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Optical Absorption Spectra of Ruby and Periclase at High Shock Pressures¹

EDWARD S. GAFFNEY² AND THOMAS J. AHRENS

Seismological Laboratory, California Institute of Technology, Pasadena, California 91109

A spectrographic system is described that is capable of measuring optical absorption spectra in solids to shock pressures of several hundred kilobars. The system utilized light from a 'point' source at about 60,000°K. Spectra have a resolution of about 40 Å and cover the visible range. With a streak camera, time resolution of about 75 nsec can be obtained. The spectrum of MgO is observed to remain featureless at 450 kb and upon unloading from this pressure. The color centers observed in shock-recovered material must result from either higher pressures or other processes. The optical absorption spectra of ruby under shock compressions of almost 15% have been measured in the range 375–600 nm. Below the elastic limit the large anisotropic strains are evident from the splitting of the ${}^4A_2 \rightarrow {}^4T_2$ (F) absorption band by 3730 cm^{-1} . Above the elastic limit this splitting is not resolved (but must be less than 800 cm^{-1}), indicating considerable loss of shear strength in such cases. Above the Hugoniot elastic limit up to pressures of 530 kb (15% volume compression) the measured value of the crystal field parameter agrees, within experimental error, with the value calculated from a point charge model ($Dq \propto r^{-5}$) if the local compressibility is equal to the bulk compressibility. This result agrees with Stephens and Drickamer's absorption data up to 150 kb and suggests that the point charge model is useful in predicting crystal field effects in mantle minerals, especially those having similar oxygen anion packings such as corundum.

The absorption spectra of minerals at very high pressures are of considerable importance to the problem of the behavior of Fe^{2+} in the interior of the earth. Specifically, measurements of the pressure shifts of absorption bands, both spin allowed and spin forbidden, over a range of several hundred kilobars provide an experimental basis for the prediction of crystal field effects in the minerals of the lower mantle [Gaffney, 1972; Burns, 1970]. Under lower mantle conditions (temperatures of 1800°–4000°K and pressures of 300–1400 kb) heat transport by radiation is thought to be an important phenomenon in this region [Clark, 1957; Pitt and Tozer, 1970; Schatz and Simmons, 1972]. This belief arises primarily from the coincidence of the maximum of the universal blackbody radiation function in this temperature range with a minimum of the absorption spectra of many silicates and oxides. The

bounds on this minimum are the metal-oxygen charge transfer bands in the ultraviolet and the vibrational absorptions in the infrared. Thus, except for the interference of electronic absorptions, due mainly to crystal field effects on transition metal impurities, principally Fe^{2+} , thermal transport in oxides and silicates at temperatures in excess of 1500°C is probably strongly affected by the radiative conductivity. To predict the thermal properties of the earth's mantle, it is important, therefore, to be able to account for the effects of both temperature and pressure on these electronic absorptions. (Movements of the charge transfer peaks can also be seen in absorption spectra. The bands may have an important effect on radiative transfer. The reader is referred to the discussions by Pitt and Tozer [1970] and Gaffney [1972].)

If a phase change should occur while experiments are being carried out in the pressure region of interest, it is likely that the local site symmetry of Fe^{2+} in the high-pressure phase could be determined from its absorption spectrum. In many cases such a knowledge, combined with the knowledge of the density of the high-pressure phase, could unequivocally determine the structure of that phase.

¹ Contribution 2232, Division of Geological and Planetary Sciences, California Institute of Technology.

² Now at Systems, Science and Software, La Jolla, California 92037.