INTRODUCTION.

1. The science of Mineralogy treats of those inorganic species called *minerals*, which together in rock masses or in isolated form make up the material of the crust of the earth, and of other bodies in the universe so far as it is possible to study them in the form of meteorites.

2. **Definition of a Mineral.**—*A Mineral is a body produced by the processes of inorganic nature, having a definite chemical composition and, if formed under favorable conditions, a certain characteristic molecular structure which is exhibited in its crystalline form and other physical properties.*

This definition calls for some further explanation.

First of all, a mineral must be a *homogeneous* substance, even when minutely examined by the microscope; further, it must have a *definite chemical composition*, capable of being expressed by a chemical formula. Thus, much basalt appears to be homogeneous to the eye, but when examined under the microscope in thin sections it is seen to be made up of different substances, each having characters of its own. Again, obsidian, or volcanic glass, though it may be essentially homogeneous, has not a definite composition corresponding to a specific chemical formula, and is hence classed as a rock, not as a mineral species. Further, several substances, as tachylyte, hyalomelane, etc., which at one time passed as minerals, have been relegated to petrology, because it has been shown that they are only local forms of basalt, retaining an apparently homogeneous form due to rapid cooling.

Again, a mineral has in all cases a *definite molecular structure*, unless the conditions of formation have been such as to prevent this, which is rarely true. This molecular structure, as will be shown later, manifests itself in the physical characters and especially in the external crystalline form.

It is customary, as a matter of convenience, to limit the name mineral to those compounds which have been formed by the processes of nature alone, while compounds made in the laboratory or the smelting-furnace are at most called artificial minerals. Further, mineral substances which have been produced through the agency of organic life are not included among minerals, as the pearl of an oyster, the opal-silica (tabasheer) secreted by the bamboo, etc. Finally, mineral species are, as a rule, limited to *solid substances;* the only liquids included being metallic mercury and water. Petroleum, or mineral oil, is not properly a homogeneous substance, consisting rather of several hydrocarbon compounds; it is hence not a mineral species.

It is obvious from the above that minerals, in the somewhat restricted sense usually adopted, constitute only a part of what is often called the Mineral Kingdom.

3. Scope of Mineralogy.—In the following pages, the general subject of Mineralogy is treated under the following heads:

(1) *Crystallography.*—This comprises a discussion of crystals in general and especially of the crystalline forms of mineral species.

(2) *Physical Mineralogy.*—This includes a discussion of the physical characters of minerals, that is, those depending upon cohesion and elasticity, density, light, heat, electricity, and so on.

(3) *Chemical Mineralogy.*—Under this head are presented briefly the general principles of chemistry as applied to mineral species; their characters as chemical compounds are described, also the methods of investigating them from the chemical side by the blowpipe and other means.

(4) *Descriptive Mineralogy.*—This includes the classification of minerals and the description of each species with its varieties, especially in its relations to closely allied species, as regards crystalline form, physical and chemical characters, occurrence in nature, and other points.

4. Literature.—Reference is made to the Introduction to the Sixth Edition of Dana's System of Mineralogy, pp. xlv–lxi, for an extended list of independent works on Mineralogy up to 1892; the names are also given of the many scientific periodicals which contain original memoirs on mineralogical subjects. For the convenience of the student the titles of a few works, mostly of a general character, are given here. Further references to the literature of Mineralogy are introduced through the first half of this work, particularly at the end of the sections dealing with special subjects.

Crystallography and Physical Mineralogy.

EARLY WORKS* include those of Romé de l'Isle, 1772; Haüy, 1822; Neumann, Krystallonomie, 1823, and Krystallographie, 1825; Kupffer, 1825; Grassmann, Krystallonomie, 1829; Naumann, 1829 and later; Quenstedt, 1846 (also 1873); Miller, 1839 and 1863; Grailich, 1856; Kopp, 1862; von Lang, 1866; Bravais, Études Crist., Paris, 1866 (1849); Schrauf, 1866–68; Rose-Sadebeck, 1873.

RECENT WORKS include the following:

Bauerman. Text Book of Systematic Mineralogy, 1881.

Goldschmidt. Index der Krystallformen der Mineralien; 3 vols., 1886–91. Also Anwendung der Linearprojection zum Berechnen der Krystalle. 1887.

Groth. Physikalische Krystallographie und Einleitung in die krystallographische Kenntniss der wichtigeren Substanzen, 1876. 3d ed., 1894–95.

Klein. Einleitung in die Krystallberechnung, 1876.

Liebisch. Geometrische Krystallographie, 1881. Physikalische Krystallographie, 1891.

Mallard. Traité de Cristallographie géométrique et physique; vol. 1, 1879; vol. 2, 1884.

Sadebeck. Angewandte Krystallographie (Rose's Krystallographie, II. Band), 1876.

Sohncke. Entwickelung einer Theorie der Krystallstruktur, 1879.

Story-Maskelyne. Crystallography: the Morphology of Crystals, 1895.

Websky. Anwendung der Linearprojection zum Berechnen der Krystalle (Rose's Krystallographie III. Band). 1887.

Williams. Elements of Crystallography, 1890.

Wülfing. Tabellarische Uebersicht der einfachen Formen der 32 krystallographischen Symmetriegruppen, etc., 1895.

In PHYSICAL MINERALOGY the most important general works are those of Schrauf (1868), Groth (1876–1895), Mallard (1884), Liebisch (1891), mentioned in the above list; also Rosenbusch, Mikr. Physiographie, etc. (1892). In addition to these (to which might be added the names of some general works on Physics) memoirs of especial importance on the different subjects are enumerated in many cases at the end of the respective sections of this work.

*The full titles of many of these are given in pp. li–lxi of Dana's System of Mineralogy, 1892.

General Mineralogy.

Of the many works, a knowledge of which is needed by one who wishes a full acquaintance with the historical development of Mineralogy, the following are particularly important. Very early works include those of Theophrastus, Pliny, Linnæus, Wallerius, Cronstedt, Werner, Bergmann, Klaproth.

Within the nineteenth century: Haüy's Treatise, 1801, 1822; Jameson, 1816, 1820; Werner's Letztes Mineral-System, 1817; Cleaveland's Mineralogy, 1816, 1822; Leonhard's Handbuch, 1821, 1826; Mohs's Min., 1822; Haidinger's translation of Mohs, 1824; Breithaupt's Charakteristik, 1820, 1823, 1832; Beudant's Treatise, 1824, 1832; Phillips's Min., 1823, 1837; Shepard's Min., 1832–35, and later editions; von Kobell's Grundzüge, 1838; Mohs s Min., 1839; Breithaupt's Min., 1836–1847; Haidinger's Handbuch, 1845; Naumann's Min.. 1846 and later; Hausmann's Handbuch, 1847; Dufrénoy's Min., 1844–1847 (also 1856–1859); Brooke & Miller, 1852; J. D. Dana's System of 1837, 1844, 1850, 1854, 1868.

More RECENT WORKS are the following:

Bauer. Lehrbuch der Mineralogie, 1886.

Bauerman. Text-Book of Descriptive Mineralogy, 1884.

Baumhauer. Das Reich der Krystalle, 1889.

Blum. Lehrbuch der Mineralogie, 4th ed., 1873–1874.

Dana, E. S. Dana's System of Mineralogy, 6th ed., New York, 1892. Also (elementary) Minerals and How to study them, New York, 1895.

Dana, J. D. Manual of Mineralogy and Petrography, 4th ed., New York, 1887.

Des Cloizeaux. Manuel de Minéralogie; vol. 1, 1862; vol. 2, 1er Fasc., 1874; 2me. 1893.

Groth. Tabellarische Uebersicht der Mineralien, 1874; 3d ed., 1889; 4th ed., 1898. Die Mineralien-Sammlung der Universität Strassburg, 1878.

Hintze. Handbuch der Mineralogie, vol. 2 (Silicates and Titanates), Leipzig, 1889–1897.

Lacroix. Minéralogie de la France et de ses Colonies, 2 vols., 1893–96.

Luedecke. Die Minerale des Harzes, 1896.

Koksharov. Materialen zur Mineralogie Russlands, St. Petersburg; vol. 1. 1853–54; vol. 10, 1888–91.

Kunz. Gems and Precious Stones of North America, 1890.

Schrauf. Atlas der Krystall-Formen des Mineralre ches, 4to, vol. 1, A–C, 1865–1877.

Tschermak. Lehrbuch der Mineralogie, 1884; 5th ed., 1897.

Weisbach. Synopsis Mineralogica, systematische Uebersicht des Mineralreiches, 1875.

Zirkel. 13th edition of Naumann's Mineralogy, Leipzig, 1897.

Wülfing. Die Meteoriten in Sammlungen, etc., 1897 (earlier works on related subjects, see Dana's System, p. 32).

For a catalogue of localities of minerals in the United States and Canada see the volume (51 pp.) reprinted from Dana's System, 6th ed. See also the volumes on the Mineral Resources of the United States published (since 1882) under the auspices of the U. S. Geological Survey.

Chemical and Determinative Mineralogy.

Bischoff. Lehrbuch der chemischen und physikalischen Geologie, 1847–54; 2d ed., 1863–66. (Also an English edition.)

Blum. Die Pseudomorphosen des Mineralreichs, 1843. With 4 Nachträge, 1847–1879.

Brush. Manual of Determinative Mineralogy, with an Introduction on Blowpipe Analysis; New York, 1875; 3d ed., 1878. Also new edition by **Penfield**, 1896.

Doelter. Allgemeine chemische Mineralogie, Leipzig, 1890.

Endlich. Manual of Qualitative Blowpipe Analysis, New York, 1892.

Kobell, F. von. Tafeln zur Bestimmung der Mineralien mittelst einfacher chemischer Versuche auf trockenem und nassem Wege, 11te Auflage, 1878.

Rammelsberg. Handbuch der krystallographisch-physikalischen Chemie, Leipzig, 1881–82. Handbuch der Mineralchemie, 2d ed., 1875. Ergänzungsheft, 1, 1886; 2, 1895.

Roth. Allgemeine und chemische Geologie; vol. 1, Bildung u. Umbildung der Mineralien, etc., 1879; 2, Petrographie, 1887–1890.

Volger. Studien zur Entwicklungsgeschichte der Mineralien, 1854.

Websky. Die Mineral Species nach den für das specifische Gewicht derselben angenommenen und gefundenen Werthen, Breslau, 1868.

Weisbach. Tabellen zur Bestimmung der Mineralien nach äusseren Kennzeichen,

3te Auflage, 1886. Also founded on Weisbach's work, **Frazer's** Tables for the determination of minerals, 4th ed.. 1897.

*Microscopic Examination of Minerals.**

Cohen, E. Sammlung von Mikrophotographieen zur Veranschaulichung der mikroskopischen Structur von Mineralien und Gesteinen, 1881–82.
Doelter. Die Bestimmung der petrographisch wichtigeren Mineralien durch das Mikroskop, 1876.
Fischer. Kritische mikroskopisch-mineralogische Studien, Freiburg, 1869–1873.
Fouqué-Lévy. Minéralogie micrographique, roches éruptives Françaises, 1879.
Lévy-Lacroix. Les minéraux des roches, 1888.
Rosenbusch. Mikroskopische Physiographie der petrographisch-wichtigen Mineralien, 1873; 3d ed., 1892. Accompanied by Hülfstabellen zur mikroskopischen Mineralbestimmung, 1888. Also English translation and abridgment of the above work by Iddings, 1888. Mikroskopische Physiographie der massigen Gesteine, 1877; 3d ed., 1896.
Thoulet. Contributions à l'étude des propriétés physiques et chimiques des minéraux microscopiques.
Tschermak. Die mikroskopische Beschaffenheit der Meteoriten, 1883.
Zirkel. Die mikroskopische Beschaffenheit der Mineralien und Gesteine, 1873. Also Petrographie, 3 vols., 1893–94.

Artificial Formation of Minerals.

Gurlt. Uebersicht der pyrogeneten künstlichen Mineralien, namentlich der krystallisirten Hüttenerzeugnisse, 1857.
Fuchs. Die künstlich dargestellten Mineralien, 1872.
Daubrée. Études synthetique de Géologie expérimentale, Paris, 1879.
Fouqué and **M. Lévy.** Synthèse des Minéraux et des Roches, 1882.
Bourgeois. Réproduction artificielle des Minéraux, 1884.
Meunier. Les méthodes de synthèse en Minéralogie.

Mineralogical Journals.

The following Journals are largely devoted to original papers on Mineralogy:
Bull. Soc. Min. Bulletin de la Société Française de Minéralogie, vol. **1**, 1878; **20**, 1897.
Jb. Min. Neues Jahrbuch für Mineralogie, Geologie und Palæontologie, etc., from 1833
Min. Mag. The Mineralogical Magazine and Journal of the Mineralogical Society of Gt. Britain, vol. **1**, 1876; **11**, 1896–97.
Min. petr. Mitth. Mineralogi-che und petrographische Mittheilungen, vol. **1**, 1878; **17**, 1897. Earlier, from 1871, Mineralogische Mittheilungen gesammelt von G. Tschermak.
Zs. Kryst. Zeitschrift für Krystallographie und Mineralogie. Edited by P. Groth. vol. **1**, 1877; **28**, 1897.

ABBREVIATIONS.

Ax. pl.	Plane of the optic axes.	**H.**	Hardness.
Bx, **Bx$_a$.**	Acute bisectrix (p. 208).	**Obs.**	Observations on occurrence, etc.
Bx$_o$.	Obtuse bisectrix (p. 208).	**O.F.**	Oxidizing Flame (p. 257).
B.B.	Before the Blowpipe (p. 256).	**Pyr.**	Pyrognostics or blowpipe and allied characters.
Comp.	Composition.	**O. Ratio.**	Oxygen Ratio (p. 249).
Diff.	Differences, or distinctive characters.	**R.F.**	Reducing Flame (p. 257).
G.	Specific Gravity.	**Var.**	Varieties.

The sign $\wedge$ is used to indicate the angle between two faces of a crystal, as *am* $(100 \wedge 110) = 44° 30'$.

* See the bibliography given by Rosenbusch.

PART I. CRYSTALLOGRAPHY.

GENERAL MORPHOLOGICAL RELATIONS OF CRYSTALS.

5. Crystallography.—The subject of Crystallography includes the description of the characters of crystals in general; of the various forms of crystals and their division into groups and systems; of the methods of studying crystals, including the determination of the mathematical relations of their faces, and the measurement of the angles between them; finally, a description of compound or twin crystals, of irregularities in crystals, of crystalline aggregates, and of pseudomorphous crystals.

Allied to Crystallography is the subject of *Crystallogeny*, which describes the methods of making crystals which may be applied in the laboratory, and discusses the theories of their origin in nature. This department is only briefly touched upon in the present work.

6. Definition of a Crystal.—*A crystal* is the regular polyhedral form, bounded by smooth surfaces, which is assumed by a chemical compound, under the action of its intermolecular forces, when passing, under suitable conditions, from the state of a liquid or gas to that of a solid.*

As expressed in the foregoing definition, a crystal is characterized, first, by its definite internal molecular structure, and, second, by its external form. A crystal is the *normal* form of a mineral species, as of all solid chemical compounds; but the conditions suitable for the formation of a crystal of ideal perfection in symmetry of form and smoothness of surface are never realized. Further, many species usually occur not in distinct crystals, but in massive form, and in some exceptional cases the definite molecular structure is absent.

7. Molecular Structure in General.—By definite molecular structure is meant the special arrangement which the physical units, called *molecules*,† assume under the action of the forces exerted between them during the formation of the solid. Some remarks are given in a later article (p. 18 *et seq.*) in regard to

* In its original signification the term *crystal* was applied only to crystals of quartz, which the ancient philosophers believed to be *water* congealed by intense cold. Hence the term, from κρύσταλλος, *ice*.

† The relation between *atoms*, *chemical molecules*, and *physical molecules* is explained under the chapter on Chemical Mineralogy. The molecules here spoken of are the physical molecules.