Age Correction

Making the proper correction to the meteorite age requires the subtraction of cosmic-ray helium from the helium sample extracted from the meteorite. (A typical sample would amount to $\sim 10^{-6}$ c.c. helium per gm. of meteorite.) It is necessary first to measure the amount of helium-3 in the sample. After subtracting the helium-3 plus the proper amount of cosmic-ray helium-4 (calculated from the ratio above), one is left presumably only with radiogenic helium-4. The age can then be calculated by conventional methods[1].

The helium isotope ratio in the sample can probably be determined with modern mass-spectrometric equipment[12]. For very small samples, however, a radiochemical procedure based on Coon's method[13] may also be of value. Helium-3 is known to have an extremely large absorption cross-section (about 5,000 barns) for thermal neutrons. The (n,p) reaction occurring produces tritium, which is β-unstable and is transformed back into helium-3 with a half-life of 12 years. Exposure of a helium sample containing only 10^{-8} c.c. of helium-3 in a nuclear pile for a few days would give sufficient tritium to produce a measurable activity. It is proposed to determine the helium-3 content of the meteorite sample by comparing this activity with those from calibrated samples (enriched with helium-3) exposed under identical conditions. (Even smaller amounts of helium-3 could be detected by the use of special triton counters[14].)

In view of the fact that a unique age should result from a series of corrected age determinations obtained from different parts of the same meteorite, it may be possible to obtain a consistency check of the numerical result given in this article for the cosmic-ray helium isotope ratio and a calibration of the variation of this isotope ratio with depth in the meteorite.

Meteorites as Integrating Cosmic-Ray Meters

Some additional applications of the cosmic-ray helium method to problems of cosmological interest are pointed out here. These remarks must be viewed with some reserve, because of the many uncertainties about the physical history of meteorites. (For example, the helium gas may have diffused through the meteorite and have escaped if the latter was exposed to high temperatures.) Essentially one wants to provide an experimental test for the following assumptions: (1) the meteorite has been exposed directly to the primary cosmic rays from the time of solidification to the time of chemical analysis (that is, over the whole time interval during which radiogenic helium was allowed to accumulate); (2) this primary cosmic-ray intensity experienced by the meteorite corresponds to the flux in the vicinity of the earth; and (3) the average intensity over the life-time of the meteorite corresponds to the present-day intensity.

(1) By making use of the fact that cosmic rays produce helium in meteorites, one can develop the concept of considering a meteorite as an integrating cosmic-ray meter which gives one the time and space integral of the cosmic-ray flux it encounters over its path and life-time. From the corrected age of the meteorite and the amount of cosmic-ray helium, an empirical rate of helium production by cosmic rays can be determined and compared with the rate calculated on the basis of the assumptions just stated. It may then be possible to gain information about the cosmic-ray intensity in prehistoric times; or the intensity in the region where the meteorite spent the major part of its existence. A low value of cosmic-ray intensity obtained in this way may also be interpreted by assuming that the meteorite did not become exposed to cosmic rays until some time after its solidification, or that it landed on the earth during prehistoric times.

(2) By virtue of the fact that (in very large meteorites) the production of helium by cosmic rays is a 'surface effect' as opposed to the volume effect of radioactivity, one may hope to learn more about the physical processes undergone by the meteorite in its creation and in its travel through space. In particular, by determining its loss of mass in its traversal of the earth's atmosphere, it may be possible to establish an experimental test for the theory[15] of astroballistic heat transfer of a meteorite.

Full details of the present work will appear in *Geochimica et Cosmochimica Acta*. Experimental work on the possibility that helium-3 exists in meteorites is now in progress.

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DR. S. F. SINGER has kindly shown me the preceding paper. It may interest readers that in a recent article[1] containing various experimental results—obtained partly in collaboration with the Clarendon Laboratory in Oxford—figures are given for the helium-3 content of five iron meteorites. They are in very good agreement with Dr. Singer's theoretical deductions, as can be seen from the accompanying table.

Name of meteorite	Helium content in 10^{-6} c.c./gm.	Helium-3/helium-4 (%)
Mount Ayliff	36·8	31·5
Carbo	22·0	28·6
Toluca (Durham)	18·9	29·7
Bethany Amalia (Krantz)	3·4	27·8
Bethany (Harvard)	0·36	17·8

For a discussion of these results in connexion with the question of the age of meteorites, the article referred to above in *Geochimica et Cosmochimica Acta* should be consulted.

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