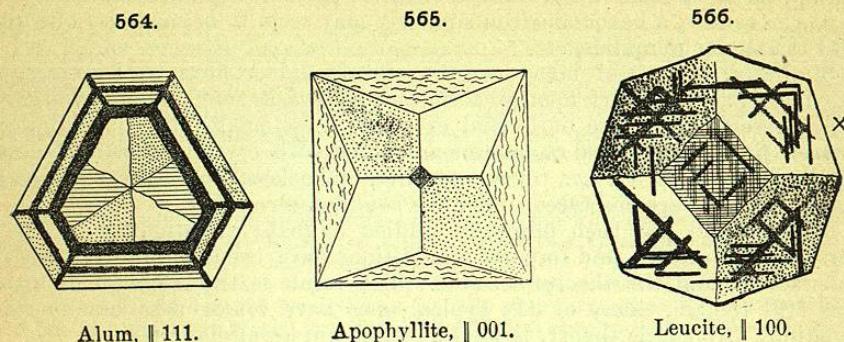


noted above. Here belongs also apophyllite, a section of which (from Golden, Colo., by Klein) is shown in Fig. 565. The section has been cut $\parallel c(001)$ through the center of the crystal and is represented as it appears in parallel polarized light.

Alum, $\parallel 111$.Apophyllite, $\parallel 001$.Leucite, $\parallel 100$.

Another quite distinct but most important class is that including species such as boracite and leucite, which are *dimorphous*; that is, those species which at a certain elevation of temperature (300° for boracite and 500° to 600° for leucite) become strictly isotropic. Under ordinary conditions, these species are anisotropic, but the fact stated makes it probable that originally their crystalline form and optical characters were in harmony. The relations for leucite deserve to be more minutely stated.

Leucite usually shows very feeble double refraction: $\omega = 1.508$, $\epsilon = 1.509$. This anomalous double refraction, early noted (Brewster, Biot), was variously explained. In 1873, Rath, on the basis of careful measurements, referred the seemingly isometric crystals to the tetragonal system, the trapezohedral face 112 being taken as 111, and 211, 121 as 421, 241, respectively; also 101, 011 as 201, 021. Later Weisbach (1880), on the same ground, made them orthorhombic; Mallard, however, referred them (1876), chiefly on optical grounds, to the monoclinic system, and Fouqué and Lévy (1879) to the triclinic. The true symmetry, corresponding to the molecular structure which they possess or tend to possess at ordinary temperatures, is in doubt, but it has been shown (Klein, Penfield) that at 500° to 600° sections become isotropic; and further (Rosenbusch), that the twinning striations disappear on heating, to reappear again in new position on cooling. Sections ordinarily show twinning-lamellæ $\parallel d(110)$; in some cases a bisectrix (+) is normal to what corresponds to a cubic face, the axial angle being very small. The structure corresponds in general (Klein) to the interpenetration of three crystals, in twinning position $\parallel d$, which may be equally or unequally developed; or there may be one fundamental individual with inclosed twinning-lamellæ. Fig. 566 shows a section of a crystal ($\parallel a, 100$) which is apparently made up by the twinning of three individuals.

Still again, in a limited number of cases it can be shown that the intergrowth of lamellæ having slightly different crystallographic orientation is the cause of the optical peculiarities. Prehnite is a conspicuous example of this class.

After all the various possible explanations have been applied there still remain, however, many species about which no certain conclusion can be reached. This is true, for example, of perovskite. To many of these species the theory of Mallard may probably be applicable. Indeed it may be added that much difference of opinion still exists as to the cause of the "optical anomalies" in a considerable number of cases.

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IV. CHARACTERS DEPENDING UPON HEAT.

412. The more important of the special properties of a mineral species with respect to heat include the following: Fusibility; conductivity and expansion, especially in their relation to crystalline structure; change in optical characters with change of temperature; specific heat; also diathermancy, or the power of transmitting radiation, that is, ether-waves. The full discussion of these

* A complete bibliography is given in the memoir by Brauns (1891), see below.

and other related subjects lies outside of the range of the present text-book. A few brief remarks are made upon them, and beyond these reference must be made to text-books on Physics and to special memoirs, some of which are mentioned in the literature (p. 233).

413. Fusibility.—The approximate relative fusibility of different minerals is an important character in distinguishing different species from one another by means of the blowpipe. For this purpose a scale is conveniently used for comparison, as explained in the articles later devoted to the blowpipe. Accurate determinations of the fusibility are difficult, and though of little importance for the above object, they are interesting from a theoretical standpoint. They have been attempted by various authors, for example by Joly, who employed the "meldometer" for this end. This consisted of a strip of platinum in which the mineral in powder was inclosed; it was heated to the necessary point by an electrical current. He obtained the following values for the minerals used in von Kobell's scale (Art. 474): Stibnite, 525°; natrolite, 965°; almandite, 1265°; actinolite, 1296°; orthoclase, 1175°; bronzite, 1300°; also for quartz, 1430°.

414. Conductivity.—The conducting power of different crystallized media was early investigated by Sénarmont. He covered the faces of the substance under investigation with wax and observed the form of the figure melted by a hot wire placed in contact with the surface at its middle point. Later investigations have been made by Röntgen (who modified the method of Sénarmont), by Jannettaz, and others. In general it is found that, as regards their thermal conductivity, crystals are to be divided into the three classes noted on p. 192. In other words, the conductivity for heat seems to follow the same general laws as the propagation of light. It is to be stated, however, that experiments by S. P. Thompson and O. J. Lodge have shown a different rate of conductivity in tourmaline in the opposite directions of the vertical axis.

415. Expansion.—Expansion, that is, increase in volume upon rise of temperature, is a nearly universal property for all solids. The increment of volume for the unit volume in passing from 0° to 1° C. is called the coefficient of expansion. This quantity has been determined for a number of species. Further, the relative expansion in different directions is found to obey the same laws as the light-propagation. Crystals, as regards heat-expansion, are thus divided into the same three classes mentioned on p. 192 and referred to in the preceding article.

The amount of expansion varies widely, and, as shown by Jannettaz, is influenced particularly by the cleavage. Mitscherlich found that in calcite there was a diminution of 8' 37" in the angle of the rhombohedron on passing from 0° to 100° C., the form thus approaching that of a cube as the temperature increased. The rhombohedron of dolomite, for the same range of temperature, diminishes 4' 46"; and in aragonite, for a rise in temperature from 21° to 100°, the angle of the prism diminishes 2' 46". In some rhombohedrons, as of calcite, the vertical axis is lengthened (and the lateral shortened), while in others, like quartz, the reverse is true. The variation is such in both cases that the birefringence is diminished with the increase of temperature, for calcite possesses negative double refraction, and quartz, positive.

It is to be noted that in general the expansion by heat, while it may serve to alter the angles of crystals, other than those of the isometric system, does not alter the zone-relations and the crystalline symmetry. In certain cases, however, the effect of heat may be to give rise to twinning-lamellæ (as in anhydrite) or to cause their disappearance (as in calcite). Rarely heat serves

to develop a new molecular structure; thus, as explained in Art. 411, boracite and leucite, which are anisotropic at ordinary temperatures, become isotropic when heated, the former to 300° the latter to 500° or 600°. The change in the optical properties of crystals produced by heat has already been noticed (Art. 404).

416. Specific Heat.—Determinations of the specific heat of many minerals have been made by Joly, by Oeberg, and others. Some of the results reached are, as follows:

	Joly.	Oeberg.		Joly.	Oeberg.
Galena, <i>cryst.</i>	0.0541	—	Orthoclase	0.1869	0.1877
Chalcopyrite	0.1271	0.1291	Albite	0.1983	0.1976
Pyrite	0.1306	—	Amphibole, <i>black</i>	0.1963	Augite 0.1880
Hematite	0.1683	0.1645	Beryl	0.2066	0.1979
Garnet, <i>red cryst.</i>	0.1780—0.1793	0.1758	Calcite	0.2034—0.2044	0.2042
Epidote	0.1877	0.1861	Aragonite	0.2036	—

417. Diathermancy.—Besides the slow molecular propagation of heat in a body, measured by its thermal conductivity, there is also to be considered the rapid propagation of what is called radiant heat through it by the wave-motion of the ether which surrounds its molecules. This is merely a part of the general subject of light-propagation already fully discussed, since heat-waves, in the restricted sense, differ from light-waves only in their relatively greater length. The degree of absorption exerted by the body is measured by its diathermancy, which corresponds to transparency in light. In this sense halite, sylvite, and fluorite are highly *diathermanous*, since they absorb but little of the heat-waves passing through them; on the other hand, selenite and, still more, alum are comparatively *athermanous*, since while transparent to the short light-waves they absorb the long heat-waves, transforming the energy into that of sensible heat. Measurements of the diathermancy were early made by Melloni, later by Tyndall, Langley, and others.

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