

MAGNETIC PROPERTIES OF LUNAR ILMENITE

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Previous studies of the magnetic susceptibility of individual microgram-size lunar glass spherules at low temperatures¹ show the existence of several antiferromagnetic temperature transitions in the glass spherules measured, but only one transition could be associated with a known mineral inclusion, namely ilmenite. It is assumed that the unidentified transitions are due to minute fragments of other mineral species or nucleated regions in the glass, the occurrence of which is directly associated with the source rocks and conditions of formation of the spherules. In order to interpret and identify the various temperature transitions found in the lunar glass spherules, it is necessary to know the Neel transitions for the various specific lunar minerals that might be found in the lunar glass. No magnetic studies have been made on separated pure lunar minerals to establish these transition temperatures, and thus, starting with ilmenite, a systematic study of lunar minerals has been initiated.

The measured transition at 56 K in the one spherule mentioned previously corresponded closely to the known Neel temperature of powdered rather than a single crystal of ilmenite. There are several reported measurements of the Neel transition for terrestrial and synthetic ilmenite powder samples, but Bizette and Tsai² are the only investigators to report measurements on a single crystal of terrestrial ilmenite. They showed ilmenite to be magnetically anisotropic and to have a Neel transition at 68 K parallel, and at approximately 55 K perpendicular to the c-axis. Terrestrial or synthetic ilmenite almost always contains a small amount of Fe³⁺. Lunar ilmenite has been formed under highly reducing conditions, will contain little or no Fe³⁺, and consequently may have a different transition temperature. In addition, neutron diffraction studies of ilmenite by Shirane et al³ indicates that, depending on the purity, ferrimagnetic clusters may form in ilmenite which can influence the transition temperature. If the inclusions are subdomain in size, the glass spherule will have superparamagnetic properties which may also have an effect on the transition temperature.

Preliminary measurements of a multifragment sample of lunar ilmenite picked from a crushed piece of lunar rock 10047 showed that in addition to the transition at 56 K, there were weak transitions at 11.3 K and at 4.3 K⁴. Later measurements on purer fragments showed only the 56 K transition; thus the low-temperature transitions have been ascribed to impurities or to instrumental error. When the ilmenite fragments of the lunar sample were oriented in the magnetic field prior to magnetic susceptibility measurements, the transition became sharper and shifted from 56 K to 60 K. Anisotropic magnetic susceptibility measurements on a single crystal fragment removed from the lunar powder sample yielded a very sharp temperature transition at 60 K.

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As the 60 K transition is only evident in the sample of the magnetically aligned fragments and for the single crystal, it is inferred that the 56 K transition observed for powder specimens and also in the glass spherules measured previously is due to multiple unoriented fragments. A single fragment or several oriented fragments imbedded in the glass would have yielded a transition at 60 K.

Additional measurements were made on terrestrial and synthetic specimens for comparison purposes. Fe^{3+} , if present at all, is at concentrations of less than 0.1 per cent in the lunar sample. The measurements also indicate that the amount of superparamagnetism in the lunar sample is small compared with that in pure synthetic ilmenite.

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