Astronomy

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Abstract

Full Text

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MAGNETIC PROPERTIES OF THE YARDYMLY IRON METEORITE

The study of the magnetic properties of the Yardymly iron meteorite is of interest because it is the freshest (fell on 24 XI 1959) of the celestial bodies on Earth ([3]) and the last iron meteorite after Sikhote-Alin (1947).

The magnetic properties of meteorites are closely connected with their mineralogical composition and with the structural relationships of the minerals. According to detailed investigations by M. A. Kashkai and V. A. Aliev, the Yardymly meteorite consists mainly (95%) of kamacite (Fe, Ni), while the remainder falls to the share of taenite (and plessite), schreibersite, and rhabdite. Graphite does not participate in the characteristic magnetic phase. The Yardymly meteorite contains 92–93% iron, ~ 6.5% nickel, about 0.40% cobalt, and very small amounts of phosphorus, sulfur, carbon, and elements rarely dispersed in meteorites: silicon, aluminum, magnesium, manganese, gallium, germanium, and others.

Fig. 1. Demagnetization of the meteorite in a constant magnetic field

Fig. 2. Demagnetization of the meteorite in an alternating magnetic field

The study of the form of the regmaglyptic relief and of the features of the fusion crust of the Yardymly iron meteorite showed that, during its flight in the Earth' s atmosphere, it was in a state of rotation, which could to some extent have been reflected in its magnetic properties.

Measurements of the residual magnetization I_n and magnetic susceptibility χ were carried out on an astatic magnetometer. For the study of the magnetic properties, a specimen was cut from the largest (127 kg) fragment of the meteorite in the form of a cube with an edge of 24 mm, with the calculation that both

Fig. 3. Dependence of the residual magnetization of the meteorite on temperature

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the inner and the outer surface would be included. The residual magnetization and magnetic susceptibility proved to be equal to

$$I_n = 4.6 \cdot 10^{-2} \text{ gauss}; \quad \chi = 1.7 \text{ CGSM}.$$

After this, four cubes with an edge of 10 mm and four rectangular prisms with sides of 4; 4; 24.75 mm were cut out and subjected to magnetic investigations. The measurements showed different values of residual magnetization at the surface and in the interior.

The demagnetization curves in a constant field showed that sample No. 4 is demagnetized in a field of 20 oersted, and sample No. 2 in a field of 32.5 oersted (Fig. 1).

In an alternating field, sample No. 1 is demagnetized in large fields and does not change its sign, while sample No. 3 changes sign in small fields and retains the sign and magnitude of magnetization in large fields (Fig. 2).

From the demagnetization curves in constant and alternating fields it may be concluded that the meteorite is a magnetically soft material and is inhomogeneous.

It is known that meteorites, when falling to Earth, overcome considerable resistance of the atmosphere, as a result of which they heat up to temperatures of several thousand degrees and then cool in the Earth’ s magnetic field. Therefore it is of interest to study the magnetization of a meteorite at different distances from the surface (thermoremanent, normal, or ideal).

In order to find the Curie temperature of the ferromagnetic components of the meteorite, and also to determine their magnetization, the samples were first magnetized with an electromagnet and then placed in an astatic thermomagnetometer, where they were heated to temperatures above the Curie point and cooled in the presence of the Earth’ s magnetic field. The results of the experiments are shown in Fig. 3, where temperature is plotted along the abscissa axis, and magnetization, in scale divisions, along the ordinate axis.

Fig. 3. Dependence of the residual magnetization of the meteorite on temperature

As can be seen from Fig. 3, the meteorite is indeed a multiphase system; moreover, the Curie point equal to 580° is clearly distinguished, whereas the Curie point equal to 350°, judging from the change in the slope of the curve, is indistinctly distinguished. We did not succeed in finding the Curie temperature for the third phase, since heating was carried out up to 720°. During cooling of the meteorite from 720° to room temperature, no visible changes in the value of I_n were observed.

To determine the Curie temperature of the third phase, the sample was again magnetized with an electromagnet, heated in the astatic thermomagnetometer to 820°, and then cooled to room temperature in the Earth' s magnetic field. As can be seen from Fig. 3b, at a Curie temperature equal to 765–

770°, a sharp demagnetization of the meteorite occurs. This temperature corresponds to the Curie point of kamacite.

From the course of the curves in Fig. 3 it can be seen that the transition from the ferromagnetic state to the paramagnetic state for nickel does not occur abruptly, as it does for kamacite and schreibersite $(Fe, Ni, Co)3P$; therefore it is difficult to determine exactly the Curie temperature of nickel. Detailed work on determining the Curie temperature of nickel was carried out by Weiss et al., whose results agree with our data (^{2}).

A Curie temperature equal to 580° corresponds to magnetite. However, the data of the mineralogical analysis of the meteorite indicate the absence of magnetite in it. According to chemical-mineralogical data, in the Yardymly meteorite kamacite (Fe, Ni) contains about 6-7% nickel, and taenite (Fe, Ni) about 24-25%; there is also the nickel-bearing mineral schreibersite $(Fe, Ni, Co)3P$.

Since Hopkins's work showed that a 25% alloy of nickel with iron is paramagnetic and becomes ferromagnetic only after cooling to a temperature of −50°, it may be asserted that the Curie point equal to 580° does not correspond to taenite, and, consequently, corresponds to schreibersite.

Upon cooling in a magnetic field, the meteorite acquires a thermoremanent magnetization equal to the magnetization of its outer part. Thus, it may be asserted that the magnetization of the outer part of the meteorite is thermoremanent, which is due to its heating above the Curie point, equal to 765–770°.

The inner part of the meteorite had a temperature lower than the Curie temperature of kamacite and therefore did not acquire complete thermomagnetization, as evidenced by its lower magnetization.

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Note: Figure translations are in progress. See original paper for figures.