THE MAGNETIC PROPERTIES OF HEMATITE.[1]

By T. Townsend Smith.

THE magnetic properties of crystals have interested many physicists since the early investigations of Plücker and Faraday, and for materials where one deals with paramagnetism or diamagnetism only, the magnetic behavior is dependent in a rather simple way upon the direction that is taken in the crystal. The treatment of this case usually passes under the name of Thomson's Theory, being due fundamentally to Sir William Thomson, though Poisson had previously noted the possibility of a dependence of the magnetic state of a crystal upon the structure of the material.

It may be shown that there are three principal directions in general in a crystal, along which the magnetization and the magnetizing field are similarly directed, and that, in the case treated by Sir William Thomson,[2] the magnetization in any other direction with a given field may be simply determined from the direction of the field and the susceptibilities along these three directions, using them as the axes in a system of rectangular coördinates. König,[3] Stenger,[4] and Tumlirz[5] attempted to put the theory to experimental test by swinging spheres of calcite and quartz in a uniform field and measuring the period of oscillation, with fair success. There have been also many determinations made of the magnetic constants along the axes of symmetry. A somewhat recent series of determinations of such constants is that of Voigt & Kinoshita,[6] in which the forces acting on the specimens in a non-uniform field were used to determine the susceptibility in these directions. There is a rather extended review of such work in Professor Voigt's Lehrbuch der Kristallphysik.[7]

When one turns to crystals in which the field is not proportional to

[1] This work was begun in the Jefferson Physical Laboratory of Harvard University, where almost all of the necessary apparatus was made and where some of the readings were taken. The work is being continued at the University of Kansas.

[2] Phil. Mag., March, 1851. Papers on Electrostatics and Magnetism, page 471.

[3] Annalen der Physik, 31: 273, 1887.

[4] Annalen der Physik, 20: 304, 1883; 35: 331, 1888.

[5] Annalen der Physik, 27: 133, 1886.

[6] Göttingen Nachr., 1907, p. 123. Annalen der Physik, 24: 492, 1907.

[7] Chapter VI., Section 5.

the resultant intensity of magnetization, one finds that the observations are not numerous and that the phenomena are complex. Professor P. Weiss,[1] of Zurich, has done more work with such material than anyone else and he, either alone or in collaboration, has published results of measurements made on magnetite and on pyrrhotite (magnetic pyrites). On hematite, which is much less strongly magnetic than either of the two just mentioned, there is some work by Westman[2] and by Jakob Kunz,[3] and likewise by Bavink,[4] who also experimented with tourmalin, garnet, and ilmenite.

The present investigation has to do with hematite, all the tests made being of the component of magnetization parallel to the exciting field. The field strengths used run as high as 3,800 gausses, within which range there is no approach to saturation, either in or perpendicular to the basal plane (plane of symmetry) of the crystal.

The quantity measured in every case was the force which pulled the specimen, a sphere, into the magnetic field, and from this force one may calculate an average intensity of magnetization for the sphere. If the susceptibility is constant throughout a spherical specimen, then to a first approximation the intensity of magnetization calculated from the pull is the value of the intensity at the center of the sphere.

This average value is the value that is given throughout the work below, though in general in hematite the susceptibility will vary, the variation being appreciable in some cases within the range of the fields that exist in the specimen. This is a drawback to the method here used. The non-uniform field is an advantage, however, in that it is possible by its use to test experimentally the homogeneity of the specimen. This may be done by the simple operation of inverting the sphere with reference to the field, in which case the pull will remain unchanged only if the upper and the lower half of the sphere are alike. Within the limits of accuracy of this test, all the specimens showed themselves to be homogeneous.

THE SPECIMENS INVESTIGATED.

Hematite crystallizes in rhombohedral crystals, with an axis of threefold symmetry, perpendicular to a plane of symmetry, which is sometimes called the principal plane of the crystal. The crystals are opaque,

[1] Magnetite: C. R., 122: 1405, 1896; Journal de Physique, Ser. III., 5: 435, 1896; L'Eclairage Electrique, 7: 487, 1896; 8: 56, 105, 1896; Thesis, Paris, 1896; Annalen der Physik, 30: 389, 1909 (Quittner). Pyrrhotite: Journal de Physique, Ser. IV., 4: 468, 829, 1905.

[2] Upsala Universitets Årsskrift, 1896.

[3] Neues Jahrbuch für Mineralogie, 1907, Vol. 1, p. 62.

[4] Neues Jahrbuch für Mineralogie, beil. B, 19: 377, 1904.