These values were corrected for the solid angle of our detectors. The calculation assumes that there is no attenuation of the angular correlation pattern caused by time dependent electric interactions in the liquid medium.[3,4] This assumption is inconsistent with McGowan's conclusions, but it can be justified by the following arguments: Consider two sets of operating conditions used by McGowan (Table II of reference 2); (a) resolving time, $2\tau_0=0.18\times 10^{-6}$ sec, and zero delay; and (b) resolving time, $2\tau_0=1.32\times 10^{-8}$ sec, and 6×10^{-9} sec delay. In an indirect manner McGowan arrived at attenuation factors $G_2=0.735$ and $G_4=0.497$. With these attenuation factors and formulas (72), (73), and (74) of Abragam and Pound[3] we calculate that the A_2 measured with operating conditions (b) should have been twenty percent higher than the A_2 measured with operating conditions (a). We also calculate that the A_4 for case (b) should be forty-five percent higher than the A_4 for case (a). These differences were not observed by McGowan.

We can obtain lower limits for G_2 and G_4 in the hydrofluoric acid medium by using McGowan's data. A difference of five percent in the A_2's or ten percent in the A_4's for the above pair of operating conditions would have been detected by McGowan. These differences correspond to $G_2=0.93$ and $G_4=0.86$, and we have taken these values as lower limits on the attenuation coefficients. If the attenuation factors actually fall at these lower limits, our result for g should be raised by about ten percent. The error quoted for g does not include the uncertainty arising from possible attenuation.

An additional argument in favor of values near unity for G_2 and G_4 in the hydrofluoric acid medium is that with such values the calculated "hard core" anisotropy does not fall significantly above the anisotropy measurements of McGowan for solid media.

At this time we are not prepared to make spin assignments to Ta^{181} but feel that this problem requires further study.

We wish to express our appreciation to Dr. F. Coester, with whom we have had many helpful discussions.

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[1] Aeppli, Albers-Schönberg, Frauenfelder, and Scherrer, Helv. Phys. Acta **25**, 340 (1952).
[2] F. K. McGowan, Phys. Rev. **93**, 471 (1954).
[3] A. Abragam and R. V. Pound, Phys. Rev. **92**, 943 (1953).
[4] F. Coester, Phys. Rev. **93**, 1304 (1954).

Radiogenic Osmium fromRhenium-Containing Molybdenite

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According to Mattauch's[1] isobar rule either osmium or rhenium should have a naturally radioactive isotope of mass number 187, and in 1948 Naldrett and Libby[2] were able to establish a natural beta activity of rhenium to which they ascribed a half-life of 4×10^{12} years, and which was attributed to the isotope 187. If follows that rhenium-containing minerals must also contain radiogenic osmium. Professor Geilmann,[3] who from earlier investigations on the occurrence of rhenium[4] was in possession of minerals with high rhenium content, very kindly provided us with molybdenite with a rhenium content of 0.32 percent. To 139 g of this mineral we added 0.147 mg of ordinary osmium (made radioactive by cyclotron irradiation for control of the completeness of the osmium separation) and were able to recover altogether 2.26 mg osmium; 0.28 mg of this osmium was investigated in a 60-degree mass spectrometer. We identified the mass spectrogram of osmium in 5 different places with the

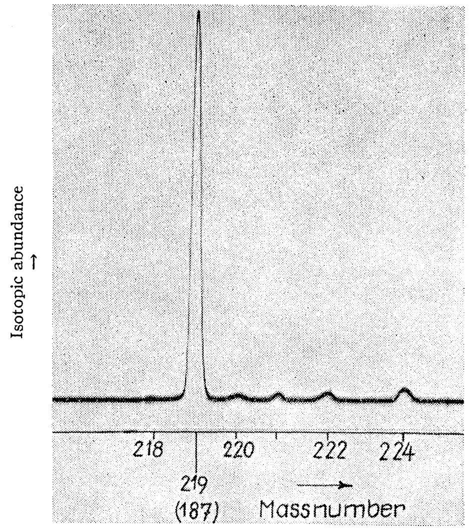

Fig. 1. Mass spectrum of radiogenic osmium in the mass range of OsO_2^+ ions.

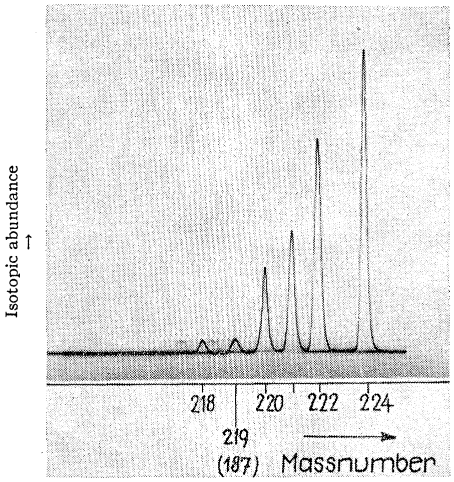

Fig. 2. Mass spectrum of normal osmium in the mass range of OsO_2^+ ions.

ions Os^+, OsO^+, OsO_2^+, OsO_3^+, and OsO_4^+. In each of these spectra the line corresponding to the isotope of mass 187 was greatly enhanced compared with that of ordinary osmium (see Figs. 1 and 2), from which it follows that, according to the isobar rule, the radioactivity of rhenium must be attributed to the isotope 187. Table I contains the abundances of the isotopes established by our measurements. The small amount of ordinary osmium visible in addition to the strong radiogenic amount can be accounted for quantitatively by the intentional addition of the cylcotron-irradiated osmium.[5] From the measured abundances of the isotopes and the quantities of added and recovered osmium, it follows that at least 99.5 percent of the osmium originally present in the mineral is radiogenic.

TABLE I. Isotopic abundance of normal and of radiogenic osmium.

	184	186	187	188	189	190	192
Normal osmium (Nier)[a]	11	97	100	811	982	1610	2500
2.113 mg radiogenic Os plus 0.147 mg normal cyclotron-irradiated Os	···	···	100	1.1 ±0.2	1.5 ±0.3[b]	1.8 ±0.1	2.8 ±0.1

[a] A. O. Nier, Phys. Rev. **52**, 885 (1937).
[b] This error comes from an unknown disturbance line.

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[1] J. Mattauch, Z. Physik. **91**, 361–371 (1934); Naturwiss. **25**, 738 (1937).

[2] S. N. Naldrett and W. F. Libby, Phys. Rev. **73**, 487, 929 (1948); see also N. Sugarman and H. Richter, Phys. Rev. **73**, 1411 (1948).

[3] We wish to thank Professor W. Geilmann for the material given to us and for valuable advice.

[4] W. Geilmann, Neues Jahrbuch für Mineralogie, 1945–1948, Abt. A, Heft 1–4, p. 3–9.

[5] We wish to thank Professor A. H. W. Aten, Jr., Amsterdam, for the active osmium.

Half-Life of Rhenium

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NALDRETT and Libby[1] have given 4×10^{12} years as the half-life of Re^{187}. As, from the preceding paper,[2] the radiogenic part of osmium prepared from a rhenium-containing molybdenite is known, it is now possible by a chemical determination of the osmium and rhenium content of the mineral to calculate the half-life, provided reasonable assumptions about the age of the mineral can be made.

By the colorimetry method of Beeston and Lewis,[3] we found (0.32±0.01) percent of rhenium; an independent determination by neutron-activation confirmed this result. For the isolation of the radiogenic osmium, a procedure based on opening up by perchloric acid was developed. The measurement was made with a spectrophotometer by using the thio-urea complex of osmium. An osmium content of (0.00161±0.00009) percent was found, a value in accordance with the isotopic abundances appearing in the mass spectrometer after dilution of the radiogenic osmium by a known quantity (0.147 mg) of ordinary osmium.

From these figures one obtains the half-life

$$T(\mathrm{Re}^{187})=91.7t \quad (t=\text{age of the mineral}).$$

Unfortunately, the age of our molybdenite is unknown; we may, however, be sure that the mineral cannot be younger than 50 million years nor older than 2500 million years. This means, for the half-life T of Re^{187}, that

$$5\times10^{9}\leqq T\leqq 2.5\times10^{11}\ \text{years}.$$

The half-life is, therefore, definitely smaller than the value of 4×10^{12} years originally given by Naldrett and Libby which, by the way, is now considered to be too high also by Libby,[4] since it is difficult to determine the half-life by counter methods because of the extreme softness of the radiation. From an age of about 500 million years, which seems reasonable for these minerals,[5] one obtains a half-life of 5×10^{10} years.

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[1] S. N. Naldrett and W. F. Libby, Phys. Rev. **73**, 487, 929 (1948); N. Sugarman and H. Richter, Phys. Rev. **73**, 1411 (1948).

[2] Hintenberger, Herr, and Voshage, preceding Letter [Phys. Rev. **95**, 1690 (1954)].

[3] Joseph M. Beeston and John R. Lewis, Anal. Chem. **25**, 651 (1953).

[4] Professor Libby (private communication).

[5] We are indebted to Professor Baier, Mainz, for valuable discussions.

Primary Alpha Particles in the Cosmic Radiation Near the Geomagnetic Equator*

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DURING a series of balloon flights in India, measurements of the flux of primary helium nuclei have been obtained with an apparatus consisting of a G-M counter coincidence train in which is interposed a high-pressure ionization chamber. Events characterized by a specific ionization at least as great as that of a primary alpha particle are recorded, whereas the slowest proton which can just penetrate the absorber beneath the chamber has an average specific ionization $I=2.3I_{\min}$.

The measurements were conducted at Aligarh, Uttar Pradesh (latitude $\lambda=18°$N), and Bangalore, Mysore ($\lambda=3°$N). At each station, the intensity $N(I>3.2I_{\min})$ of particles producing ionization-chamber pulses exceeding the bias setting corresponding to $3.2I_{\min}$, plotted on a logarithmic scale as a function of atmospheric depth, follows a straight line at high altitudes. The intensity N_{total} was also measured with counter-ion

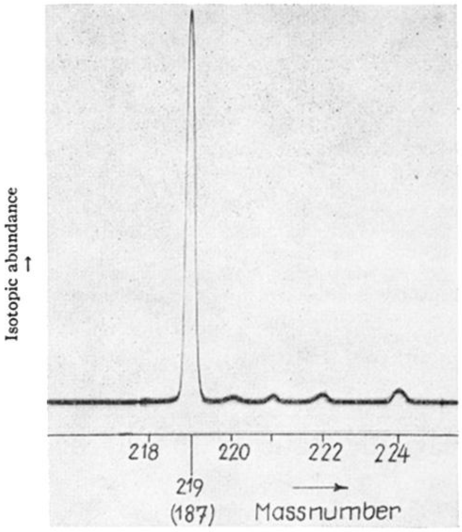

FIG. 1. Mass spectrum of radiogenic osmium in the mass range of OsO_2^+ ions.

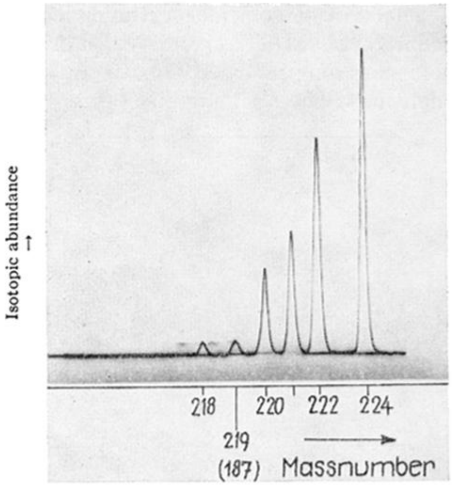

FIG. 2. Mass spectrum of normal osmium in the mass range of OsO_2^+ ions.