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Abstract

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THE COSMIC AGE OF THE SIKHOTE-ALIN METEORITE

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Along with the importance of studying the stable products of reactions of high-energy cosmic particles with the substance of meteorites, no less interest attaches to the investigation of the content of radioactive nuclei that have arisen in meteorites. In addition to being of independent interest, determination of the content of radioactive isotopes makes it possible to estimate the cosmic age of a meteorite, i.e., the time during which the meteorite has existed as an isolated fragment of a celestial body. This age, obviously, must differ from the age determined from the isotope ratios of lead or from the ratio A^{40}/K^{40}, which give either the age of the meteoritic material or the time elapsed since the last alteration (metamorphism) of the meteorite.

The purpose of the present work was to study the content of the radioactive isotopes H^3 and A^{39} in the Sikhote-Alin meteorite. Naturally, for a successful determination of the content of H^3 and A^{39} it is necessary to have recently fallen meteorites. This condition applies primarily to tritium, because of its comparatively short half-life.

Table 1

Radioactive isotope	Sample weight (g)	Count (imp/min · g)* a	Count (imp/min · g)* b
H^3	110.0	$(2.4 \pm 0.4) \cdot 10^{-2}$	$(2.8 \pm 0.4) \cdot 10^{-2}$
A^{39}	1200.0	$(5.7 \pm 0.4) \cdot 10^{-3}$	$(6.6 \pm 0.4) \cdot 10^{-3}$

* *a* —reduced to the moment of the meteorite fall; *b* —after introducing the correction for end losses (1).

For the measurement of low activities, which could be expected, a counting apparatus was assembled that had a comparatively small background. Reduction of the natural background in the Geiger–Müller counter used for counting was achieved by using steel shielding 15–25 cm thick and a ring of counters connected in an anticoincidence circuit. The former excluded the soft component, the latter the hard component of cosmic rays. The use of these measures made it possible to reduce the background from 360 to 10 imp/min. A detailed description of the counting apparatus and of the experimental procedure will be given elsewhere.

Table 1 gives the results of the measurements. To calculate the irradiation time from the total amount of He^3, equal to $1.7 \cdot 10^{-6}$ cm^3/g, it is necessary to exclude the part which in deep-spallation reactions appears directly in the form of He^3. Previously, on the basis of evaporation theory, it was assumed that the yield of H^3 exceeds the yield of He^3 nuclei, with $He^3/H^3 = 0.3 \div 0.7$. However, experimental data obtained by irradiating iron targets with protons of energy $3 \cdot 10^3$ MeV lead to the value $He^3/H^3 = 2.4$ (2).

Using the experimentally found value for He^3/H^3, one can calculate the amount of He^3, equal to $1.3 \cdot 10^{13}$ atoms/g, which is obtained through the decay of tritium. Using the latter value and the decay rate of tritium (i.e., the rate of formation after equilibrium has been established), one can calculate the irradiation time, or the cosmic age of the meteorite, as $(900 \pm 200) \cdot 10^6$ years.

The calculation of the total number of decayed A^{39} nuclei is more complicated. The decay product of A^{39} is K^{39}, which is added to the potassium contained in the meteorite. This addition of potassium is too small to be reliably established experimentally. An estimate of the number of decayed A^{39} nuclei can be made from the content of A^{38}, equal to $1.1 \cdot 10^{-7}$ cm^3/g. The ratio of the formation cross sections for A^{39} and A^{38} at a proton energy of $0.43 \cdot 10^3$ MeV is $A^{39}/A^{38} = 0.5$ ([2]). An increase in the proton energy apparently increases this ratio somewhat, while the decay of the isobaric nucleus Cl^{38} should, on the contrary, decrease it. Taking into account the mutually opposite influence of these factors, the ratio $A^{39}/A^{38} = 0.5$ was adopted.

After the introduction of these corrections, the number of K^{39} atoms formed by the decay of A^{39} will be $1.7 \cdot 10^{12}$ atoms/g, whence the irradiation time is $T = (430 \pm 50) \cdot 10^6$ years.

The value of the age given here is close to the value obtained by Fireman ([3]) and apparently is the most reliable. A discrepancy is observed between the age according to H^3 and A^{39}, which is outside the limits of experimental error. A systematic error of the counting apparatus, if it exists at all, would give a decrease in the amount of H^3, which would lead to an even greater increase in the age according to H^3.

The obtained value of the irradiation time makes it possible to estimate, from the amount of A^{38}, the number N of cosmic particles crossing 1 cm^2 in 1 sec.

$$N = \frac{2n_1}{\sigma_{A^{38}} n_2 T},$$

where n_1 is the number of A^{38} atoms in 1 g, n_2 is the number of iron atoms in 1 g, and $\sigma_{A^{38}}$ is the mean cross section for the formation of A^{38} ([2], [4]). Hence we obtain $N \simeq 2.3$ particles/cm$^2 \cdot$ sec.

The obtained value is in satisfactory agreement with experimental data for the density of cosmic radiation in the polar regions of the Earth at the present time (2 particles/cm$^2 \cdot$ sec).

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CITED LITERATURE

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