES.

Adularia.—Colorless to white, transparent, often opalescent. Usually in crystals.

Sanidine and Rhyacolite.—Glassy, white or colorless crystals in lava, trachyte, etc.

Loxoclase.—Grayish-white or yellowish crystals, which have a tendency to cleave parallel to the ortho pinacoid.

Felsite.—Jaspery or flint-like masses of red or brown color.

SIMILAR SPECIES.—Differs from the other feldspars in the cleavage at 90°, the greater difficulty of fusion, the absence of striations, etc.

REMARKS.—Usually of igneous origin, sometimes secondary. With micaceous quartz it forms the important rocks granite, gneiss, and mica schist, and is also the basis of aynite, trachyte, porphyry, etc. It changes to kaolin, quartz, opal, epidote and mica, by the removal of bases through the action of acid waters. Orthoclase is quarried at South Glastonbury and Middletown, Conn.; Edgecomb and Brunswick, Me.; Chester, Mass.; Brandywine Summit, Pa.; Tarrytown and Fort Ann, N. Y.

USES.—It is one of the constituents of porcelain and chinaware, chiefly to form the glaze, but partly mixed with the kaolin and quartz in the body of the ware.

MICROCLINE.

COMPOSITION.—K₃AlSi₃O₈.

GENERAL DESCRIPTION.—Like orthoclase, except that 3 axis is at 89° 30′ instead of 90°, and the basal cleavage often shows the triclinic fine striations. In thin basal sections between crossed nicols it shows a peculiar interlaced structure of light and dark lines.

PHYSICAL CHARACTERS.—Essentially as in orthoclase. Sp. gr., 2.54 to 2.57. 2nd cleavage at 89° 30′ instead of 90°.

BEFORE BLOWPIPE, ETC.—As for orthoclase.

REMARKS.—Includes varieties, Amazon stone, perthite, chesterlite, etc., formerly grouped under orthoclase. Often interlaminated with albite or orthoclase.

ALBITE.—Soda Feldspar, Pericline.

COMPOSITION.—NaAlSi₃O₈.

GENERAL DESCRIPTION.—Pure white, coarse, or fine granular masses or in straight, curved, and waving laminae. Less frequently in white or colorless triclinic crystals, usually small and often with re-entrant angles. Repeated twining of a large number of very thin crystals results, or when the individuals are very thin and
their number great the re-entrant angles appear as parallel scratches
or striations on the basal plane or basal cleavage.

**Crystallization.**—Triclinic \( a = 94° 3' \), \( \beta = 116° 29' \), \( \gamma = 88° 9' \). \( I \times I = 120° 46' \). \( O \times I = 110° 59' \). Rarely simple
forms.

**Physical Characters.**
- H., 6 to 6.5. Sp. gr., 2.62 to 2.65.
- Lustre, vitreous. Transparent to opaque.
- Streak, white. Tenacity, brittle.
- Color, pure white, colorless, or tinted blue, gray, red, green.

Cleavage at angle of 86° 24'.

**Before Blowpipe, Etc.**—Fuses in small pieces to a white
enamel and colors the flame deep yellow. Insoluble in acids.

**Similar Species.**—Differs from other feldspars in whiteness,
granular, and lamellar structure and strong yellow flame.

**Remarks.**—Frequently found in cavities and seams in granite and schistose rocks,
especially those high in silica, often enclosing the rarer minerals, tourmaline, beryl,
chrysoberyl, topaz, etc. Is chief constituent of diorite. Not easily altered.

**Oligoclase.**—Soda Lime Feldspar.

**Composition.**—\( n(NaAlSiO_3) + CaAl_2Si_2O_8 \), \( n = 2 \) to 5.

**General Description.**—Cleavable masses, usually with fine
striations on the basal cleavage surface. Color greenish-white,
also in reddish or grayish masses, sometimes with fire-like reflections
(sunstone). Less frequently in triclinic crystals.

**Physical Characters.**
- H., 6 to 7. Sp. gr., 2.65 to 2.67.
- Lustre, vitreous or pearly. Transparent to opaque.
- Streak, white. Tenacity, brittle.
- Color, greenish, white, gray, reddish, yellowish.

Cleavage, at angle of 86° 32'.
BEFORE BLOWPIPE, Etc.—Fuses rather easily to a clear or enamel-like glass. Insoluble in acids.

REMARKS.—Of igneous origin, occurring with orthoclase and albite in rocks of the granite type and in lavas, trachyte, serpentine, etc. It alters to epidote, natrolite, etc. Good crystals are found at Fine and McComb, St. Lawrence County, N. Y.

LABRADORITE.—Lime Soda Feldspar.

COMPOSITION.—NaAlSi$_2$O$_8$ + n(CaAl$_2$Si$_2$O$_8$). n = 1, 2, or 3.

GENERAL DESCRIPTION.—Dark gray cleavable masses, which frequently show beautiful changing colors, blue, gold, red, etc. Less frequently in small triclinic crystals or colorless and glassy or granular to flint-like.

Physical Characters. H., 5 to 6. Sp. gr., 2.7 to 2.72.
Lustre, vitreous or pearly. TRANSLUCENT to opaque.
Streak, white. TENACITY, brittle.
Color, dark gray, greenish, brown, colorless, white.
Cleavage, at angle of 86° 4′.

BEFORE BLOWPIPE, Etc.—Fuses rather easily to colorless glass. Partially soluble in hydrochloric acid.

REMARKS.—Labradorite is of igneous origin, usually accompanied by pyroxene, amphibole, melanite or magnetite, forming the gabbros, dolerites, and other basic rocks; but is notably absent in localities containing orthoclase and quartz. It alters readily to zeolites, calcite, dolomite, etc. Found abundantly in the Adirondacks, N. Y., in the Wichita Mountains, Ark., in Quebec and in Labrador.

USES.—It is polished for ornaments, table tops, inlaid work, etc.

ANORTHITE.—Indianite, Lime Feldspar.

COMPOSITION.—CaAl$_2$Si$_2$O$_8$.

GENERAL DESCRIPTION.—White or red granular masses (indianite), small to rather large, glassy, colorless, white, or reddish-yellowish triclinic crystals and gray or pink cleavable masses.

Physical Characters. H., 6 to 6.5. Sp. gr., 2.74 to 2.76.
Lustre, vitreous. TRANSPARENT to opaque.
Streak, white. TENACITY, brittle.
Color, white, colorless, gray, yellow, red.
Cleavage, at 85° 30′.

BEFORE BLOWPIPE, Etc.—Fuses with difficulty to a colorless
glass. In fine powder, is decomposed by hydrochloric acid, sometimes with gelatinization. The solution will yield a copious white precipitate on addition of sulphuric acid.

REMARKS.—Frequently of volcanic origin, often enclosing grains of chrysolite.

THE METASILICATES.

The Metasilicates are derivatives of \( \text{H}_2\text{SiO}_3 \), and are described in the following order:

Leucite.

Pyroxene Group.—Enstatite, Hypersthene, Pyroxene, Spodumine, Wollastonite, Pectolite, Rhodonite.

Amphibole.

Beryl.

Cyanite.

Iolite is an intermediate species between metasilicates and orthosilicates.

Many of the hydrous silicates are also derivatives of metasilicic acid.

LEUCITE.

Composition.—\( \text{KAl} (\text{SiO}_3)_2 \).

General Description.—Gray, translucent to white and opaque, disseminated grains and trapezohedral crystals in volcanic rock.

Crystallization.—Isometric externally, but with polarized light, showing double refraction at all temperatures below 500° C.

Physical Characters. H., 5.5 to 6. Sp. gr., 2.45 to 2.50.

Lustre, vitreous to greasy, translucent to opaque.

Streak, white.

Tenacity, brittle.

Color, white or gray, or with yellowish or red tint.

Before Blowpipe, Etc. Infusible. With cobalt solution, becomes blue. Soluble in hydrochloric acid, leaving a fine powder of silica.

REMARKS.—A constituent of lavas, sometimes the chief constituent. By alteration, changes to kaolin, mica, nepheline, orthoclase, quartz, etc. It is not common in America, but is found in the Leucite Hills, Wyoming, and also in the northwestern part of the same State. Very common in the Vesuvian lavas.

USES.—Leucite rock has long been used for millstones.
ENSTATITE.—Bronzite.

Composition.—(Mg,Fe)\(_2\)SiO\(_4\).

General Description.—Brown to gray or green, lamellar or fibrous masses, with sometimes a peculiar metalloidal lustre (bronzite). Rarely in columnar orthorhombic crystals.


Before Blowpipe, etc.—Fusible on the edges. Almost insoluble in acids. With cobalt solution it turns pink.

Remarks.—It is rare in quartzose rocks, but occurs frequently in meteorites and with chrysolite, basaltic and granular eruptive rocks. Occurs also associated with chondrodite, epidote, talc, etc. By alteration it forms serpentine, talc, and limonite.

HYPERSTHENE.

Composition.—(Mg,Fe)SiO\(_3\), with more iron than enstatite.

General Description.—Dark-green to black, foliated masses or rare orthorhombic crystals, which grade into enstatite. Frequently shows a peculiar iridescence, due to minute interspersed crystals.


Before Blowpipe, etc.—Fuses on coal to a black, magnetic mass. Partially soluble in hydrochloric acid.

Remarks.—Hypersthene is common in certain granular eruptive rocks, gabbros, norites, etc.

PYROXENE.—Augite.

Composition.—RSiO\(_3\), R = Ca, Mg, Mn, Fe, Al, chiefly.

General Description.—Monoclinic crystals. Usually short and thick, with square or nearly square cross-section, or octagonal and with well-developed terminal planes. Granular, foliated and columnar masses and rarely fibrous. Color, white, various shades of green, rarely bright green, and black.

Fig. 296.

\[ a, i = 1, j = 1, k = -1. \]

Fig. 297.

\[ c, i = 1, j = 1, k = 2. \]

Fig. 298.

\[ o, i = 1, j = 1, k = -2. \]
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CRYSTALLIZATION.—Monoclinic. $\beta = 74^\circ \ 10'$, $\overline{\alpha} : \overline{\beta} : \overline{\gamma} = 1.092$ : 1 : 0.589. $I \wedge I = 87^\circ \ 10'$. $O \wedge -1 = 146^\circ \ 11'$. $O \wedge -2 = 130^\circ \ 6'$. $i - i \wedge -1 = 129^\circ \ 12'$. $i - i \wedge -2 = 133^\circ \ 17'$. $O \wedge -1 = 146^\circ \ 10'$. $O \wedge 1 = 137^\circ \ 38'$. Contact twins occur.

Lustre, vitreous, dull or resinous. Opaque to transparent.
Streak, white to greenish. Tenacity, brittle.
Color, white, green, black, brown.
Cleavage, prismatic (angle 87° 10'), sometimes basal.


Varieties.
Analcite or Diopside.—CaMg(SiO$_3$)$_2$. Usually white or pale-green.
Hedenbergite.—(Ca,Fe)(SiO$_3$)$_2$. Grayish-green.
Augite.—Chiefly CaMg(SiO$_3$)$_2$, but containing also Al and Fe. Dark-green to black, and many others which grade into each other imperceptibly.
Diaplectic.—Thin foliated pyroxene, green or brown in color.
Similar Species.—Differs from amphibole, as therein described.

Remarks.—Next to the feldspars, pyroxene is the most common constituent of igneous rocks. It occurs also in crystalline limestones and dolomites, and usually of some light-green or white color (diopside). In serpentine it is apt to be lamellar disclage. In granite it is usually green, and in eruptive rocks is dark-green or black augite. It alters to chlorite, serpentine, amphibole, etc.

SPODUMENE.

Composition.—LiAl(SiO$_3$)$_2$, with some sodium replacing lithium.

General Description.—White, greenish-white and rarely emerald-green, monoclinic crystals, sometimes of enormous size. Also in masses. Characterized by breaking in broad, smooth plates, in addition to regular prismatic cleavage.

Physical Characters. H., 6.5 to 7. Sp. gr., 3.13 to 3.20.
Lustre, vitreous. Transparent to opaque.
Streak, white. Tenacity, brittle.
Color, white, pale green, emerald, green, pink, purple.

Before Blowpipe, Etc.—Becomes opaque, intumesces, swells.
and fuses to a white or colorless glass, coloring the flame purple-red, especially with hydrochloric acid. Insoluble in acids.

**Similar Species.**—Distinguished by its tendency to split into thin pearly plates and by the red flame.

**Remarks.**—Occurs in granitic rocks with garnet, tourmaline and the granite minerals, quartz, feldspars and micas. It alters readily to a mechanical mixture of albite and mica. Important localities are Stony Point, N. C.; Chesterfield and Huntington, Mass.; Branchville, Conn.; Pennington County, S. D., etc.

**Uses.**—The variety Hiddenite is used as a gem.

**WOLLASTONITE.**

**Composition.**—CaSiO₃.

**General Description.**—Cleavable to fibrous white or gray masses. Also in monoclinic crystals, near pyroxene in angle. Sometimes compact. Usually intermixed with calcite.

**Physical Characters.** H., 4.5 to 5. Sp. gr., 2.8 to 2.9.

**Lustre,** vitreous to silky. **Translucent.**

**Streak,** white. **Tenacity,** brittle.

**Color,** white, gray, or light tints of yellow, red, brown.

**Cleavage.** O and i—i at angle of 84° 30′.

**Before Blowpipe, Etc.**—Fuses with difficulty, coloring the flame red. Soluble in hydrochloric acid, generally effervescing and always gelatinizing.

**Similar Species.**—Differ from pectolite and natrolite in red flame, difficulty of fusion, and absence of water. Tremolite does not gelatinize.

**Remarks.**—Occurs in granular limestone, granite, basalt, lava, etc., with pyroxene, calcite, garnet, etc. By the action of carbonated or sulphurated waters it changes to calcite or glass.

**PECTOLITE.**

**Composition.**—H₃Ca₃(SiO₃)₂.

**General Description.**—White or gray radiating needles and fibres of all lengths up to one yard. Also in tough compact masses and a few isolated monoclinic crystals.

**Physical Characters.**—Translucent to opaque. Lustre, vitreous or silky. Color, white or gray. Streak, white. H., 5. Sp. gr., 2.68 to 2.78. Brittle.

**Before Blowpipe, Etc.**—Fuses easily to a white enamel. Yields water in closed tube. Gelatinizes with hydrochloric acid.

**Remarks.**—Occurs with zeolites, prehnite, etc., in cavities and seams of igneous rocks.

**RHODONITE.**

**Composition.**—MnSiO₃, with replacement by Fe, Zn or Ca.

**General Description.**—Brownish red to bright red, fine grained.
or cleavable masses and disseminated grains, often externally coated with a black oxide. Sometimes in triclinic crystals closely like the monoclinic forms of pyroxene.

**Physical Characters.** H., 5.5 to 6.5. Sp. Gr., 3.4 to 3.68.
- **Lustre**, vitreous. **Transparent to opaque.**
- **Streak**, white. **Tenacity**, brittle.
- **Color**, brownish-red to flesh-red, bright-red, greenish, yellowish. **Cleavage**, prismatic, angle 87° 38’ and basal.

**Before Blowpipe, etc.**—Blackens and fuses easily with slight intumescence. With fluxes reacts for manganese and zinc. In powder is partially dissolved by hydrochloric acid, leaving a white residue. If altered may effervesce slightly during solution.

**Similar Species.**—Rhodochrosite is infusible, dissolves completely with effervescence in warm acids. Red feldspars are less fusible, and do not give manganese reactions.

**Remarks.**—Occurs with iron-ore, franklinite, tetrahedrite, etc., and is altered by light, air, and carbonated waters to the oxides and the carbonates.

**AMPHIBOLE.**—Hornblende.

**Composition.**—RSiO₃. R generally stands for more than one of the elements, Ca, Mg, Fe, Al, Na and K.

**General Description.**—Monoclinic crystals usually with acute rhombic section; columnar, fibrous and granular masses, rarely lamellar, sometimes radiated. Colors white, shades of green, brown, and black.
Crystallization.—Monoclinic. \( \beta = 73^\circ 58' \), \( a:b:c = 0.5311 \), \( 1:0.204 \). \( 1 \wedge l = 124^\circ 11' \), \( 1 - i \wedge 0 = 164^\circ 14' \). Prismatic crystals, usually with flat clinodome. Vertical faces often show fibres extending vertically like striations.

Physical Characters. H., 5 to 6. Sp. gr., 2.9 to 3.4.
Lustre, vitreous to silky. Transparent to opaque.
Streak, white or greenish. Tenacity, brittle to tough.
Color, white, gray, green, black, brown, yellow and red.
Cleavage, prismatic, angle of 124° 11'.

Before Blowpipe, Etc.—Varies. Usually fuses easily to a colored glass, which may be magnetic. Not affected by acids.

Varieties:
Trinitite.—CaMg_2(SiO_4)_6, white to gray in color.
Actinolite.—Ca(Mg,Fe)_2(SiO_4)_6, bright green or grayish-green.
Hornblende and Edomite.—Aluminous varieties, black or green in color, with lustre something like horn.
All of these occur in crystals and columnar to fibrous.
Nephrite or Jade is compact and extremely tough, microscopically fibrous, may have composition of tremolite or actinolite.
Asbestos is in fine, easily separable fibres, white, gray, or greenish.

Similar Species.—Differs from tourmaline in cleavage, crystal line form and tendency to separate into fibres. The differences between it and pyroxene are:
Amphibole, prism angle and cleavage 124°; tough, often fibrous, rarely lamellar, often blade-like or pseudo-hexagonal crystals. Pyroxene, prism and cleavage angle 87°; brittle, rarely fibrous, often lamellar crystals, square or octagonal.

Remarks.—Occurs with pyroxene, serpentine, talc, magnetite, quartz, the feldspars, etc., and forms by alteration, epidote, serpentine, talc, chlorite, iron-ores, etc.
Much of the material passing under the name of asbestos is fibrous serpentine. The best of the pure material is imported from Germany and Italy. Producing mines in the United States are located in California, Wyoming and Oregon. North Carolina, Georgia, Pennsylvania and other States have large deposits, but the quality and mode of occurrence do not allow it to be profitably mined at present. For most purposes the fibrous serpentine of Canada is superior to any American asbestos.

Uses.—Asbestos is made into cloth and boards, which are incombustible and are good non-conductors of heat. It is used for
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roofing, coverings for steam pipes, piston packing, theatre curtains, firemen's suits, fire-proof paints and cements, and for lining sailes. It is made into yarns, ropes and paper for fire-proof purposes.

Nephrite or jade has had many uses in prehistoric times and in historic times among semi-civilized or non-civilized nations. It is the toughest of all known stones and in the stone age was used for weapons and tools. In China and India and in ancient Mexico it was carved into ornaments, symbols of authority, sacrificial vessels, etc. It has had a false value as a cure for kidney diseases, and both its names are derived from words meaning "kidneys."

**BERYL.**—Emerald, Aquamarine.

**Composition.**—$\text{Ga}_3\text{Al}_2(\text{SiO}_3)_6$.

**General Description.**—Hexagonal, flattened prisms, from mere threads to several feet in length. Usually some shade of green. Sometimes occurring in columnar or granular masses. Harder than quartz.

**Crystallization.**—Hexagonal. $\varepsilon = 0.499$. Vertically striated prisms. Distinct terminal planes rare.

**Physical Characters.**  
H., 7.5 to 8. Sp. gr., 2.63 to 2.8.  
Luster, vitreous. Transparent to nearly opaque.  
Streak, white. Tenacity, brittle.  
Color, emerald to pale-green, blue, yellow, white, red, colorless.  
Cleavage, imperfect basal and prismatic.

**Before Blowpipe, Etc.**—Fuses on thin edges, often becoming white and translucent. Slowly dissolved in salt of phosphorus to an opalescent bead. Insoluble in acids.

**Varieties.**  
*Emerald.*—Bright emerald green, from the presence of a little chromium.  
*Aquamarine.*—Sky-blue to greenish-blue.  
*Goshenite.*—Colorless.

**Similar Species.**—Harder than apatite, quartz or tourmaline.
DESCRIPTIVE MINERALOGY.

Differs in terminal planes from quartz. Lacks distinct cleavage of topaz.

REMARKS.—Occurs in granite, mica-schist, clay-slate, etc., frequently penetrating the other minerals, showing that it was formed before them. It is associated with quartz, micas, feldspars, garnet, corundum, zircon, etc. By alteration, it forms kaolinite, muscovite, etc. Beryls are especially abundant at Ackworth and Grafton, N. H.; Royalton, Mass.; Paris and Stoneham, Me.; Alexander County, N. C.; the Black Hills of South Dakota, and Litchfield, Conn. Those at Ackworth and Grafton are sometimes of immense size. One crystal, near the railroad station of Grafton Centre, measures 3 feet 4 inches by 4 feet 3 inches on horizontal section and is exposed for over 3 feet. Good emeralds have been obtained in this country from Alexander County, S. C., and especially from Stony Point. Aquamarines and other gem specimens have been obtained at Paris and Stoneham, Me.; Mount Anton, Colo., and several places in North Carolina.Emeralds of finest quality are obtained near Muro, United States of Colombia, also from India, Brazil, Siberia and Australia.

USES.—Emerald and aquamarine are cut as gems.

Fig. 303.  

CYANITE.—Kyanite.*

COMPOSITION.—(Al₂O₃)₂SiO₃, probably a basic metasilicate.

GENERAL DESCRIPTION.—Found in long flattened blade-like crystals, rarely with terminal planes. The color is a blue, deeper along the centre of the blades, and at times passes into green or white. The crystals are triclinic and show many cross cracks.

Physical Characters.  
H., 5 to 7.  
Sp. gr., 3.56 to 3.67.  
LUSTRE, vitreous.  
STREAK, white.  
COLOR, blue, white, gray, green to nearly black.  
CLEAVAGE, parallel to the three pinacoids.

BEFORE BLOWPIPE, ETC.—Infusible, with cobalt solution becomes blue. Insoluble in acids.

REMARKS.—Occurs chiefly in gneiss and mica schist, and must have been formed below 1300°, as at this temperature it is changed into feldspar. It is associated with pyrophyllite, andalusite, corundum, etc., and is found throughout the corundum regions of Massachusetts, Pennsylvania, North Carolina, and Georgia.

* Dana places cyanite with the orthosilicates for convenience.
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IOLITE.—Dichroite, Cordierite.

Composition.—Mg(Al,Fe)4(SiO4)4(SiO2)4.

General Description.—Short, six- or twelve-sided orthorhombic prisms and large, glassy, quartz-like material. Usually blue in color. The color is often deep blue in one direction and gray or yellow in a direction at right angles with the first.

Physical Characters.—Transparent or translucent. Lustre, vitreous. Color, light to smoky blue, gray, violet or yellow. Dichroic. Streak, white. H., 7 to 7.5. Sp. gr., 2.6 to 2.66. Brittle. Cleaves parallel to brachy pinacoids.

Before Blowpipe, Etc.—Fuses with difficulty, becoming opaque. With cobalt solution becomes blue-gray. Partially soluble in acids.

Remarks.—Occurs in gneiss and sometimes in granite, rarely in volcanic rocks, and is formed by contact with igneous matter. It is easily altered to a soft lamellar or fibrous material of green or yellow color, and is rarely found entirely unaltered.

ORTHOSILICATES.

The Orthosilicates are derivatives of H2SiO4, as Zircon, ZrSiO4; Phenacite, G1SiO4. Isomorphous mixtures are well represented by Biotite, (H.K)(Mg,Fe)Al2(SiO4)3; acid salts by Prehnite, H2Ca2Al2SiO6; and basic salts by Sillimanite, Al(Al2O)SiO4. Häüynite is an example of a crystalline mixture of an orthosilicate and a sulphate. As a rule, the orthosilicates are less stable than the meta-silicates.

The orthosilicates described here are: NEPHELITE, HÄÜYNITE, LAZURITE, GARNET, CHRYSOLITE, PHENACITE, WERNERITE, VESUVIANITE, ZIRCON, TOPAZ, ANDALUSITE, SILLIMANITE, DATOLITE, EPIDOTE, ALLANITE, PREHNITE.

BIOTITE, PHLOGOPITE and MUSCOVITE, although derivatives of orthosilicic acid, are, according to the system of Dana, classified as hydrous silicates, while the probable orthosilicates, CHONDRODITE and STAUROLITE are classed as subsilicates.

NEPHELITE.—Elæolite.

Composition.—7NaAlSiO3 + NaAl(SiO2)2. With partial replacement of Na by K or Ca.

General Description.—Small, glassy, white or colorless grains or hexagonal prisms with nearly flat ends, in lavas and eruptive rocks, or translucent reddish-brown or greenish masses and coarse crystals, with peculiar greasy lustre.

Physical Characters. H., 5.5 to 6. Sp. gr., 2.55 to 2.65.

Lustre, vitreous or greasy. Transparent to opaque.

Streak, white. Tenacity, brittle.

Color, white, colorless, reddish, brownish, greenish or gray.

Cleavage, prismatic and basal.
DESCRIPITIVE MINERALOGY.

BEFORE BLOWPIPE, ETC.—Fuses to a colorless glass. When heated with cobalt solution, becomes blue. Soluble in hydrochloric acid, with residue of gelatinous silica.

VARIETIES.—The usually massive varieties, with greasy lustre, are called elaeolite.

REMARKS.—Nephelite occurs in eruptive rocks and lavas. Elaeolite occurs in granular, crystalline rocks such as syenite. Nephelite alters easily and is the source of many of the zeolites. Austin, Texas; Litchfield, Me., and the Ozark Mountains, Arkansas, are important localities of elaeolite. Nephelite is abundant in the lavas of Vesuvius.

HAÜYNITE.

COMPOSITION.—$2(Na_3Ca)Al_2(SiO_4)$. (Na_2Ca)SO_4 possibly, but very complex and with varying proportions of Na and Ca.

GENERAL DESCRIPTION.—Glassy blue to green imbedded grains, or rounded isometric crystals in igneous rock.


BEFORE BLOWPIPE, ETC.—Fuses slowly to a white glass, which will blacken silver. Gelatinizes with hydrochloric acid.

LAPIS LAZULI or LAZURITE.—Native Ultramarine.

COMPOSITION.—An orthosilicate of sodium and aluminium, with a sulphate and a polysulphide of sodium.

GENERAL DESCRIPTION.—Deep-blue masses intimately mixed with other minerals. Rarely in isometric forms.


BEFORE BLOWPIPE, ETC.—Fuses easily to a white glass, with innumescence. In closed tube, glows with a green light and yields water. Soluble in hydrochloric acid with evolution of hydrogen sulphide and residue of gelatinous silica.

USE.—It is employed in inlaid work, and before the invention of artificial ultramarine it was very valuable as a durable, deep blue, color for oil paintings.

GARNET.

COMPOSITION.—$R''R'''(SiO_4)$. R'' is Ca, Mg, Fe or Mn. R''' is Al, Fe'' or Cr, rarely Ti.

GENERAL DESCRIPTION.—Imbedded isometric crystals, either complete or in druses and granular, lamellar and compact masses. Usually of some brown, red or black color, but occurring of all colors except blue, and harder than quartz. Also found in alluvial material as rounded grains.
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Crystallization. — Isometric. Usually either the rhombic dodecahedron or the tetragonal trisoctahedron, 2−2, or these in combination.

Physical Characters. H., 6.5 to 7.5. Sp. gr., 3.15 to 4.38. LUSTRE, vitreous or resinous. TRANSPARENT to opaque. STREAK, white. TENACITY, brittle to tough. COLOR, brown, black, violet, yellow, red, white, green. CLEAVAGE, dodecahedral, imperfect.

Before Blowpipe, Etc.—Fuses rather easily to light brown glass, except in case of infusible chromium and yttrium varieties. Insoluble before fusion, but after fusion will usually gelatinize with hydrochloric acid. Bead reactions vary with composition.

Varieties.

Grossularite.—Ca₃Al₂(SiO₄)₃. White, pale yellow, pale-green, brown-red rose-red.
Pyrope.—Mg₂Al₃(SiO₄)₃. Deep-red to nearly black, often transparent.
Almandite.—Fe₂Al₃(SiO₄)₃. Fine deep-red to black. Includes part of precious and of common garnet.
Spessartite.—Mn₃Al₃(SiO₄)₃ Brownish-red to purplish hyacinth red.
Andradite.—Ca₃Fe₂(SiO₄)₃. Yellow, green, red, brown, black. Includes many of the common garnets.
Uvarovite.—Ca₃Cr₂(SiO₄)₃. Emerald green, small crystals.

Remarks.—Garnet is common in schists, gneiss, etc., and also occurs in granites, limestone, serpentine, and even in volcanic rocks. By oxidation of their ferrous iron and by the action of carbonated waters, garnets are altered, forming calcite, iron ores, etc.

Magnesian varieties lightest.
soapstone, serpentine, gypsum, etc. The common garnet is a very common mineral in many localities throughout the United States. Precious garnets are found on the Navajo Reservation, New Mexico; in Southern Colorado, Arizona, Utah, Elliot County, Ky.; Amelia County, Va.; Oxford County, Me.; and in North Carolina, Georgia, Montana, Idaho and Alaska. In Lewis and Warren Counties, N. Y.; Raburn County, Ga., and Burke County, N. C., garnets are so plentiful that they are mined for use as an abrasive.

USES.—Thousands of tons are used as an abrasive material intermediate in hardness between quartz and corundum. A marble containing large pink garnets is quarried at Morelos, Mexico, as an ornamental stone. Transparent red garnets are sometimes highly valued as gems, and the green variety is also sometimes cut.

CHRYSOLITE.—Olivine, Peridot.

COMPOSITION.—\((\text{Mg,Fe})_2\text{SiO}_4\).

GENERAL DESCRIPTION.—Transparent to translucent, yellowish-green granular masses, or disseminated glassy grains, or olive-green sand. When containing much iron, the color may be reddish-brown, or even, by alteration, opaque-brown or opaque-green. Rarely in orthorhombic crystals.

Physical Characters. H., 6,5 to 7. Sp. gr., 3.27 to 3.57.

LUSTRE, vitreous. TRANSPARENT to translucent.

STREAK, white or yellowish. TENACITY, brittle.

COLOR, yellowish-green to brownish-red.

BEFORE BLOWPIPE, ETC.—Loses color, whitens, but is infusible unless proportion of iron is large, when it fuses to a magnetic globule. Soluble in hydrochloric acid with gelatinization of silica.

SIMILAR SPECIES.—Diffs by gelatinization from green granular pyroxene. Is harder than apatite and less fusible than tourmaline.

REMARKS.—Of igneous origin, occurring in basalts, trapps and crystalline schists, associated with such minerals as pyroxene, enstatite, amphibole, labradorite, chromeite, etc. By alteration of its ferrous iron and by hydration forms limonite and serpentine, and the excess of magnesium usually forms magnesite. Further change may alter the serpentine to magnesite, leaving quartz or opal. Found at Thetford, Vt., Webster, N. C., Waterville, N. H., also in Virginia, Pennsylvania, New Mexico, Oregon, etc. Small gems are found in the garnet and sapphire regions of New Mexico, Arizona, Colorado, and Montana.

USES.—Transparent varieties are sometimes cut as gems.
PHENACITE.

Composition: \( \text{Si}_2\text{Al}_2\text{Si}_4\text{O}_{12} \) (GIO 45.5%, SiO 54.5% per cent.),

General Description: Colorless, transparent, rhombohedral crystals, usually small. Sometimes yellowish and sometimes in prismatic forms. Extremely hard.


Before Blowpipe, Etc.: Infusible and unaffected by acids. Made dull blue by cobalt solution.

Remarks: Occurs with amazon stone, quartz, topaz, emerald, etc., and is sometimes used as a gem.

WERNERITE.—Scapolite.


General Description: Coarse, thick, rough, tetragonal crystals, usually quite large and dull and of some gray, green, or white color. Cleavage surfaces have a characteristic fibrous appearance. Also in columnar and granular masses.

Crystallization: Tetragonal \( \epsilon = 0.438 \), \( I \perp I = 156^\circ 15' \). \( I \perp 1 = 121^\circ 48' \). Usually the two prisms and the pyramid.

Physical Characters. H., 5 to 6. Sp. gr., 2.66 to 2.73.

Lustre, vitreous to dull. Opaque to translucent. Tenacity, brittle.

Streak, white. Color, gray, green, white, bluish, reddish.

Cleavage, parallel to both prisms.

Before Blowpipe, Etc.: Fuses with intumescence to a white glass containing bubbles. Imperfectly soluble in hydrochloric acid.

Remarks: Wernerite has been formed by heat at or near fusion. It is most abundant in granular limestone near contact with granite or similar rock. It occurs with pyroxene, apatite, garnet, zircon, biotite, etc., and is changed to pinite, mica, talc, etc., by atmospheric influence. Especially abundant at Bolton, Mass. Other localities common in New England, New York, New Jersey and elsewhere.

VESUVIANITE.—Idocrase.

Composition: \( \text{Ca}_2\text{Al}_2(\text{OH})_6\text{Si}_2\text{O}_7 \), or perhaps \( \text{HCA}_2(\text{Al} \cdot \text{Fe})_6\cdot(\text{OH})_6(\text{SiO}_4)_6 \), with replacement of Ca by Mn, and Al by Fe.
GENERAL DESCRIPTION.—Brown or green square and octagonal prisms and radiated columnar masses. Less frequently in pyramidal forms or granular or compact.

CRYSTALLIZATION.—Tetragonal \( c = 0.537 \). \( a \times b = 129^\circ 21' \). \( c \times a = 142^\circ 45' \). Commonly prismatic with base and pyramid or sometimes pyramidal. Prismatic faces often vertically striated.

Lustre, vitreous to resinous. Translucent to opaque.
Streak, white. Tenacity, brittle.
Color, brown or green, rarely yellow or blue. Dichroic.
Cleavage, indistinct, prismatic and basal.

Before Blowpipe, Etc.—Fuses easily with intumescence to a green or brown glass. At high heat yields water in the closed tube. Very slightly affected by hydrochloric acid, but after ignition is dissolved leaving a gelatinous residue.

Similar Species.—The crystals and the columnar structure distinguish it from epidote, tourmaline, or garnet. The colors are not often like those of pyroxene.

Remarks.—Vesuvianite occurs most frequently in metamorphic rocks, granular limestone, serpentine, chlorite, gneiss, etc., with garnet, muscovite, calcite, etc. It alters to talc, serpentine and calcite. Found at Parsonsfield and Rumford Falls, Me., Warren, N. H., Newton, N. J., Amity, N. Y. Also in California, Ontario and Quebec.

ZIRCON.—Hyacinth.

Composition. —ZrSiO₄ (ZrO 67.2, SiO₂ 32.8 per cent.).

General Description.—Small, sharp cut, square prisms and pyramids with adamantine lustre and brown or grayish color. Sometimes in large crystals and in irregular lumps and grains.
SILICA AND THE SILICATES.

CRYSTALLIZATION.—Tetragonal \( c = 0.640 \). \( 1 \wedge 1 = 123^\circ 19' \)
\( 3 \wedge 3 = 96^\circ 51' \). Pyramid faces sometimes convex.

Physical Characters. H., 7.5. Sp. gr., 4.68 to 4.70.
LUSTRE, adamantine. TRANSPARENT to opaque.
STREAK, white. TENDACITY, brittle.
COLOR, brown, reddish gray, colorless, green, yellow.
CLEAVAGES, imperfect, parallel to both pyramid and the prism.

BEFORE BLOWPIPE, ETC.—Infusible, losing color and sometimes
becoming white. Insoluble in acids or in soda.

REMARKS.—Zircon is one of the first formed rock constituents, and is common as an
enclosure in the others, especially the older eruptive rocks, granular limestone, schists,
gneiss, syenite, granite, and iron ore. It is also found in alluvial deposits.
Zircons have been mined at Green River, Henderson county, N. C., where they are
especially abundant. Specimen localities are common throughout the United States
and Canada.

USES.—As a source of zirconium oxide used in one variety of
incandescent light. Transparent, red and brown varieties are cut
under the name of hyacinth. Colorless or smoke varieties are called
jargon, and are comparatively worthless.

TOPAZ.

COMPOSITION.—\( \text{Al}_{12} \text{Si}_{4} \text{O}_{22} \text{F}_{10} \) or \( \text{Al}(\text{Al}(\text{O.F})_{4})\text{SiO}_{4} \).

GENERAL DESCRIPTION.—Hard, colorless or yellow transparent
orthorhombic crystals with easy basal cleavage. Also massive in
columnar aggregates, and as rolled fragments and crystals in allu-
vial deposits.

THE LOCKWOOD MEMORIAL LIBRARY
Crystallization.—Orthorhombic. \( \alpha : \beta : \gamma = 0.529 : 1 : 0.477 \). 
\( \alpha \wedge \beta = 124^\circ 17' \), \( \alpha - \beta \wedge \gamma = 86^\circ 49' \). \( \alpha \wedge \gamma \) (macro) = 141°. \( \beta \wedge \gamma \) (macro) = 130° 25'. \( 4 - \gamma \wedge 4 - \gamma \) top = 55° 19'.

Prisms often vertically striated. Crystals rarely double terminated. From predominance of \( \alpha - \beta \) the section is often nearly square.

**Physical Characters.** H., 8. Sp. gr., 3.4 to 3.65.

- **Lustre,** vitreous. **Transparent** to nearly opaque.
- **Streak,** white. **Tenacity,** brittle.
- **Color,** colorless, yellow, pale-blue, green, white, pink.
- **Cleavage,** basal perfect.

**Before Blowpipe, Etc.—**Infusible, but yellow varieties may become pink. With cobalt solution the powder becomes blue. Slowly dissolved in borax. If powdered and heated with previously fused salt of phosphorus in open tube the glass will be etched. Insoluble in acids.

**Remarks.—**Probably always formed under the influence of heat. Occurs with minerals of similar origin in granite and gneiss, or less frequently in cavities in volcanic rock. Associates are the granite minerals and apatite, fluorite, cassiterite, beryl, zircon, etc.

Fine crystals of Topaz are found at Deseret, Utah, at Crystal Park, Cheyenne, and Devil's Head Mountain, Colo., Nathrop, Cal., Stoneham, Me., and Bald Mountain, N. H. Gems are also obtained from Siberia, Brazil, Japan, Australia, Mexico and other countries.

**Uses.—** Transparent varieties are cut as gems.
SILICA AND THE SILICATES.

ANDALUSITE.—Chiastolite.

COMPOSITION.—Al₂(AlO₃)SiO₄. (Al₂O₃ 63.2, SiO₂ 36.8 per cent.)

GENERAL DESCRIPTION.—Coarse, nearly square prisms of pearl gray or pale red color, or in very tough, columnar or granular masses. An impure soft variety (chiastolite) occurs in rounded prisms, any cross section of which when polished shows a white cross or other geometric figure, due to the symmetrical deposition of the impurities.

CRYSTALLIZATION.—Orthorhombic. \( a:b:c = 0.986:1:0.702 \), \( \alpha = 90°\ \ 48' \), \( \beta \equiv 1 - 2 = 144°\ \ 50' \).


LUSTRE, titreous. TRANSPARENT to opaque.

STREAK, white. TENACITY, brittle to tough.

COLOR, rose-red, flesh-red, violet, pale green, white, pearl-gray.

Cleavage, prismatic, imperfect at angle of 90° 48'.

Before Blowpipe, Etc.—Infusible. In powder becomes blue with cobalt solution. Insoluble in acids.

REMARKS.—It occurs in clay slates and in gneiss and schists with cyanite, fibrolite, quartz, etc. It alters rather readily to cyanite or kaolin. Found in many localities in the New England States, also in Pennsylvania and California. Foreign localities are numerous. Transparent crystals are found in Minas Gerais, Brazil.
SILLIMANITE or FIBROLITE.

Composition.—Al₂SiO₃.

General Description.—Long, almost fibrous orthorhombic crystals, and fibrous or columnar masses of brown or gray color.


Before Blowpipe, etc.—In fusible, becomes dark blue with cobalt solution. Insoluble in acids.

Remarks.—Chiefly found in mica schist, gneiss, etc. Sometimes with andalusite.

Uses.—In the stone age it was used for tools, weapons, etc., being second only to jade in toughness.

DATOLITE.

Composition.—Ca₂(OH)₂SiO₄.

General Description.—Highly modified, glassy, monoclinic crystals. Usually colorless, but also white or greenish. Also in compact, dull, white or pink masses, resembling unglazed porcelain.

Crystallization.—Monoclinic. β = 89° 51'. a: b: c = 0.634: 1: 1.266. l. = 115° 13'.

Physical Characters. H., 5 to 5.5. Sp. gr., 2.9 to 3.

Lustre, vitreous. Translucent to nearly opaque.

Streak, white. Tenacity, brittle.

Color, colorless, white, greenish.

Before Blowpipe, etc.—In forceps or on charcoal fuses easily to a colorless glass, and if mixed with a flux of acid potassium sulphate and calcium fluoride and a little water it will color flame green. In closed tube yields water at a high heat. Soluble in hydrochloric acid, with gelatinization.
SIMILAR SPECIES.—Differs from the zeolites in crystalline form and flame.

REMARKS.—It is a secondary mineral found in igneous rocks and sometimes in metallic veins. Usually occurs with the zeolites, prehnite, calcite, etc. Found at Bergen Hill and Paterson, N. J.; at Harford, Tariffville and Roaring Brook, Conn. Also in New York, Michigan, Massachusetts, California, etc.

EPIDOTE.

COMPOSITION.—Ca₂Al₂(AlO₂)(SiO₄)₉ with some iron replacing aluminum.

GENERAL DESCRIPTION.—Coarse or fine granular masses of peculiar yellowish-green color, sometimes fibrous. Also in monoclinic crystals and columnar groups, from yellow-green to blackish-green in color.

CRYSSTALLIZATION.—Monoclinic. \( \beta = 64° 37' \)  \( a : b : c = 1.579 \)  \( 1 : 1.804 \)  \( 1 : 1 = 109° 31' \). Crystals abnormally long in direction of ortho axis.

PHYSICAL CHARACTERs.  H., 6 to 7.  Sp. gr., 3.25 to 3.5.

LUSTRE, vitreous.  TRANSPARENT to opaque.

STREAK, white.  TENACITY, brittle.

COLOR, yellowish-green to nearly black and nearly white, also red and gray.  CLEAVAGE, basal, easy.

BEFORE BLOWPIPE, ETC.—Fuses easily with intumescence to a dark, usually slightly magnetic, globule. At high heat yields water. Slightly soluble in hydrochloric acid, but if previously ignited, it dissolves, leaving gelatinous silica.

REMARKS.—Formed chiefly by alteration of the feldspars, hornblende or biotite, etc., and is common in many crystalline rocks, often accompanying beds of iron in these rocks. It is not readily altered. Common throughout New England and many of the western States.
ALLANITE.

Composition.—Analogous to epidote, but a silicate of the cerium and yttrium groups with lime and iron.

General Description.—Pitch black or brownish embedded veins and masses and flat tabular or prismatic monoclinic crystals.


Before Blowpipe, Etc.—Fuses very easily, becoming strongly magnetic, and at high temperature yielding water. Usually gelatinizes with hydrochloric acid, but after ignition is insoluble.

PREHNITE.

Composition.—H₂Ca₂Al₂(SiO₄)₃.

General Description.—Hard green to grayish-white vitreous masses, frequently reniform or botryoidal, or as crust or lining to cavities, and usually with surface crystalline or studded with tabular and barrel-shaped orthorhombic crystals, usually united by the basal planes.

Physical Characters. H., 6 to 6 5. Sp. gr., 2 8 to 2 95.

Lustre, vitreous. Translucent.

Streak, white. Tenacity, brittle.

Color, light to dark green or grayish-white. Cleavage, basal.

Before Blowpipe, Etc.—Easily fusible to a whitish glass containing bubbles. In closed tube yields a little water. Soluble in hydrochloric acid, and after fusion is soluble with a gelatinous residue.

Similar Species.—Resembles calamine or green smithsonite somewhat, but is more easily fused, and does not gelatinize unless previously ignited.

Remarks.—Occurs in granite gneiss, trap, syenite, etc., as a secondary mineral derived from their alteration, and associated with other secondary minerals as datolite or the zeolites. Bergen Hill and Paterson, N. J., have furnished a few gem stones. Other localities are Farmington, Conn., the Tamarack and Quincy copper mines, Mich., Perry, Me., and Westport, N. Y.

Uses.—To a limited extent has been cut as a gem.

BASIC OR SUBSILICATES.

Made a division by Dana because their constitution is not definitely settled, though probably each belongs to one of the preceding groups.
SILICA AND THE SILICATES.

Here are described CHONDRODITE, TOURMALINE, and STAUROLITE.

CHONDRODITE.

COMPOSITION. — H₁₃Mg₃₂Si₁₄O₃₄F₈, or (Mg₂Fe)₁₃(Mg₂F)₁₆(MgOH)₁₈(SiO₄)₁₂ with some iron replacing magnesium.

GENERAL DESCRIPTION. — The chemical compound occurs as three crystallographically distinct species, chondrodite, humite, clinohumite. Chondrodite proper consists of compact brown masses or disseminated grains and yellowish-brown to red, monoclinic, pseudo orthohombic, crystals of great complexity.


BEFORE BLOWPIPE, Etc. — Infusible, sometimes blackens and then turns white. Fused with powdered salt of phosphorus glass will yield fluorine. Soluble in hydrochloric acid with gelatinization.

REMARKS. — Chiefly found in crystalline limestone or with other magnesium minerals. Alters to serpentine.

TOURMALINE. — Schorl.

COMPOSITION. — R₃B₃₂Si₃₂, R chiefly Al, K, Mn, Ca, Mg, Li.

GENERAL DESCRIPTION. — Prismatic crystals, the cross sections of which frequently show very prominently a triangular prism. Color, usually some dark smoky or muddy tint of black, brown or blue, also bright green, red, and blue, or rarely colorless. Sometimes the centre and outer shell are different colors, as red and green. Sometimes the color is different at two opposite ends. Occurs also columnar in bunches or radiating aggregates and in compact masses.

CRystallization. — Hexagonal. ϵ = 0.448. R = 135° 8', -2 = 105°. 1 = -2 = 141° 30'. Usually prismatic, trigonal.
prism often predominates. Hemimorphic. Cross section 3, 6 or 9 sided.

**Physical Characters.** H. 7 to 7.5. Sp. gr., 2.98 to 3.20.
Lustre, vitreous or resinous. Transparent to opaque.
Streak, white. Tenacity, brittle.
Color, black, brown, green, blue, red, colorless.
Cleavage, difficult, parallel to \( R \) and \( \{\overline{2}\} \).

Before Blowpipe, Etc.—Usually fuses, sometimes very easily.
With a paste of \( \text{KHSO}_4 \cdot \text{CaF}_2 \) and water it yields a green flame.
Insoluble in acids, but after strong ignition gelatinizes.

**Similar Species.**—Differs from hornblende in hardness, crystalline form and absence of prismatic cleavage. Differs from garnet or vesuvianite in form, difficult fusion, and green flame.

Remarks.—Occurs in crystalline rocks: granite, gneiss, mica-schists, crystalline limestone, etc., with many associates. By alteration it forms cookeite, lepidolite, talc, and chlorite. Tourmalines of gem value have been obtained in some quantity from Paris, Auburn, and Hebron, Me., and from Riverside county, California.

Uses.—Transparent, red, yellow, and green varieties are cut as gems. Thin plates are used to polarize light.

**Staurolite.**

Composition.—\( \text{Fe} (\text{AlO})_4 (\text{AlOH}) (\text{SiO}_4)_6 \), but varying. May contain Mg or Mn.

General Description.—Dark brown to nearly black orthorhombic prisms often twinned, or in threes, crossing at 90° and 120°. Surfaces bright if unaltered. Very hard.

\[ \text{Fig. 325.} \quad \text{Fig. 326.} \]

![Diagram](image)

Crystallization.—Orthorhombic. \( a : b : c = 0.473 : 1 : 0.683 \).
\( I \wedge I = 129° \ 20' \). \( O \wedge 1 - 1 = 124° \ 49' \).
SILICA AND THE SILICATES


Before Blowpipe, etc.—Infusible, except when manganiferous. Partially soluble in sulphuric acid.

Remarks.—Occurs chiefly in schistose rock with andalusite, garnet, tourmaline, cyanite, etc., but is not found in schists rich in amphibole. Abundant at Claremont, Grantham, and Lisbon, N. H., at Windham, Me., Chesterfield, Mass., Litchfield, Conn., and several other localities in New England. Also in New York, North Carolina, Georgia, and Pennsylvania.

HYDROUS SILICATES.

Compounds containing water of crystallization with certain closely related species in which the water plays the part of a base or is in doubt.

The minerals described here are:
Zolite Division.—Aphylite, Heulandite, Stilbite, Chabazite, Analcite, Natrolite.
Mica Division.—Muscovite, Biotite, Phlogopite, Lepidolite, Prochiorite.
Serpentine and Talc Division.—Serpentine, Talc, Sepiolite.
Kaolin Division.—Kaolinite, Pyrophyllite.

ZEOLITES.

The zeolites are a group of silicates, all of which are of a secondary origin and are usually found in the seams or cavities of basic igneous rocks, such as basalt or diabase, and less frequently in granite or gneiss.

They are similar to the feldspars in constituents and combining ratios, and are chiefly formed from the feldspars and from nephelite, leucite, etc. Most of them fuse easily, with appearance of boiling, and all contain water of crystallization. The hardness varies from 3.5 to 5.5, and the specific gravity from 2.0 to 2.4.

APOPYLLITE.

Composition.—\( \text{H}_4\text{K}_2\text{Ca}_6(\text{SiO}_3)_6 + 9\text{H}_2\text{O} \), with replacement by fluorine.
GENERAL DESCRIPTION.—Colorless and white or pink, square crystals. Sometimes flat, square plates or approximate cubes; at other times pointed and square to nearly cylindrical in section. Notably pearly on base or may show in vertical direction a peculiar—fish eye—internal opalescence. Found occasionally in lamellar masses.

CRYSTALLIZATION.—Tetragonal. \( c = 1.252 \). \( 1 \wedge i = 104^\circ \). \( O \wedge i = 119^\circ 28' \). Prism faces irregularly striated.

Physical Charactars. \( H. \), 4.5 to 5. Sp. gr., 2.3 to 2.4.
Lustre, vitreous or pearly. Transparent to nearly opaque.
Streak, white.
Tenacity, brittle.
Color, colorless, white, pink or greenish. Cleavage, basal.

BEFORE BLOWPIPE, ETC.—Exfoliates and fuses to a white enamel. In closed tube yields water. In hydrochloric acid forms flakes and lumps of jelly.

REMARKS.—Occurs in volcanic rocks and mineral veins with zeolites, datolite, pectolite, etc. It is a secondary mineral.

HEULANDITE.

COMPOSITION.—\( \text{H}_2\text{CaAl}_4\text{(SiO}_3\text{)}_6 = 3\text{H}_2\text{O} \).

GENERAL DESCRIPTION.—Monoclinic crystals, with very bright, pearly cleavage.
slices. The face parallel to cleavage is also bright pearly, and is less symmetrical than the corresponding face of stilbite as is shown in Figs. 330 and 331.


Before Blowpipe, Etc.—Exfoliates and fuses easily to white enamel. In closed tube yields water. Soluble in hydrochloric acid, with residue of fine powder.

STILBITE.—Desmine.

Composition—$H_2(Na_{x}Ca)Al_{2}(SiO_4)_2 + 4H_2O$.

General Description.—Tabular crystals, of white, brown or red color, pearly in lustre on broad faces and frequently united by these faces in sheaf-like groups. Sometimes globular or radiated. Crystals are apparently orthorhombic, but really complex monoclinic twins.

Physical Characters. H., 3.5 to 4. Sp. gr., 2.09 to 2.2.

Lustre, vitreous or pearly.

Streak, white.

Color, yellow, brown, white, red.

Cleavage, parallel to pearly face.

Before Blowpipe, Etc.—Swells and exfoliates in fan shapes, and fuses easily to a white, opaque glass. Yields water in closed tube. Soluble in hydrochloric acid, with a pulverulent residue.

Remarks.—Occurs with other zeolites.

CHABAZITE.

Composition.—Near $(H_2K)_xCaAl_{2}(SiO_4)_2 + 6H_2O$.

General Description.—Simple rhombohedral crystals, almost cubic, also in modified forms and twins. Faces striated parallel to edges.

Color, white, pale-red and yellow.

Crystallization.—Hexagonal. $c = 1.086$. $R \perp R = 92^\circ 46^\prime$. $R \perp \beta = 127^\circ 25^\prime$.


Before Blowpipe, Etc.—Instumesces and fuses to a nearly white glass containing bubbles. Yields water in closed tube. Soluble in hydrochloric acid, leaving flakes and lumps of jelly.
ANALCITE.

Composition.—NaAl(SiO₃)₂ + H₂O.
General Description.—Small white or colorless, tetragonal trisoctahedrons (2–2), and occasionally modified by the cube. Less frequently granular and compact.

Physical Characters.—H., 5 to 5.5. Sp. gr., 2.2 to 2.29. Transparent to opaque. Tenacity, brittle.
Lustre, vitreous. Streak, white. Color, white, colorless, greenish, red.

Before Blowpipe, Etc.—Fuses easily and quietly to a clear, colorless glass. Yields water in closed tube. Gelatinizes with hydrochloric acid.

Remarks.—A secondary mineral, usually with other zeolites.

NATROLITE.

Composition.—Na₂Al(AlO)₂(SiO₃)₂ + 2H₂O.
General Description.—Colorless to white, slender, nearly square prisms, with very flat pyramids. Usually in radiating and interlacing clusters and bunches. Also fibrous granular and compact.

Crystallization.—Orthorhombic. a : b : c = 0.979 : 1 : 0.354. l + f = 91° 14'. l + t = 116° 49.'

Physical Characters. H., 5 to 5.5. Sp. gr., 2.2 to 2.25. Transparent to opaque. Tenacity, brittle.
Lustre, vitreous. Streak, white. Color, colorless, white, yellow, red. Cleavage, prismatic.
SILICA AND THE SILICATES.

Before Blowpipe, Etc.—Fuses very easily to a colorless glass. In closed tube, yields water. Soluble in hydrochloric acid, with gelatinization.

Similar Species.—Differs from pectolite in square cross-section and fusion to a clear, colorless glass.

Remarks.—Occurs with other zeolites and with prehnite, calcite and datolite.

THE MICA DIVISION.

Muscovite.—Potash Mica, White Mica, Isinglass.

Composition.—$\text{H}_2(\text{K,Na})\text{Al}_6(\text{SiO}_4)_6$, with some replacement by Mg or Fe.

General Description.—Disseminated scales and crystals, which cleave with great ease into thin, elastic, transparent leaves. Also in masses of coarse or fine scales grouped in globular and plumose forms. Usually gray in color.

Crystallization.—Monoclinic. $\beta = 89^\circ 54'$. $I \times I = 120^\circ 12'$. Crystals usually rhombic or hexagonal in section, with rough faces, and usually tapering. Cleavage is approximately at right angles to the prism.

Physical Characters. H., 2 to 2.5. Sp. gr., 2.76 to 3.

Lustre, vitreous, pearly on cleavage. Transparent in laminae.

Streak, white.

Color, gray, brown, green, yellow, violet, red, black.

Cleavage, basal, eminent.

Before Blowpipe, Etc.—Fuses only on thin edges to a yellowish glass. Insoluble in acids.

Similar Species.—Differs from talc or gypsum in being elastic. Is usually lighter colored than biotite.

Remarks.—Muscovite is of both igneous and secondary origin. It occurs with quartz and feldspars, in granite, gneiss and mica schist and related rocks and more or less disseminated in other rocks, and it also is found formed from cyanite, topaz, feldspars, corundum, etc. The most productive mica mines of the United States are in Mitchell, Yancey, Jackson and Macon Counties, S. C., and Groton, N. H. Other large deposits exist at Grafton, N. H.; Las Vegas and Cribbenville, N. M., and Deadwood and the Black Hills, S. D., many of which are intermittently mined. Also in Nevada, California, Colorado and Pennsylvania in quantity and quality fit for use. Large quantities of mica are annually imported from India.

Uses.—As transparent material in doors of furnaces, stoves, etc.
Descriptive Mineralogy.

As insulating material in electrical apparatus, especially on the armatures of dynamos. As coating for spangling wall papers and some fabrics such as brocade.

Biotite.—Black Mica, Magnesium Mica.

Composition.—An orthosilicate approximating \( \text{H}_2\text{K}_2\text{Mg}\text{Fe}_2\text{Al}_2\text{Si}_4\text{O}_{10} \).

General Description.—Like muscovite, but usually dark green to black in color. It cleaves into thin, elastic leaves.

Physical Characters. H., 2.5 to 3. Sp. gr., 2.7 to 3.1.
Lustre, pearly, vitreous, submetallic. Transparent to opaque.
Streak, white.
Color, commonly black to green. Cleavage, basal, eminent.

Before Blowpipe, Etc.—Whitens and fuses on thin edges. Decomposed by boiling sulphuric acid, with separation of scales of silica.

Remarks.—Occurrence and associates like muscovite, but is more common than muscovite in the eruptive rocks. It is found in most of the muscovite localities, and is a very common constituent of rocks and soils in the form of small scales. It alters more readily than muscovite to chlorite or to epidote, quartz and iron oxide.

Phlogopite.—Amber Mica.

Composition.—\( \text{R}_2\text{Mg}_2\text{Al}_3\text{Si}_4\text{O}_{10} \), where \( R = \text{H, K, MgF} \).

General Description.—Large and small, brownish-red to nearly black crystals. Usually oblong, tapering, six-sided prisms. Thin plates often show a six-rayed star by transmitted light.

Physical Characters. H., 2.5 to 3. Sp. gr., 2.78 to 2.85.
Lustre, pearly or submetallic. Transparent to translucent.
Streak, white.
Color, yellowish-brown, brownish-red, green, colorless.
Cleavage, basal eminent.

Before Blowpipe, Etc.—Whitens and fuses on thin edges. In closed tube yields water. Soluble in sulphuric acid with separation of scales of silica.

Remarks.—Phlogopite is usually found in crystalline limestones or in serpentine. It occurs in enormous crystals in Ontario and Quebec, and in various localities through New York and New Jersey.

Uses.—It is largely used in electrical work.
SILICA AND THE SILICATES.

LEPIDOLITE.—Lithia Mica.

Composition.—$R_2Al(SiO_3)_4$, $R = Li, K, NaF$, etc.

General Description.—Scaly, granular masses of pale-pink color and gray crystals, with easy mica cleavage into elastic plates.


Before Blowpipe, Etc.—Fuses easily to white glass. Colors flame purple-red. Partially soluble in hydrochloric acid.

PROCHLORITE.

Composition.—$H_{10}(Fe, Mg)Al_2Si_3O_{9}$.

General Description.—Dark-green masses, composed of coarse to very fine scales. Also tabular and curiously twisted six-sided crystals, which easily cleave into thin plates which are not elastic. Also frequently distributed as a pigment in other minerals.

Physical Characters. H., 1 to 2. Sp. gr., 2.78 to 2.96.

Lustre, feebly pearly. Translucent to opaque.

Streak, white or greenish. Tenacity, flexible, non-elastic.

Color, grass-green to blackish-green.

Cleavage, basal. Feel, slightly soapy.

Before Blowpipe, Etc.—Whitens and fuses to a nearly black glass. In closed tube yields water. Soluble in sulphuric acid.

Remarks.—Formed by decomposition of mica and aluminous varieties of amphibole, garnet, pyroxene, etc., and occasionally found in crystalline schists and serpentines.

SERPENTINE AND TALC DIVISION.

SERPENTINE.

Composition.—$H_2Mg_5Si_2O_9$, with replacement by Fe.

General Description.—Fine granular masses or microscopically fibrous. Also foliated and coarse or fine fibrous. Color, green, yellow or black, and usually of several tints dotted, striped and clouded. Very feeble, somewhat greasy lustre and greasy feel. Crystals unknown.

Physical Characters. H., 2.5 to 4. Sp. gr., 2.5 to 2.65.

Lustre, greasy, waxy or silky. Translucent to opaque.

Streak, white. Tenacity, brittle.

Color, green to yellow, brown, red, black, variegated.
BETORE BLOWPIPE, Etc.—Fuses on edges. In closed tube, yields water. In cobalt solution becomes pink. Soluble in hydrochloric acid, with a residue.

REMARKS.—A secondary mineral formed from chrysolite, amphibole, pyroxene, enstatite, etc. It is associated with these and with magnetite, garnierite, chromite, dolomite, etc. Serpentine asbestos is not produced in the United States, but large amounts are annually imported from the Thetford and Coleraine mines of Quebec. Massive serpentine, or Verd Antique marble, is quarried at Milford, Conn.

USES.—It takes a fine polish, and is used for ornamental work, as table-tops, mantels, etc. The fibrous variety, chrysotile, is used as asbestus.

TALC.—Steatite, Soapstone.

COMPOSITION.—\( \text{H}_2\text{Mg}_6\text{(SiO}_3\text{)}_4 \).

GENERAL DESCRIPTION.—A soft, soapy material, occurring foliated, massive, and fibrous, with somewhat varying hardness. Usually white, greenish or gray in color. Crystals almost unknown.

Physical Characters. H., 1. Sp. gr., 2.55 to 2.87.
LUSTRE, pearly or wax-like. TRANSLEUCENT.
STREAK, white. TENACITY, sectile.
COLOR, white, greenish, gray, brown, red.
CLEAVAGE, into non-elastic plates. FEEL, greasy.

BETORE BLOWPIPE, Etc.—Splits and fuses on thin edges to white enamel. With cobalt solution, becomes pale pink. Insoluble in acid.

VARIETIES.

 Foliated Talc.—H = 1. White or green in color. Cleavable into non-elastic plates.
 Soapstone or Steatite.—Coarse or fine, gray to green, granular masses. H., 1.5 to 2.5.
 French Chalk.—Soft, compact masses, which will mark cloth.
 Agolite.—Fibrous masses of H. 3 to 4.
 Reusselaerite.—Wax-like masses. H., 3 to 4. Pseudomorphous after pyroxene.

SIMILAR SPECIES.—Softer than micas or brucite or gypsum.
SILICA AND THE SILICATES.

Further differentiated by greater infusibility, greasy feel, and the flesh-color obtained with cobalt solution.

Remarks.—Talc is an alteration product of pyroxene, amphibole, muscovite, enstatite, etc., and occurs with dolomite, serpentine, magnesite, tourmaline, etc. An immense deposit at Gouverneur, N. Y., is mined, and the total output is ground for use in paper-making, etc. Large soapstone quarries are worked at Francesstown, N. H. Chester, Saxon’s River, Cambridgeport and Perkinsville, Vt., Coopstown, Md., and Webster, N. C. Massachusetts, New Jersey, Pennsylvania, Virginia and Georgia are also producing States.

Uses.—Soapstone is cut in slabs for hearths, linings of stoves, sinks and other articles of refractory nature. It is ground and moulded into gas-tips, and used as a preparation for blackboards and as a fine quality of tinted plastering. Agolite is used to mix with wood pulp in paper manufacture. Talc is used in soap, as a dressing for fine skin and leather, as a lubricant and as pencils, tailors’ chalk, etc.

SEPIOLITE.—Meerschaum.

Composition.—$\text{H}_4\text{Mg}_2\text{Si}_4\text{O}_{10}$.

General Description.—Soft compact white, earthy to clay-like masses, of very light weight. Rarely fibrous.

Physical Characters. H., 2 to 2.5. Sp. gr., 1 to 2. Lustre, dull. Opaque.
Streak, white. Tenacity, brittle.
Color, white, gray, rarely bluish-green. Feel, smooth.

Before Blowpipe, Etc.—Blackens, yields odor of burning and fuses on thin edges. In closed tube yields water. With cobalt solution becomes pink. In hydrochloric acid gelatinizes.

Similar Species.—Resembles chalk, kaolinite, etc., but is characterized by lightness and gelatinization with acids.

Remarks.—Possibly formed from Magnesite. The name “meerschaum” refers to the fact that it will float on water when dry. Most of the material used for pipes is obtained from Turkey. It occurs in large amount in Spain, and in smaller quantities in Greece, Morocco and Moravia. There are no productive American localities.

Uses.—As material for costly tobacco pipes. In Spain it is a building stone. In Algeria it is used as a soap.
KAOLINITE—Kaolin, China Clay.

Composition. $H_4Al_2Si_4O_{10}$, with more or less iron, silica, and organic matter.

General Description. Compact and clay-like or loose and mealy masses of pure white, yellow, brown, red and blue color. Also in white, scale-like crystals, with the lustre of satin. Usually unctuous and plastic.

Physical Characters. H., 2 to 2.5. Sp. gr., 2.6 to 2.65.
Lustre, dull or pearly. Opaque or translucent.
Streak, white or yellowish. Tenacity, brittle.
Color, white, yellow, brown, red and blue.

Before Blowpipe, Etc.—Infusible. Yields water in closed tube. With cobalt solution, becomes deep blue. Decomposed by sulphuric acid, but insoluble in nitric or hydrochloric acids.

Similar Species. It is not harsh like infusorial earth and is softer than bauxite.

Remarks. Kaolinite is formed by alteration of feldspars and other silicates. Carbonated waters remove the basic oxides and part of the silica. Its associates are feldspars, corundum, diaspore, topaz, etc. In the United States kaolinite is mined at Okanumka, Lake County, Florida, at Sylva, Dillsboro and Webster, N. C., and at several places in New Castle County, Del., and Chester and Delaware Counties, Pa. Kaolin of poorer quality is obtained in Ohio and New Jersey, and many other deposits are known throughout the Atlantic States.

Uses. It is the chief constituent of porcelain, chinaware, ornamental tiles, etc.

PYROPHYLLITE.—Pencil Stone.

Composition. $NaAl_2(SiO_3)_2$.

General Description. Radiated foliæ or fibres and compact masses of soapy feeling and soft and smooth like talc.

Physical Characters. Translucent to opaque. Lustre, pearly or dull. Color, white, greenish, brownish or yellow. Streak, white. H., 1 to 2. Sp. gr., 2.5 to 2.9. Flexible.

Before Blowpipe, Etc.—Whitens and fuses on the edges, and often swells and spreads like a fan. In closed tube yields water. Partially soluble in sulphuric acid.

Remarks. Occurs in large beds and as gangue of cyanite.

Uses. Extensively manufactured into slate pencils.
TITANO-SILICATES.

TITANITE.—Sphene.

Composition.—CaSiTiO₄.

General Description.—Brown, green or yellow, wedge-shaped or tabular monoclinic crystals, with adamantine or resinous lustre. Also compact, massive. Rarely lamellar.

Crystallization.—Monoclinic. \( \beta = 60^\circ \) 17'. \( a:b:c = 0.755:1:0.854 \). \( I \perp I = 113^\circ \) 31'. \( O \perp -1 = 121^\circ \) 44'. Crossed and contact twins occur. Simple crystals, often flattened parallel to the vertical axis. Sometimes prismatic or pyramidal.

Physical Characters. H., 5 to 5.5. Sp. gr., 3.4 to 3.56.

Lustre, adamantine or resinous. Transparent to opaque.

Streak, white.

Color, brown to black, yellow, green, rarely rose-red.

Cleavage, prismatic easily, pyramidal less easily.

Before Blowpipe, Etc.—Fuses, with intumescence, to a dark glass, sometimes becoming yellow before fusion. In salt of phosphorus after reduction, the bead is violet. Partly soluble in hydrochloric acid, completely so in sulphuric acid.

Remarks.—Occurs both as original and secondary mineral derived from alteration of menaccaine, brookite, etc. Its associates are pyroxene, amphibole, feldspars, zircon, iron ores, apatite, etc. Good gem stones have been found at Brewster, N. Y.; Bridgewater, Pa., and Magnet Cove, Ark.

Uses.—As a gem.
PART IV.

DETERMINATIVE MINERALOGY.

CHAPTER XXXII.

TABLES FOR RAPID DETERMINATION OF THE
COMMON MINERALS.

Minerals of metallic lustre, and non-metallic minerals of colored streak are more rapidly determined by hardness, color, and streak, than by a blowpipe method, and if supplemented by a little experience and by frequent reference to a descriptive text-book, such a method is equally safe. Minerals which have in general vitreous or sub-vitreous lustre, white or gray streak, and often great diversity of color in the same species, need a much more thorough eye-knowledge in order to satisfactorily use a method of "external signs," while to any one possessing even an elementary knowledge of blowpipe analysis, the blowpipe method is for these minerals nearly as rapid and much more safe.

For accurate results these precautions must be taken:

1. All tests should be made upon homogeneous material, preferably crystalline, as the tests may be unreliable if the material is impure, unless the effect of the impurity upon the test is known.

2. The classifying tests must be decided, and if weak should be attributed either to improper manipulation, or to the presence of some accidental impurity.

3. The lustre must be observed on a fresh fracture.

4. The determination must be confirmed by reference to the description of the species, and, when possible, by comparison with known specimens.

(320)
GENERAL TABLE.

I. Minerals of Metallic or Submetallic Lustre.
   1. Color, dark gray to iron black.
   2. Color, silver white, tin white and light steel gray.
   3. Color, lead gray.
   4. Color, brass yellow, golden yellow, bronze or copper red.

II. Blowpipe Confirmations for Table I.
   1. On charcoal with reducing flame a garlic odor is produced.
   2. On charcoal with reducing flame the mineral becomes magnetic but no garlic odor is observed.
   3. With bismuth flux coatings or colored flames are produced.
   4. Not included in 1, 2 or 3.

III. Minerals without Metallic Lustre.
     Blowpipe Scheme for fusions and solubilities.

IV. Physical Characters, Confirmation Table III.
    1. Minerals with decided taste.
    3. Minerals with white or gray streak.
TABLE I.—MINERALS OF METALLIC OR SUBMETALLIC LUSTRE.


<table>
<thead>
<tr>
<th>Name</th>
<th>Habit</th>
<th>Streak or Powder</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>GRAPHITE</td>
<td>1/2 Black</td>
<td>2.1 to 2.2</td>
<td></td>
<td>Greasy feeling, compact or foliated</td>
</tr>
<tr>
<td>ARGENTITE</td>
<td>2 Dark gray</td>
<td>7.2 to 7.3</td>
<td></td>
<td>Very soft</td>
</tr>
<tr>
<td>STEPHANITE</td>
<td>2 Black</td>
<td>6.3</td>
<td></td>
<td>Rather brittle, somewhat like tremolite</td>
</tr>
<tr>
<td>PYROLUSITE</td>
<td>2 Black</td>
<td>4.8</td>
<td></td>
<td>Fibrous radiating or dense</td>
</tr>
<tr>
<td>POLYBARITE</td>
<td>2 1/2 Black</td>
<td>6 to 6.2</td>
<td></td>
<td>Flat crystals with triangular zoning</td>
</tr>
<tr>
<td>CHALCOCITE</td>
<td>2 1/2 Dark gray</td>
<td>5.5 to 5.6</td>
<td></td>
<td>Often with the green carbonatite</td>
</tr>
<tr>
<td>PYARGYRITE</td>
<td>2 1/2 Purple red</td>
<td>5.7 to 5.9</td>
<td></td>
<td>Usually some red in the color</td>
</tr>
<tr>
<td>BOURNITE</td>
<td>3 Grayish black</td>
<td>5.8 to 6.2</td>
<td></td>
<td>Sometimes crossed “cog-wheel” crystals</td>
</tr>
<tr>
<td>TESORITE</td>
<td>3 Black</td>
<td>5.8 to 6.2</td>
<td></td>
<td>Fine scales or dull black masses</td>
</tr>
<tr>
<td>ENARGITE</td>
<td>3 Black</td>
<td>4.3 to 4.9</td>
<td></td>
<td>Columnar or fine grained</td>
</tr>
<tr>
<td>TETRABEDRITE</td>
<td>4 Black or reddish brown</td>
<td>4.5 to 5.5</td>
<td></td>
<td>Isometric crystals, rarely massive.</td>
</tr>
<tr>
<td>ALBANITE</td>
<td>4 Olive green</td>
<td>4.5</td>
<td></td>
<td>Tetrahedral crystals or fine grained massive</td>
</tr>
<tr>
<td>MANGANITE</td>
<td>4 Dark reddish brown</td>
<td>4.2 to 4.4</td>
<td></td>
<td>Cubic cleavage, brown tarnish</td>
</tr>
<tr>
<td>GYPSITE</td>
<td>5 1/2 Brownish yellow</td>
<td>4.2 to 4.4</td>
<td></td>
<td>Prismatic, vertically striated crystals</td>
</tr>
<tr>
<td>LIMONITE</td>
<td>5 1/2 Yellowish brown</td>
<td>3.6 to 4.1</td>
<td></td>
<td>Needle of acule-like crystals, also velevty and foliated</td>
</tr>
<tr>
<td>WOLFRAMITE</td>
<td>5 1/2 Dark brown</td>
<td>7.2 to 7.3</td>
<td></td>
<td>Frequently radiated, never in crystals</td>
</tr>
<tr>
<td>MANACCANITE</td>
<td>5 1/2 Black or reddish brown</td>
<td>4.5 to 5</td>
<td></td>
<td>Rarer. Large monoclinic crystals</td>
</tr>
<tr>
<td>CHROMITE</td>
<td>5 3/4 Dark brown</td>
<td>4.9 to 4.6</td>
<td></td>
<td>Thin plates, glassy grains and massive</td>
</tr>
<tr>
<td>HAUWHITE</td>
<td>5 1/2 Chestnut brown</td>
<td>4.7 to 4.8</td>
<td></td>
<td>Octahedral grains or massive with serpentine.</td>
</tr>
<tr>
<td>PHILOMELAN</td>
<td>5 1/2 Brownish black</td>
<td>3.7 to 3.7</td>
<td></td>
<td>Twinned square pyramids and granular</td>
</tr>
<tr>
<td>URANKITE</td>
<td>5 1/2 Brownish or greenish black</td>
<td>8.4 to 7</td>
<td></td>
<td>Like a black limonite</td>
</tr>
<tr>
<td>MAGNETITE</td>
<td>6 Black</td>
<td>4.9 to 5.2</td>
<td></td>
<td>Pitch-like mass</td>
</tr>
<tr>
<td>HEMATITE</td>
<td>6 reddish brown</td>
<td>4.5 to 5.3</td>
<td></td>
<td>Magnetic, octahedral, granular, coarse or fine.</td>
</tr>
<tr>
<td>FRANKLINITE</td>
<td>6 Dark brown</td>
<td>5 to 5.2</td>
<td></td>
<td>Massive, brilliant crystals or micaceous</td>
</tr>
<tr>
<td>ALLANITE</td>
<td>6 Gray, brownish or greenish</td>
<td>3.3 to 4.2</td>
<td></td>
<td>Octahedrons, rounded edges</td>
</tr>
<tr>
<td>OCTAHEDRITE</td>
<td>6 Colorless</td>
<td>3.8 to 3.8</td>
<td></td>
<td>Pitch-like lustre</td>
</tr>
<tr>
<td>BROOKITE</td>
<td>6 Pale</td>
<td>3.8 to 4</td>
<td></td>
<td>Small pyramids or tabular crystals</td>
</tr>
<tr>
<td>RUTILE</td>
<td>6 Pale brown</td>
<td>4.2 to 4.25</td>
<td></td>
<td>Opaque crystals sometimes pseudo-hexagonal</td>
</tr>
<tr>
<td>COLUMBITE</td>
<td>6 Brownish red to black</td>
<td>5.5 to 7.5</td>
<td></td>
<td>Prismatized often twinned</td>
</tr>
<tr>
<td>BRAUNITE</td>
<td>6 Brownish black</td>
<td>4.7 to 4.8</td>
<td></td>
<td>Lustre often brilliant</td>
</tr>
</tbody>
</table>

Confirm by Table II.
TABLE I.—Continued.
2. Color, Silver White, Tin White and Light Steel Gray.

<table>
<thead>
<tr>
<th>Name</th>
<th>Hardness</th>
<th>Streak or Powder</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>MERCURY</td>
<td>Liq</td>
<td></td>
<td>13.5</td>
<td>Minute disseminated globules</td>
</tr>
<tr>
<td>TETRADYMITE</td>
<td>1½ Gray</td>
<td></td>
<td>7.2 to 7.6</td>
<td>Flexible, marks paper, sectile.</td>
</tr>
<tr>
<td>BISMUTH</td>
<td>2 Gray</td>
<td></td>
<td>9.7</td>
<td>Arborescent, red tarnish.</td>
</tr>
<tr>
<td>BISMUTHNITE</td>
<td>2 Dark gray</td>
<td></td>
<td>6.4 to 7.2</td>
<td>Needle or hair crystals or massive.</td>
</tr>
<tr>
<td>SYLVESTRE</td>
<td>2 Gray</td>
<td></td>
<td>8 to 8.3</td>
<td>&quot;graphic&quot; crystals.</td>
</tr>
<tr>
<td>TELLURIUM</td>
<td>2½ Tin white</td>
<td></td>
<td>6.1 to 6.3</td>
<td>Granular.</td>
</tr>
<tr>
<td>HESSITE</td>
<td>3 Gray</td>
<td></td>
<td>8.3 to 8.9</td>
<td>Granular massive.</td>
</tr>
<tr>
<td>SILVER</td>
<td>3 Silver white</td>
<td></td>
<td>10.1 to 11.1</td>
<td>Malleable, wire-like plate-like and massive.</td>
</tr>
<tr>
<td>ANALGAM</td>
<td>3 Gray</td>
<td></td>
<td>13.7 to 14</td>
<td>Cus with grating noise.</td>
</tr>
<tr>
<td>BOCKSGITITE</td>
<td>3 Grayish black</td>
<td></td>
<td>5.7 to 5.9</td>
<td>Cross or &quot;Cog-wheel&quot; crystals frequent.</td>
</tr>
<tr>
<td>ANTIMONY</td>
<td>3½ Gray</td>
<td></td>
<td>6.6 to 6.7</td>
<td>Fine granular or feather-like structure.</td>
</tr>
<tr>
<td>ARSENIC</td>
<td>3½ Grayish black</td>
<td></td>
<td>5.9</td>
<td>Rounded crusts, blackish.</td>
</tr>
<tr>
<td>STANINE</td>
<td>4 Blackish</td>
<td></td>
<td>4.3 to 4.5</td>
<td>Massive and intermixed with chalcopyrite.</td>
</tr>
<tr>
<td>PLATINUM</td>
<td>4 Silver white</td>
<td></td>
<td>14 to 19</td>
<td>Malleable grains or lumps.</td>
</tr>
<tr>
<td>IRON</td>
<td>4½ Gray</td>
<td></td>
<td>7.5 to 7.8</td>
<td>Strongly magnetic.</td>
</tr>
<tr>
<td>LEUCOPRASEITE</td>
<td>3½ Grayish black</td>
<td></td>
<td>7 to 7.4</td>
<td></td>
</tr>
<tr>
<td>LINDONITE</td>
<td>3½ Grayish black</td>
<td></td>
<td>4.5 to 5</td>
<td>Octahedral, red tarnish.</td>
</tr>
<tr>
<td>COBALITE</td>
<td>3½ Grayish black</td>
<td></td>
<td>6 to 6.0</td>
<td>Cubes or pyritohedrons.</td>
</tr>
<tr>
<td>SMALTEITE</td>
<td>3½ Black</td>
<td></td>
<td>6.4 to 7.2</td>
<td>Cubic, often with reddish arsenate.</td>
</tr>
<tr>
<td>ARSENOUSPITE</td>
<td>6 Grayish black</td>
<td></td>
<td>5.9 to 6.2</td>
<td>Massive or rhomboic crystals.</td>
</tr>
<tr>
<td>IRIDONINE</td>
<td>6½ Gray</td>
<td></td>
<td>10.3 to 21.2</td>
<td>Flatnosed grains.</td>
</tr>
</tbody>
</table>

Confirm by Table II.
## Table I.—Continued.

### 3. Color, Lead Gray.

<table>
<thead>
<tr>
<th>Name</th>
<th>Hardness</th>
<th>Streak or Powder</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>MOLYBDENITE</td>
<td>1</td>
<td>Bluish lead gray</td>
<td>4.7 to 4.9</td>
<td>Foliated, greasy, green streak on unglazed porcelain.</td>
</tr>
<tr>
<td>LEAD</td>
<td>1½ Gray</td>
<td></td>
<td>11.4</td>
<td>Thin plates or massive.</td>
</tr>
<tr>
<td>STIBNITE</td>
<td>2</td>
<td>Lead gray</td>
<td>4.5</td>
<td>Brilliant prismatic, or confined masses of needle crystals, also columnar. Imbedded needle crystals or massive.</td>
</tr>
<tr>
<td>AKBITE</td>
<td>2</td>
<td>Gray</td>
<td>6.1 to 6.8</td>
<td>Needle or wool-like crystals.</td>
</tr>
<tr>
<td>JANESONITE</td>
<td>2½</td>
<td>Grayish black</td>
<td>5.5 to 6</td>
<td>Cubic cleavage or granular.</td>
</tr>
<tr>
<td>GALENITE</td>
<td>2½</td>
<td>Dark lead gray</td>
<td>7.4 to 7.6</td>
<td>Fine granular.</td>
</tr>
<tr>
<td>CLAUSTHALITE</td>
<td>3</td>
<td>Grayish black</td>
<td>7.6 to 8.3</td>
<td>Fine granular.</td>
</tr>
<tr>
<td>ABSITE</td>
<td>2½</td>
<td>Grayish black</td>
<td>5.9</td>
<td>Botryoidal crust, black tarnish.</td>
</tr>
</tbody>
</table>

Confirm by Table II.

### 4. Color, Brass Yellow, Golden Yellow, Bronze or Copper Red.

<table>
<thead>
<tr>
<th>Name</th>
<th>Hardness</th>
<th>Streak or Powder</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>GOLD</td>
<td>3</td>
<td>Golden yellow</td>
<td>15.4 to 19.2</td>
<td>Malleable grains, scales, wire, etc.</td>
</tr>
<tr>
<td>COPPER</td>
<td>3</td>
<td>Copper red</td>
<td>8.3 to 8.9</td>
<td>Malleable sheets, grains and masses.</td>
</tr>
<tr>
<td>BORNITE</td>
<td>3</td>
<td>Grayish black</td>
<td>4.4 to 4.5</td>
<td>Dark tarnish, but fresh surfaces, bronze red.</td>
</tr>
<tr>
<td>MILLERITE</td>
<td>3</td>
<td>Greenish black</td>
<td>1.6 to 5.6</td>
<td>Hair-like or radiating brassy crystals.</td>
</tr>
<tr>
<td>CHALCOPRITE</td>
<td>4</td>
<td>Greenish black</td>
<td>4.1 to 4.5</td>
<td>Often variegated colors on brassy mass.</td>
</tr>
<tr>
<td>PYRRHOTITE</td>
<td>4</td>
<td>Black</td>
<td>4.85 to 4.64</td>
<td>Magnetic bronze-like masses.</td>
</tr>
<tr>
<td>NICCOLITE</td>
<td>3</td>
<td>Brownish black</td>
<td>7.3 to 7.6</td>
<td>Pale copper red.</td>
</tr>
<tr>
<td>PYRITE</td>
<td>6</td>
<td>Brownish black</td>
<td>4.9 to 5.1</td>
<td>Brassy cubic crystals, nodules, etc.</td>
</tr>
<tr>
<td>MARCASITE</td>
<td>5</td>
<td>Brownish black</td>
<td>4.7 to 4.8</td>
<td>Paler brass color than pyrite usually.</td>
</tr>
</tbody>
</table>

Confirm by Table II.
TABLE II.—BLOWPIPE CONFIRMATIONS FOR MINERALS WITH METALLIC OR SUBMETALLIC LUSTRE.


<table>
<thead>
<tr>
<th>The mineral is completely volatilized.</th>
<th>There is a Magnetic Residue which will impart a Blue or Green Color to Borax in oxidizing flame.</th>
<th>There is a Magnetic Residue which will impart a Yellow to Red Color to Borax in oxidizing flame.</th>
<th>There is a non-magnetic Residue.</th>
</tr>
</thead>
<tbody>
<tr>
<td>ARSENIC As.</td>
<td>COBALTITE CoAsS</td>
<td>ARSENOPYRITE PrAs</td>
<td>ENARGITE Cu₃As₄</td>
</tr>
<tr>
<td>SMALTITE (CoNi)As₂</td>
<td>LEUCOFRANKLINITE Fe₃As₄</td>
<td>TETRANICKELITE Cu₃As₂</td>
<td></td>
</tr>
<tr>
<td>NICCOLITE Ni₅As</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>


<table>
<thead>
<tr>
<th>The Streak is BLACK.</th>
<th>The Streak is DARK.</th>
<th>The Streak is BROWN.</th>
<th>The Streak is BROWNISH RED.</th>
<th>The Streak is BROWNISH YELLOW.</th>
</tr>
</thead>
<tbody>
<tr>
<td>MAGNETITE Fe₃O₄</td>
<td>CHROMITE Fe₂O₃</td>
<td>HEMATITE Fe₂O₃</td>
<td>GOSERITE Fe(OH)₃</td>
<td></td>
</tr>
<tr>
<td>COLEMANITE Fe(CO₃)₂</td>
<td>FRANKLINITE Fe₃(Al₂O₃)</td>
<td>MENACCANITE (Fe₈(OH)₃)</td>
<td>LIMONITE Fe₂O₃Fe₂(OH)₃</td>
<td></td>
</tr>
<tr>
<td>PYRRHOTITE Fe₉S₈</td>
<td>WOLFRAMITE (Fe,Mn)WO₄</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>PYRITE FeS</td>
<td>MARCASITE Fe₃S₂</td>
<td>MAYERITE Fe₃S₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>MILLERITE NiS</td>
<td>LINNÉITE (CoNi)S₄</td>
<td>FORNIET Cu₃FeS₂</td>
<td></td>
<td></td>
</tr>
<tr>
<td>CHALCOPYRITE CuFeS₂</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
**TABLE II.—Continued.**

Part 3. The Mineral Heated on Charcoal Yields no Garlic Odor or Magnetic Residue, but Mixed in Fine Powder with Bismuth Flux and Fused on Plaster it Yields:

<table>
<thead>
<tr>
<th>(a) A Strong Can-ary-yellow Coating.</th>
<th>(b) Chocolate and Scarlet Coatings.</th>
<th>(c) A Purplish Brown Coating.</th>
<th>(d) Orange to Peach Red Coatings.</th>
<th>(e) An Intense Emerald Green Flame.</th>
</tr>
</thead>
<tbody>
<tr>
<td>LEAD Pb</td>
<td>BISMUTH Bi</td>
<td>TELLURIUM Te</td>
<td>ANTIMONY Sb</td>
<td>COPPER Cu</td>
</tr>
<tr>
<td>GALENITE PbS</td>
<td>MERCURY Hg</td>
<td>HESSITE Ag₂Te</td>
<td>STIBNITE Sb₃S₅</td>
<td>CHALCOCITE Cu₂S₃</td>
</tr>
<tr>
<td>CLAUDERITE Pb₃S₅</td>
<td>BISMUTHNITE Bi₃S₅</td>
<td>SYLVANITE (Ag₃Ag₃S₅)</td>
<td>PYRARGYRITE Ag₂S₃S₅</td>
<td>STANNITE Cu₃S₅FeS</td>
</tr>
<tr>
<td>JAMESONITE Pb₃S₅</td>
<td>ALKERSITE Pb₃S₅</td>
<td></td>
<td>STEPHANITE Ag₂S₅S₅</td>
<td>TETRAHEDRITE (Ag₃Ag₃S₅)</td>
</tr>
<tr>
<td>BOURNONITE Cu₃P₃S₅</td>
<td>TETRAHYDRITE (Bi₂Te₂)</td>
<td></td>
<td>POLYHYDRITE (Ag₃Ag₃S₅)</td>
<td>TETRAHEX.</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>DRITE Cu₃S₅S₅</td>
</tr>
</tbody>
</table>

Part 4. Minerals not Included in Parts 1, 2 or 3:

<table>
<thead>
<tr>
<th>The Streak is Black.</th>
<th>The Streak is Silver White to Lead Gray.</th>
<th>The Streak is Dark Brown.</th>
<th>The Streak is Greenish.</th>
<th>The Streak is Yellowish.</th>
</tr>
</thead>
<tbody>
<tr>
<td>PYROXOLITE MnO₂</td>
<td>SILVER Ag</td>
<td>MANGANITE MnO₂</td>
<td>URANINITE L₂O₂</td>
<td>GOLD (Ag, Au)</td>
</tr>
<tr>
<td>BEAUXITE MnO₂</td>
<td>ANALAN</td>
<td>HAUSMANNITE Mn₂O₃</td>
<td>ALABANDITE Mn₂O₄</td>
<td>OCTARERITE TiO₂</td>
</tr>
<tr>
<td>PSILOMELANE MnO₂</td>
<td>PLATINUM Pd</td>
<td>IRISODMITH (Ir₃O₈)</td>
<td>ARGENTITE Ag₃</td>
<td>RUTILE TiO₂</td>
</tr>
<tr>
<td>GRAPHITE C</td>
<td></td>
<td>ARGENTITE Ag₃</td>
<td>MOLYBDENITE Mo₅</td>
<td>SNOOKITE TiO₂</td>
</tr>
</tbody>
</table>
TABLE IV  HARDNESS, ETC., CONFIRMATIONS FOR MINERALS OF NON-METALLIC LUSTRE.

1. The Mineral possesses Decided Taste, that is: it is Soluble in Water.

<table>
<thead>
<tr>
<th>Name</th>
<th>Taste</th>
<th>Hardness</th>
<th>Usual Color</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>SASSOLITE</td>
<td>Acid, slightly saline.</td>
<td>1</td>
<td>White, yellow.</td>
<td>1.48</td>
<td>Penny scales.</td>
</tr>
<tr>
<td>MIRABELITE</td>
<td>Bitter, cooling.</td>
<td>2</td>
<td>White.</td>
<td>1.48</td>
<td>Efflorescent crusts.</td>
</tr>
<tr>
<td>MANGANESE</td>
<td>&quot; pungent.</td>
<td>2½</td>
<td>Gray, yellow.</td>
<td>1.70 to 1.75</td>
<td>Nealy crusts.</td>
</tr>
<tr>
<td>EPISOME</td>
<td>&quot; and salt.</td>
<td>2½</td>
<td>White, yellow, red.</td>
<td>1.75</td>
<td>Massive or fibrous crusts.</td>
</tr>
<tr>
<td>APHTHALITE</td>
<td>&quot;</td>
<td>3</td>
<td>White, bluish.</td>
<td>2.61 to 2.65</td>
<td>Delicate crystals on horn or crusts.</td>
</tr>
<tr>
<td>BORAX</td>
<td>Alkaline, sweetish.</td>
<td>4</td>
<td>White, grey.</td>
<td>1.69 to 1.72</td>
<td>White crystals or crusts.</td>
</tr>
<tr>
<td>THROM</td>
<td>&quot;</td>
<td>4½</td>
<td>White, grey, yellow.</td>
<td>2.11 to 2.14</td>
<td>White glistening crusts or beds.</td>
</tr>
<tr>
<td>ARSENOLITE</td>
<td>Astringent, sweetish.</td>
<td>1½</td>
<td>White, yellow.</td>
<td>3.90 to 3.79</td>
<td>Capillary or incrusting.</td>
</tr>
<tr>
<td>ALUMINUM</td>
<td>&quot;</td>
<td>2</td>
<td>White, yellow, red.</td>
<td>1.6 to 1.8</td>
<td>Fibrous silky masses.</td>
</tr>
<tr>
<td>MELANITRITE</td>
<td>&quot; sweetish.</td>
<td>2</td>
<td>Green, white.</td>
<td>1.89 to 1.99</td>
<td>Efflorescence on sulphide of iron.</td>
</tr>
<tr>
<td>OXYDITE</td>
<td>&quot; manganese.</td>
<td>2</td>
<td>White, grey.</td>
<td>1.8 to 2.4</td>
<td>On or near sphalerite.</td>
</tr>
<tr>
<td>KALITE</td>
<td>&quot;</td>
<td>2½</td>
<td>White.</td>
<td>1.75</td>
<td>Massive or crusts on clay minerals.</td>
</tr>
<tr>
<td>CHALCANTHITE</td>
<td>&quot; manganese.</td>
<td>2½</td>
<td>Blue.</td>
<td>2.12 to 2.39</td>
<td>Vitreous crystals or masses.</td>
</tr>
<tr>
<td>COPRITITE</td>
<td>&quot;</td>
<td>3½</td>
<td>Brownish yellow.</td>
<td>2.1</td>
<td>Massive or in crystalline scales.</td>
</tr>
<tr>
<td>SODA NITRE</td>
<td>Saline, cooling.</td>
<td>1½</td>
<td>White.</td>
<td>2.24 to 2.39</td>
<td>Pellucident.</td>
</tr>
<tr>
<td>SALT ALUMENIT</td>
<td>&quot;</td>
<td>2</td>
<td>White, yellow.</td>
<td>1.53</td>
<td>Vitreous crystals or incrusting.</td>
</tr>
<tr>
<td>NITRE</td>
<td>&quot;</td>
<td>2</td>
<td>White.</td>
<td>2.69 to 2.14</td>
<td>Acicular crystals or tufts. Not altered by exposure.</td>
</tr>
<tr>
<td>SYLVAITE</td>
<td>&quot;</td>
<td>2</td>
<td>White, red, blue.</td>
<td>1.97 to 1.99</td>
<td>Transparent cubes or white masses.</td>
</tr>
<tr>
<td>THERMITE</td>
<td>&quot;</td>
<td>2½</td>
<td>White or brownish.</td>
<td>2.68 to 2.69</td>
<td>Crooked and simple crystals.</td>
</tr>
<tr>
<td>HALITE</td>
<td>&quot;</td>
<td>2½</td>
<td>White, grey, red,</td>
<td>2.1 to 2.6</td>
<td>Massive or cubic.</td>
</tr>
<tr>
<td>GLAUBERITE</td>
<td>&quot;</td>
<td>3</td>
<td>Yellow, grey, red.</td>
<td>2.7 to 2.85</td>
<td>Tabular crystals. Efflorescent on long exposure.</td>
</tr>
<tr>
<td>Name</td>
<td>Streak or Powder</td>
<td>Hardness</td>
<td>Usual Color</td>
<td>Luster</td>
<td>Sp. Gr.</td>
</tr>
<tr>
<td>-----------------------</td>
<td>------------------</td>
<td>----------</td>
<td>-------------------</td>
<td>--------</td>
<td>--------</td>
</tr>
<tr>
<td>Molybdenite</td>
<td>Pale Yellow</td>
<td>1½</td>
<td>Straw yellow or whitish red</td>
<td>Dull</td>
<td>4.5</td>
</tr>
<tr>
<td>Rutile</td>
<td>&quot;</td>
<td>1</td>
<td>Yellow or greenish brown</td>
<td>Adamantine</td>
<td>5.7</td>
</tr>
<tr>
<td>Orthite</td>
<td>&quot;</td>
<td>2</td>
<td>Yellow to dark orange</td>
<td>Pearly</td>
<td>3.1 to 3.5</td>
</tr>
<tr>
<td>Sulfur</td>
<td>Pale</td>
<td>2</td>
<td>Yellow, green or brown</td>
<td>Resinous</td>
<td>2</td>
</tr>
<tr>
<td>Arsenite</td>
<td>&quot;</td>
<td>2</td>
<td>Lemon to yellowish brown</td>
<td>Pearly</td>
<td>3.95 to 3.97</td>
</tr>
<tr>
<td>Pharmacosiderite</td>
<td>&quot;</td>
<td>2½</td>
<td>Yellowish brown or honey yellow</td>
<td>Adamantine</td>
<td>2.8 to 3</td>
</tr>
<tr>
<td>VANADINITE</td>
<td>&quot;</td>
<td>3½</td>
<td>Ruby red, yellow, brown</td>
<td>Resinous</td>
<td>6.6 to 7.2</td>
</tr>
<tr>
<td>GONIRITE</td>
<td>Brownish</td>
<td>5</td>
<td>Yellow, red, brown</td>
<td>Adamantine</td>
<td>4 to 4.4</td>
</tr>
<tr>
<td>TIPHITE</td>
<td>Grayish</td>
<td>5½</td>
<td>Dark brown to nearly black</td>
<td>Resinous</td>
<td>3.4 to 3.8</td>
</tr>
<tr>
<td>REALGAR</td>
<td>Reddish Orange</td>
<td>2</td>
<td>Amber red to orange</td>
<td>Resinous</td>
<td>3.5</td>
</tr>
<tr>
<td>Crocoite</td>
<td>Yellow</td>
<td>2½</td>
<td>Hyacinth red</td>
<td>Adamantine to vitreous</td>
<td>5.9 to 6.1</td>
</tr>
<tr>
<td>MIOSH</td>
<td>&quot;</td>
<td>2½</td>
<td>Bright red</td>
<td>Adamantine to vitreous</td>
<td>4.6</td>
</tr>
<tr>
<td>DESCOLORITE</td>
<td>Red or brown</td>
<td>3½</td>
<td>Cherry red, brown-black</td>
<td>Resinous</td>
<td>5.9 to 6.2</td>
</tr>
<tr>
<td>GREENSAGEITE</td>
<td>Yellow or red</td>
<td>3½</td>
<td>Orange or brown-yellow</td>
<td>Adamantine</td>
<td>4½ to 5</td>
</tr>
<tr>
<td>ZINCITE</td>
<td>Yellow</td>
<td>4½</td>
<td>Deep red to orange</td>
<td>Adamantine</td>
<td>5.4 to 5.7</td>
</tr>
<tr>
<td>KERIMOSITE</td>
<td>Brownish Red</td>
<td>1½</td>
<td>Cherry red</td>
<td>Adamantine</td>
<td>4.5 to 4.6</td>
</tr>
<tr>
<td>HYDROXYTAPE</td>
<td>Crimson</td>
<td>2</td>
<td>Crimson to peach red</td>
<td>Dull or vitreous</td>
<td>2.94</td>
</tr>
<tr>
<td>CINNBAR</td>
<td>Scarlet</td>
<td>2½</td>
<td>Cinnabar red</td>
<td>Adamantine</td>
<td>8 to 8.2</td>
</tr>
<tr>
<td>PROXITE</td>
<td>&quot;</td>
<td>2½</td>
<td>Scarlet vermilion</td>
<td>Adamantine</td>
<td>5.57 to 5.67</td>
</tr>
<tr>
<td>PYRARGYRITE</td>
<td>Purple</td>
<td>3½</td>
<td>Grayish black</td>
<td>Adamantine</td>
<td>5.77 to 5.83</td>
</tr>
<tr>
<td>BAUXITE</td>
<td>&quot;</td>
<td>3½</td>
<td>Red</td>
<td>Adamantine</td>
<td>2.5</td>
</tr>
<tr>
<td>CUPRITE</td>
<td>Brownish</td>
<td>4½</td>
<td>Cinnabar to black-red</td>
<td>Adamantine dull &amp; silty</td>
<td>5.8 to 6.1</td>
</tr>
<tr>
<td>HEMATITE</td>
<td>Cherry or brownish</td>
<td>6½</td>
<td>Iron red</td>
<td>Dull</td>
<td>4.2 to 5.3</td>
</tr>
<tr>
<td>WAD</td>
<td>Brown</td>
<td>1½</td>
<td>Red</td>
<td>Dull</td>
<td>4½ to 5.3</td>
</tr>
<tr>
<td>Minerals (Without Metallic Lustre)</td>
<td>R.F. on Coal</td>
<td>Volarised, Usually with Coating on Other</td>
<td>B.F. on Coal</td>
<td>In the Presence of G.F. the Plane is Coloured</td>
<td>In the Presence the Mineral Forms a Reflecting Surface</td>
</tr>
<tr>
<td>-----------------------------------</td>
<td>-------------</td>
<td>------------------------------------------</td>
<td>-------------</td>
<td>------------------------------------------</td>
<td>------------------------------------------</td>
</tr>
<tr>
<td>Ammonium.</td>
<td>Azurite</td>
<td>Azurite</td>
<td>Chalcopyrite</td>
<td>Chalcopyrite</td>
<td>Cuprite</td>
</tr>
<tr>
<td>Antimony.</td>
<td>Antimony</td>
<td>Antimony</td>
<td>Antimony</td>
<td>Antimony</td>
<td>Antimony</td>
</tr>
<tr>
<td>Chrome.</td>
<td>Chrome</td>
<td>Chrome</td>
<td>Chrome</td>
<td>Chrome</td>
<td>Chrome</td>
</tr>
</tbody>
</table>

**Notes:**
- R.F. on Coal: Reflective on coal.
- Volarised: Usually with coating on other.
- B.F. on Coal: Brittle on coal.
- G.F.: Ground-fine.
- Coating: Coated.
### TABLE IV.—Continued.

<table>
<thead>
<tr>
<th>Name</th>
<th>Streak or Powder</th>
<th>Hardness</th>
<th>Usual Color</th>
<th>Lustre</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>SPHALERITE</td>
<td>Pale Brown</td>
<td>4</td>
<td>Brown to black</td>
<td>Resinous to adamantine</td>
<td>3.9 to 4.1</td>
<td>Isometric crystals, cleavable and fine-grained. Earthy or stalactitic with fibrous structure.</td>
</tr>
<tr>
<td>LIMONITE</td>
<td>Yellowish</td>
<td>5/6</td>
<td>Dark brown</td>
<td>Dull</td>
<td>3.6 to 4</td>
<td>Earthy or stactitic with fibrous structure.</td>
</tr>
<tr>
<td>PSZHOMELANE</td>
<td>Blackish</td>
<td>5/6</td>
<td>Black</td>
<td>Adamantine</td>
<td>3.7 to 4.7</td>
<td>Massive, botryoidal.</td>
</tr>
<tr>
<td>RUTILE</td>
<td>Pale Brown</td>
<td>6</td>
<td>Brownish red</td>
<td>Adamantine</td>
<td>4.18 to 4.25</td>
<td>Prismatic.</td>
</tr>
<tr>
<td>GALENTITE</td>
<td>&quot;</td>
<td>6/6</td>
<td>Brown or black</td>
<td>Adamantine</td>
<td>6.8 to 7.1</td>
<td>Brilliant crystals and rounded pebbles.</td>
</tr>
<tr>
<td>VIVIANITE</td>
<td>Pale Blue</td>
<td>1 1/6</td>
<td>Dark blue or green</td>
<td>Pearly to vitreous</td>
<td>2.85 to 2.90</td>
<td>Colorless when unaltered.</td>
</tr>
<tr>
<td>LINARITE</td>
<td>Pale</td>
<td>2 1/2</td>
<td>Deep azure blue</td>
<td>Vitreous or adamantine</td>
<td>3.3 to 5.4</td>
<td>Transparent crystals.</td>
</tr>
<tr>
<td>CHRYSOCOLLA</td>
<td>&quot;</td>
<td>3</td>
<td>Blue to green</td>
<td>Vitreous or dull</td>
<td>2 to 2.4</td>
<td>Earthy or oval like.</td>
</tr>
<tr>
<td>AZURITE</td>
<td>&quot;</td>
<td>4</td>
<td>Bright to dark blue</td>
<td>Vitreous</td>
<td>3.77 to 3.80</td>
<td>Crystals and crusts.</td>
</tr>
<tr>
<td>LAPIS LAZULI</td>
<td>&quot;</td>
<td>5/6</td>
<td>Azure or greenish blue</td>
<td>Vitreous</td>
<td>3.28 to 3.41</td>
<td>Insoluble.</td>
</tr>
<tr>
<td>PROCHLORITE</td>
<td>Pale Green</td>
<td>1 1/6</td>
<td>Green to dark green</td>
<td>Slightly pearly,</td>
<td>2.78 to 3.01</td>
<td>Muscovitic or fine scaly.</td>
</tr>
<tr>
<td>HEPHYRITES-EMBRITE</td>
<td>&quot;</td>
<td>1 to 2</td>
<td>Yellow to green</td>
<td>Resinous</td>
<td>5.8 to 6.4</td>
<td>Very scaly, Waxy like.</td>
</tr>
<tr>
<td>ANNABERGITE</td>
<td>Whiter</td>
<td>2 1/2</td>
<td>Apple green</td>
<td>Dull</td>
<td>2.9 to 3</td>
<td>Crystalline or fibrous.</td>
</tr>
<tr>
<td>THERMONITE</td>
<td>&quot;</td>
<td>2 1/2</td>
<td>Emerald to apple green</td>
<td>Pearly,</td>
<td>2.9 to 3</td>
<td>Small cubes.</td>
</tr>
<tr>
<td>PHARNACODIRITE</td>
<td>Light</td>
<td>3</td>
<td>Light to dark green</td>
<td>Vitreous</td>
<td>2.57 to 2.67</td>
<td>Always massive.</td>
</tr>
<tr>
<td>GARNETITE</td>
<td>&quot;</td>
<td>3</td>
<td>Emerald green</td>
<td>Vitreous</td>
<td>3.57 to 3.77</td>
<td>Confused crystalline aggregates.</td>
</tr>
<tr>
<td>ZARATITE</td>
<td>Apple</td>
<td>3</td>
<td>Emerald to black</td>
<td>Adamantine to vitreous</td>
<td>4.1 to 4.4</td>
<td>Prismatic or fibrous.</td>
</tr>
<tr>
<td>ATACARITE</td>
<td>&quot;</td>
<td>3</td>
<td>Olive green to brown</td>
<td>Duramantine or vitreous</td>
<td>3.8</td>
<td>Velvety or needle crystals.</td>
</tr>
<tr>
<td>OLIVINE</td>
<td>Olive</td>
<td>4</td>
<td>Emerald to dark green</td>
<td>Vitreous</td>
<td>3.6 to 3.8</td>
<td>Short prismatic.</td>
</tr>
<tr>
<td>BROCANTITE</td>
<td>&quot;</td>
<td>4</td>
<td>Dark olive green</td>
<td>Resinous</td>
<td>3.9 to 4</td>
<td>Fibrous, stalactitic incrusting.</td>
</tr>
<tr>
<td>LITHONITE</td>
<td>&quot;</td>
<td>4</td>
<td>Bright green</td>
<td>Silky or vitreous</td>
<td>6.1 to 7</td>
<td>Massive.</td>
</tr>
<tr>
<td>MALACHITE</td>
<td>&quot;</td>
<td>5</td>
<td>Black</td>
<td>Pitted-like</td>
<td>3.28 to 3.30</td>
<td>Hexagonal prisms.</td>
</tr>
<tr>
<td>URANITE</td>
<td>&quot;</td>
<td>5</td>
<td>Emerald green</td>
<td>Vitreous</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

*Pyroxene, Amphibole and Spinel occasionally gives pale green streaks.*
<table>
<thead>
<tr>
<th>Name</th>
<th>Hardness</th>
<th>Usual Color.</th>
<th>Luster.</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>GEMARGYRITE</td>
<td>1</td>
<td>Gray brown, green.</td>
<td>Wax like, resinous.</td>
<td>5.55</td>
<td>Very soluble, horn like.</td>
</tr>
<tr>
<td>CALOMEL</td>
<td>1</td>
<td>Gray, brown.</td>
<td>Adamantite.</td>
<td>6.48</td>
<td>Horn like, transparent.</td>
</tr>
<tr>
<td>ULEXITE</td>
<td>1</td>
<td>White.</td>
<td>Silky fracture.</td>
<td>1.65</td>
<td>Loose rounded masses.</td>
</tr>
<tr>
<td>TALC</td>
<td>1</td>
<td>White, green.</td>
<td>Pearly, dull.</td>
<td>2.7 to 2.8</td>
<td>Soapy feel, Friable or compact.</td>
</tr>
<tr>
<td>FERROPHYLLITE</td>
<td>2</td>
<td>White, green, yellow.</td>
<td>Pearly or dull.</td>
<td>2.8 to 2.9</td>
<td>Soapy feel, Radiating or compact.</td>
</tr>
<tr>
<td>ALOMORHITE</td>
<td>1.5</td>
<td>White.</td>
<td>Dull.</td>
<td>1.65</td>
<td>Clulky like masses, harsh to the touch.</td>
</tr>
<tr>
<td>PROCHLORITE</td>
<td>1.5</td>
<td>Dark green.</td>
<td>Pearly or dull.</td>
<td>2.8 to 2.9</td>
<td>Micaceous or in fine scales, somewhat soapy.</td>
</tr>
<tr>
<td>KAOLINITKE</td>
<td>2</td>
<td>White.</td>
<td>Dull or pearly.</td>
<td>2.6 to 2.6</td>
<td>Plastic masses or small pearly scales.</td>
</tr>
<tr>
<td>SULPHUR</td>
<td>2</td>
<td>Yellow, gray, brown.</td>
<td>Resinous or adamantine.</td>
<td>2.55 to 2.60</td>
<td>Transparent or translucent, electric by friction.</td>
</tr>
<tr>
<td>GYPSUM</td>
<td>2</td>
<td>White, yellow, red.</td>
<td>Pearly, silty, vitreous.</td>
<td>2.31 to 2.32</td>
<td>Transparent cleavable, to silty or opaque massive.</td>
</tr>
<tr>
<td>AUROCVITE</td>
<td>2.5</td>
<td>Gray, colorless, brown</td>
<td>Pearly or vitreous.</td>
<td>2.7 to 3</td>
<td>Cleavable to thin elastic transparent plates or fine scaly.</td>
</tr>
<tr>
<td>BIOTITE</td>
<td>2.5</td>
<td>Black, dark brown.</td>
<td>Pearly or vitreous.</td>
<td>2.7 to 3.1</td>
<td>Cleavable to thin elastic plates.</td>
</tr>
<tr>
<td>PHLOGOPITE</td>
<td>2.5</td>
<td>Brown to reddish.</td>
<td>Pearly, submetallic.</td>
<td>2.78 to 2.85</td>
<td>Often shows six-rayed star by transmitted light.</td>
</tr>
<tr>
<td>LEPIDOLITE</td>
<td>2.4</td>
<td>Violet, gray.</td>
<td>Pearly or vitreous.</td>
<td>2.8 to 2.9</td>
<td>Cleavable to thin elastic plates or fine scaly.</td>
</tr>
<tr>
<td>HELCITE</td>
<td>2.3</td>
<td>White.</td>
<td>Pearly or waxy.</td>
<td>2.4</td>
<td>Cleavable to plates or fibrous.</td>
</tr>
<tr>
<td>SCHIAPARELLITE</td>
<td>2.5</td>
<td>White.</td>
<td>Dull.</td>
<td>2</td>
<td>&quot;Microcline&quot; clay like or earthy.</td>
</tr>
<tr>
<td>SERPENTINE</td>
<td>2.5</td>
<td>Yellow, green, gray, red</td>
<td>Pearly, resinous, silky.</td>
<td>2.5 to 2.6</td>
<td>Color often varies in same piece.</td>
</tr>
<tr>
<td>CRYSTALITE</td>
<td>2.5</td>
<td>White, brown.</td>
<td>Greasy, vitreous.</td>
<td>2.9 to 3</td>
<td>Transparent like frosted snow.</td>
</tr>
<tr>
<td>HYDROTHERMITE</td>
<td>2.5</td>
<td>White.</td>
<td>Dull.</td>
<td>3.6 to 3.8</td>
<td>Chalk like crusts.</td>
</tr>
<tr>
<td>SIEBERRICHITE</td>
<td>2.5</td>
<td>White or red.</td>
<td>Silky or vitreous.</td>
<td>2.64 to 2.75</td>
<td>Fibrous, horripilous.</td>
</tr>
<tr>
<td>VALENTEITE</td>
<td>2.5</td>
<td>Colorless or gray.</td>
<td>Resinous.</td>
<td>5.2 to 5.3</td>
<td>Detahedral.</td>
</tr>
<tr>
<td>BAXITE</td>
<td>3</td>
<td>Colorless or white.</td>
<td>Pearly or silty.</td>
<td>5.6</td>
<td>Tabular or radiating.</td>
</tr>
<tr>
<td>GALENITE</td>
<td>3</td>
<td>White, yellow, brown.</td>
<td>Dull.</td>
<td>2.5</td>
<td>Massive earthy or granular.</td>
</tr>
<tr>
<td>BARIITE</td>
<td>3</td>
<td>White, yellow, brown.</td>
<td>Vitreous, resinous.</td>
<td>4.3 to 4.5</td>
<td>Cleave to rhombohedral plates, angle of 100°.</td>
</tr>
<tr>
<td>GALENITE</td>
<td>3</td>
<td>White, bluish.</td>
<td>Vitreous, pearly.</td>
<td>3.9</td>
<td>Tabular or fibrous, cleaves to rhomb of 101°.</td>
</tr>
<tr>
<td>GALENITE</td>
<td>3</td>
<td>White, yellowish.</td>
<td>Vitreous to dull.</td>
<td>2.7</td>
<td>Rhombohedral cleavage.</td>
</tr>
<tr>
<td>GALENITE</td>
<td>3</td>
<td>White or yellow.</td>
<td>Pearly or vitreous.</td>
<td>2.3 to 2.4</td>
<td>Granular crystals.</td>
</tr>
<tr>
<td>FLUORITE</td>
<td>3</td>
<td>White.</td>
<td>Adamantine.</td>
<td>6</td>
<td>Square prismatic.</td>
</tr>
</tbody>
</table>
### TABLE IV.—Continued.

3. The Mineral has a **WHITE** or **GRAY STREAK** and no Decided Taste.

<table>
<thead>
<tr>
<th>Name</th>
<th>hardness</th>
<th>usual color</th>
<th>lustre</th>
<th>sp gr.</th>
<th>special characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>Wulfenite</td>
<td>3</td>
<td>yellow, red, brown</td>
<td>Resinous or adamantine</td>
<td>6.7 to 7</td>
<td>Square plates.</td>
</tr>
<tr>
<td>Anglesite</td>
<td>2</td>
<td>white</td>
<td>vitreous or adamantine</td>
<td>6.1 to 6.4</td>
<td>Simple crystals or massive.</td>
</tr>
<tr>
<td>Vanadinite</td>
<td>3</td>
<td>red, yellow, brown</td>
<td>Resinous</td>
<td>6.0 to 7.2</td>
<td>Hexagonal prisms.</td>
</tr>
<tr>
<td>Smaltite</td>
<td>3</td>
<td>gray</td>
<td>Resinous</td>
<td>7.8 to 8.1</td>
<td>Small acute square pyramids.</td>
</tr>
<tr>
<td>Giresite</td>
<td>3½</td>
<td>white to dark gray</td>
<td>Adamantine</td>
<td>6.6 to 6.9</td>
<td>Twin, fibrous and massive.</td>
</tr>
<tr>
<td>Murexite</td>
<td>3½</td>
<td>yellow, brown, gray</td>
<td>Resinous</td>
<td>7 to 7.25</td>
<td>Hexagonal prisms and globular groups.</td>
</tr>
<tr>
<td>Pyromorphite</td>
<td>3½</td>
<td>green, brown, yellow,  gray</td>
<td>Resinous</td>
<td>6.8 to 7.1</td>
<td>Parallel hexagonal prisms.</td>
</tr>
<tr>
<td>Anhydrite</td>
<td>3½</td>
<td>white, blue, red</td>
<td>Vitreous or pearly</td>
<td>3 to 3.5</td>
<td>Rectangular cleavages or fine granular.</td>
</tr>
<tr>
<td>Witherite</td>
<td>3½</td>
<td>white</td>
<td>Vitreous</td>
<td>3.9 to 4.25</td>
<td>Rough faced pseudo-hexagonal crystals.</td>
</tr>
<tr>
<td>Alunite</td>
<td>3½</td>
<td>white</td>
<td>Vitreous</td>
<td>2.5 to 2.7</td>
<td>Nearly cubic and massive.</td>
</tr>
<tr>
<td>Chrysocolla</td>
<td>3½</td>
<td>green, blue, brown</td>
<td>Vitreous to dull</td>
<td>2 to 2.38</td>
<td>Opal-like crusts.</td>
</tr>
<tr>
<td>Wavellite</td>
<td>3½</td>
<td>white, green, yellow,  gray</td>
<td>Vitreous to pearly</td>
<td>2.35</td>
<td>Radiating, often hemispherical crystal groups.</td>
</tr>
<tr>
<td>Aragonite</td>
<td>4</td>
<td>white, pink, yellow</td>
<td>Vitreous</td>
<td>2.9 to 2.95</td>
<td>Pseudo-hexagonal, also columnar and eudal like.</td>
</tr>
<tr>
<td>Barite</td>
<td>4</td>
<td>white</td>
<td>Vitreous</td>
<td>2 to 3.3</td>
<td>Prismatic and massive.</td>
</tr>
<tr>
<td>Strontianite</td>
<td>4</td>
<td>white, pale yellow or pale green</td>
<td>Vitreous</td>
<td>3.65 to 3.71</td>
<td>Groups of spear shaped crystals.</td>
</tr>
<tr>
<td>Dolomite</td>
<td>4</td>
<td>white, yellow, pink,  brown</td>
<td>Vitreous or pearly</td>
<td>2.6 to 2.9</td>
<td>Curved rhombohedral and rhombohedral cleavage.</td>
</tr>
<tr>
<td>Ankerite</td>
<td>4</td>
<td>brown, yellow</td>
<td>Vitreous or pearly</td>
<td>2.9 to 3.1</td>
<td>&quot;</td>
</tr>
<tr>
<td>Siderite</td>
<td>4</td>
<td>brown or gray</td>
<td>Vitreous or pearly</td>
<td>3.8 to 3.9</td>
<td>&quot;</td>
</tr>
<tr>
<td>Rhodochrosite</td>
<td>4</td>
<td>rose red to brown</td>
<td>Vitreous or pearly</td>
<td>3.4 to 3.6</td>
<td>&quot;</td>
</tr>
<tr>
<td>Magnetite</td>
<td>4</td>
<td>white to brown</td>
<td>Dull or vitreous</td>
<td>3.3 to 3.25</td>
<td>Massive chalk like or as above.</td>
</tr>
<tr>
<td>Fluorite</td>
<td>4</td>
<td>wine yellow, purple,  green</td>
<td>Vitreous</td>
<td>3 to 3.2</td>
<td>Cubic but with octahedral cleavage.</td>
</tr>
<tr>
<td>Colemanite</td>
<td>4</td>
<td>colorless or white</td>
<td>Vitreous or dull</td>
<td>2.36 to 2.45</td>
<td>Transparent crystals or dull masses.</td>
</tr>
<tr>
<td>Schalerite</td>
<td>1</td>
<td>yellow, brown, nearly black</td>
<td>Resinous or adamantine</td>
<td>3.0 to 4.1</td>
<td>Massive or highly complex isometric forms.</td>
</tr>
</tbody>
</table>
### TABLE IV.—Continued.

3. **The Mineral has a WHITE or GRAY STREAK and no Decided Taste.**

<table>
<thead>
<tr>
<th>Name</th>
<th>Hardness</th>
<th>Usual Color</th>
<th>Luster</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>SCORODITE</td>
<td>4</td>
<td>Dull green, brown</td>
<td>Vitreous</td>
<td>3.1 to 3.3</td>
<td>Groups of small pointed crystals.</td>
</tr>
<tr>
<td>STELLITE</td>
<td>4</td>
<td>Brown, white, yellow</td>
<td>Pearly and vitreous</td>
<td>2.69 to 2.16</td>
<td>Short like groups.</td>
</tr>
<tr>
<td>HUELLERITE</td>
<td>4</td>
<td>White, dark red, brown</td>
<td>Pearly and vitreous</td>
<td>2.18 to 2.22</td>
<td>Pearly faces often diamond shaped.</td>
</tr>
<tr>
<td>CHROMITE</td>
<td>4½</td>
<td>White, flesh red</td>
<td>Vitreous</td>
<td>2.68 to 2.16</td>
<td>Streaked rhombohedrons.</td>
</tr>
<tr>
<td>APOPHYLLITE</td>
<td>4½</td>
<td>White, greenish</td>
<td>Vitreous and pearly</td>
<td>2.3 to 2.1</td>
<td>Half cleavage spidery in direction vertical axis.</td>
</tr>
<tr>
<td>BORACITE (massive)</td>
<td>4½</td>
<td>White</td>
<td>Bull</td>
<td>2.9 to 3</td>
<td>Fine grained like marble.</td>
</tr>
<tr>
<td>WOLLASTONITE</td>
<td>5</td>
<td>White, gray</td>
<td>Vitreous, dull</td>
<td>2.8 to 2.9</td>
<td>Semi fibrous with calcite.</td>
</tr>
<tr>
<td>PECTOLITE</td>
<td>5</td>
<td>White</td>
<td>Silky or vitreous</td>
<td>2.68 to 2.78</td>
<td>Radiating fibers.</td>
</tr>
<tr>
<td>CALAMINE</td>
<td>5</td>
<td>White, yellow</td>
<td>Vitreous</td>
<td>3.4 to 3.5</td>
<td>Brittle surfaces or botryoidal or massive.</td>
</tr>
<tr>
<td>SMITHSONITE</td>
<td>5</td>
<td>Yellow, brown, white</td>
<td>Vitreous to pearly</td>
<td>4.3 to 4.4</td>
<td>Botryoidal or drusy surfaces or massive.</td>
</tr>
<tr>
<td>SCHILLERITE</td>
<td>5</td>
<td>Yellow, brown, white</td>
<td>Vitreous or adamantine</td>
<td>5.9 to 6.1</td>
<td>Pyramidal or massive.</td>
</tr>
<tr>
<td>APATITE</td>
<td>5</td>
<td>Green, red, white</td>
<td>Vitreous</td>
<td>3.17 to 3.22</td>
<td>Hexagonal prisms and massive.</td>
</tr>
<tr>
<td>TURITE</td>
<td>5½</td>
<td>Bluish gray</td>
<td>Vitreous</td>
<td>3.42 to 3.56</td>
<td>Massive.</td>
</tr>
<tr>
<td>PRASENOITE</td>
<td>5½</td>
<td>Brown, black</td>
<td>Resinous</td>
<td>3.41 to 3.8</td>
<td>Resinous.</td>
</tr>
<tr>
<td>MONAZITE</td>
<td>5½</td>
<td>Brown, yellow, red</td>
<td>Resinous</td>
<td>4.9 to 5.3</td>
<td>Rectangular cleavage.</td>
</tr>
<tr>
<td>CYANITE</td>
<td>5½</td>
<td>Blue, green, white</td>
<td>Vitreous to pearly</td>
<td>5.56 to 5.67</td>
<td>Bladed like crystal groups.</td>
</tr>
<tr>
<td>ANALCITE</td>
<td>5½</td>
<td>White, colorless</td>
<td>Vitreous</td>
<td>2.22 to 2.25</td>
<td>Tetragonal trapezohedron.</td>
</tr>
<tr>
<td>MONTOLITE</td>
<td>5½</td>
<td>Colorless, white, yellow</td>
<td>Vitreous</td>
<td>2.29 to 2.35</td>
<td>Square prisms or radiating.</td>
</tr>
<tr>
<td>BERYL</td>
<td>5½</td>
<td>Colorless or white</td>
<td>Vitreous</td>
<td>3.29 to 3.3</td>
<td>Brilliant glassy crystals or dull porcelain masses.</td>
</tr>
<tr>
<td>TITANITE</td>
<td>5½</td>
<td>Brown, greenish yellow</td>
<td>Vitreous</td>
<td>3.4 to 3.56</td>
<td>Easily cleavable masses or monoclinic crystals.</td>
</tr>
<tr>
<td>LAZULITE</td>
<td>5½</td>
<td>Blue</td>
<td>Vitreous</td>
<td>3.06 to 3.15</td>
<td>Acute pyramids.</td>
</tr>
<tr>
<td>VERNEERITE</td>
<td>5½</td>
<td>Grayish white, green</td>
<td>Vitreous</td>
<td>2.46 to 2.75</td>
<td>Coarse square or octagonal prisms with flat pyramid.</td>
</tr>
<tr>
<td>WILLEMITE</td>
<td>5½</td>
<td>Yellow, green, red, brown</td>
<td>Vitreous to resinous</td>
<td>3.59 to 4.18</td>
<td>Coarse hexagonal prisms or massive.</td>
</tr>
<tr>
<td>PYROXENE</td>
<td>5½</td>
<td>White, green, gray and black</td>
<td>Vitreous</td>
<td>3.2 to 3.6</td>
<td>Inclined prisms with angle and cleavage of 65° N.</td>
</tr>
</tbody>
</table>
TABLE IV.—Continued.

3. The Mineral has a **WHITE** or **GRAY** STREAK and no Decided Taste.

<table>
<thead>
<tr>
<th>Name</th>
<th>Hardness</th>
<th>Usual Color</th>
<th>Luster</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>AMPHIBOLITE</td>
<td>5–5½</td>
<td>White, green, gray, black.</td>
<td>Vitreous to silky.</td>
<td>2.9 to 3.4</td>
<td>Prismatic cleavage 120°, 30°, blade like crystals, often radiated and fibrous.</td>
</tr>
<tr>
<td>ENSTATITE</td>
<td>3–3½</td>
<td>Brown, green, gray.</td>
<td>Pearly to metallic.</td>
<td>3.1 to 3.3</td>
<td>Polished.</td>
</tr>
<tr>
<td>HYPERTHENE</td>
<td>3–3½</td>
<td>Black, dark green.</td>
<td>Pearly to metallic.</td>
<td>3.4 to 3.5</td>
<td>Polished.</td>
</tr>
<tr>
<td>RHODONITE</td>
<td>5–5½</td>
<td>Red, brown.</td>
<td>Vitreous.</td>
<td>3.4 to 3.7</td>
<td>Often with black coating of oxide of manganese.</td>
</tr>
<tr>
<td>OCTAHEDRITE</td>
<td>6–6½</td>
<td>Brown to black.</td>
<td>Adamantine.</td>
<td>3.6 to 3.9</td>
<td>Pyramidal or tabular.</td>
</tr>
<tr>
<td>BERYL</td>
<td>6–6½</td>
<td>White, gray, pale green.</td>
<td>Vitreous to greasy.</td>
<td>2.65 to 2.85</td>
<td>Vitreous hexagonal crystals or greenish, colored masses.</td>
</tr>
<tr>
<td>HARRYHITE</td>
<td>6–6½</td>
<td>Blue.</td>
<td>Vitreous.</td>
<td>2.4 to 2.5</td>
<td>Rounded grains in volcanic rock.</td>
</tr>
<tr>
<td>LEDUCITE</td>
<td>6–6½</td>
<td>Gray or white.</td>
<td>Vitreous.</td>
<td>2.4 to 2.6</td>
<td>Rounded crystals or tetrahexahedrons in volcanic rock.</td>
</tr>
<tr>
<td>THÉQUOIS</td>
<td>6–6½</td>
<td>Sky blue to green.</td>
<td>Waxy.</td>
<td>2.6 to 2.8</td>
<td>Thin Volvo, crystals.</td>
</tr>
<tr>
<td>OPAL</td>
<td>6–6½</td>
<td>Colorless, white red, yellow, brown.</td>
<td>Vitreous, resinous.</td>
<td>1.9 to 2.3</td>
<td>Translucent &quot;opal-like&quot; or massive resinous.</td>
</tr>
<tr>
<td>FREHNAITE</td>
<td>6–6½</td>
<td>Green, gray.</td>
<td>Vitreous.</td>
<td>2.8 to 2.95</td>
<td>Barrel shaped and hemispherical groups and druse surfaces.</td>
</tr>
<tr>
<td>ANORTHITE</td>
<td>6–6½</td>
<td>White, reddish, yellowish.</td>
<td>Vitreous.</td>
<td>2.74 to 2.70</td>
<td>Cleavage near 90°. Massive granular or glassy crystals.</td>
</tr>
<tr>
<td>OLIGOCLASITE</td>
<td>6–6½</td>
<td>Greenish white, red.</td>
<td>Vitreous to pearly.</td>
<td>2.65 to 2.67</td>
<td>Cleavage near 90°. Fine parallel striations on cleavage.</td>
</tr>
<tr>
<td>LABRADORITE</td>
<td>6–6½</td>
<td>Dark gray.</td>
<td>Vitreous.</td>
<td>2.7</td>
<td>Cleavage near 90°. Crystals rare, play of color.</td>
</tr>
<tr>
<td>ADITE</td>
<td>6–6½</td>
<td>White or colorless.</td>
<td>Vitreous.</td>
<td>2.62 to 2.69</td>
<td>Cleavage or cleavable. Cleavage planes slightly curved.</td>
</tr>
<tr>
<td>MICROLITE</td>
<td>6–6½</td>
<td>Green, white, red, etc.</td>
<td>Vitreous.</td>
<td>2.6 to 2.6</td>
<td>Cleavage near 90°. Fine striation.</td>
</tr>
<tr>
<td>ORTHOCLASE</td>
<td>6–6½</td>
<td>White, red, yellow.</td>
<td>Vitreous to pearly.</td>
<td>2.65 to 2.67</td>
<td>Cleavage near 90°. Not striated, often ripple structure.</td>
</tr>
<tr>
<td>CHOROBORITE</td>
<td>6–6½</td>
<td>Brown, yellow.</td>
<td>Resinous or vitreous.</td>
<td>3.14 to 3.2</td>
<td>Crystals, and included grains in massive.</td>
</tr>
<tr>
<td>PINKITE</td>
<td>6–6½</td>
<td>White.</td>
<td>Vitreous.</td>
<td>2.38 to 2.46</td>
<td>Massive, cleavable.</td>
</tr>
<tr>
<td>ALLANITE</td>
<td>6–6½</td>
<td>Black or brown.</td>
<td>Resinous, submetallic.</td>
<td>3.5 to 4.3</td>
<td>Pitch-like masses or submetallic crystals.</td>
</tr>
<tr>
<td>RUTILE</td>
<td>6–6½</td>
<td>Pistachio green.</td>
<td>Vitreous.</td>
<td>3.25 to 3.5</td>
<td>Crystals, fibers and granular masses.</td>
</tr>
<tr>
<td>VESUVIANITE</td>
<td>6½–6½</td>
<td>Brown, green.</td>
<td>Vitreous to resinous.</td>
<td>3.35 to 3.5</td>
<td>Square prism in groups. Vertical striations.</td>
</tr>
<tr>
<td>CHRYSTOLITE</td>
<td>6½–6½</td>
<td>Olive green to brown.</td>
<td>Vitreous.</td>
<td>3.37 to 3.37</td>
<td>Cleavage in mass or compacted in masses.</td>
</tr>
<tr>
<td>SILLIMARITE</td>
<td>6½–6½</td>
<td>Tiny or brown.</td>
<td>Vitreous.</td>
<td>3.25 to 3.27</td>
<td>Fibrous radiating or crystals. Resembles tremolite.</td>
</tr>
</tbody>
</table>
TABLE IV.—Continued.

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<table>
<thead>
<tr>
<th>Name</th>
<th>Hardness</th>
<th>Usual Color</th>
<th>Luster</th>
<th>Sp. Gr.</th>
<th>Special Characters</th>
</tr>
</thead>
<tbody>
<tr>
<td>CASSITERITE</td>
<td>5</td>
<td>Brown, black</td>
<td>Adamantine</td>
<td>6.8 to 7.1</td>
<td>Brilliant crystals and dull rolled pebbles.</td>
</tr>
<tr>
<td>QUARTZ</td>
<td>7</td>
<td>Colorless and all colors</td>
<td>Vitreous, waxy</td>
<td>2.6</td>
<td>Vitreous hexagonal crystals, translucent waxy and opaque masses.</td>
</tr>
<tr>
<td>THERMITE</td>
<td>7</td>
<td>White</td>
<td>Vitreous</td>
<td>2.38 to 2.33</td>
<td>Minute tubular hexagonal crystals.</td>
</tr>
<tr>
<td>FORACLE</td>
<td>7</td>
<td>Colorless, white</td>
<td>Vitreous</td>
<td>2.9 to 3</td>
<td>Small bismuthic crystals.</td>
</tr>
<tr>
<td>SODUMENENE</td>
<td>7</td>
<td>White, pale green, emerald</td>
<td>Vitreous</td>
<td>3.15 to 3.2</td>
<td>Broad cleavages.</td>
</tr>
<tr>
<td>DIAPORE</td>
<td>7</td>
<td>Pink, brown, white</td>
<td>Vitreous, pearly</td>
<td>3.3 to 3.5</td>
<td>Thin prismatic, vertically striated.</td>
</tr>
<tr>
<td>GARNET</td>
<td>7</td>
<td>Brown to black</td>
<td>Vitreous, resinous</td>
<td>3.15 to 4.3</td>
<td>Dodecahedron and tetragonal triclinic.</td>
</tr>
<tr>
<td>STAUROPLITE</td>
<td>7</td>
<td>Brown, gray</td>
<td>Vitreous, resinous</td>
<td>3.05 to 3.35</td>
<td>Prismatic often crossed at 90° or 120°.</td>
</tr>
<tr>
<td>TOURMALINE</td>
<td>7.5</td>
<td>Black, brown, green, red</td>
<td>Vitreous, resinous</td>
<td>3.08 to 3.2</td>
<td>Prismatic roughly triangular crystals.</td>
</tr>
<tr>
<td>IOLITE</td>
<td>7.5</td>
<td>Blue</td>
<td>Vitreous to adamantine</td>
<td>2.4 to 2.66</td>
<td>Resembles quartz.</td>
</tr>
<tr>
<td>ZIRCON</td>
<td>7</td>
<td>Gray, brown</td>
<td>Adamantine</td>
<td>4.2 to 4.8</td>
<td>Sharp square prisms.</td>
</tr>
<tr>
<td>ANDALUSITE</td>
<td>7</td>
<td>Pearly gray, rose red</td>
<td>Vitreous</td>
<td>3.16 to 3.2</td>
<td>Coarse square prisms.</td>
</tr>
<tr>
<td>BERYL</td>
<td>8</td>
<td>Greenish to bluish green, yellow, white</td>
<td>Vitreous</td>
<td>2.65 to 2.8</td>
<td>Hexagonal prisms.</td>
</tr>
<tr>
<td>PHENACITE</td>
<td>8</td>
<td>Colorless or yellowish</td>
<td>Vitreous</td>
<td>2.97 to 3</td>
<td>Rhombohedrons.</td>
</tr>
<tr>
<td>SPINEL</td>
<td>8</td>
<td>Black, green, red, blue</td>
<td>Vitreous</td>
<td>3.5 to 4.1</td>
<td>Octahedrons.</td>
</tr>
<tr>
<td>TOPAZ</td>
<td>8</td>
<td>White, yellow, pale blue</td>
<td>Vitreous</td>
<td>3.1 to 3.35</td>
<td>Transparent orthorhombic. Broad cleavage.</td>
</tr>
<tr>
<td>CHEYROBERYL</td>
<td>8.5</td>
<td>Yellowish to emerald green</td>
<td>Vitreous</td>
<td>3.5 to 3.24</td>
<td>Pseudo hexagonal plates or pyramids.</td>
</tr>
<tr>
<td>CORUNDUM</td>
<td>9</td>
<td>Sticky, blue, red</td>
<td>Vitreous to adamantine</td>
<td>3.95 to 4.1</td>
<td>Truly, sapphire, emery.</td>
</tr>
<tr>
<td>DIAMOND</td>
<td>10</td>
<td>Colorless, yellow, black</td>
<td>Adamantine</td>
<td>3.5 to 3.52</td>
<td>Adamantine.</td>
</tr>
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|                                      | Clinopyrope, see clinopyroxene      |
|                                      | Clinopyroxenite, see clinopyroxene  |
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**Note:** The above text is a page from a book, containing an index of geological and mineralogical terms. The index entries are organized alphabetically and include various types of mineral and crystal forms, as well as their properties and usage in geological studies.
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