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Rare Gas Isotope Contents in Mineral Fractions of the Indarch Meteorite*

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We have measured the rare gas isotopes in mineral concentrates of the Indarch meteorite. We obtained samples from C. Frondel, who crushed some of the meteorite into small particles mainly in the 44 to 88 micron size. He fractionated the minerals into groups according to specific gravity, using heavy liquids and magnetic techniques. The fraction with specific gravity less than 2.4 is approximately 95% tridymite and represents about 1% of the whole stone. The fraction with specific gravity between 2.4 and 2.8 contains calcium sulfide, calcium phosphate, two unidentified minerals, and tridymite and enstatite impurities. This fraction represents a few percent of the meteorite. The fraction with specific gravity between 2.8 and 3.3 consists largely of clinoenstatite and represents about 75% of the meteorite. The troilite is concentrated in the fraction with specific gravity greater than 3.3, and kamacite is concentrated in the magnetic fraction. Each represents about 10% of the stone. The magnetic fraction is coarsest. Frondel plans to publish more detailed descriptions of the mineral fractions.

We heated samples of 45 to 182 mg weight in a molybdenum crucible by an R.F. generator. Most of the sample evaporated during the heating process.

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We cleaned the released gas with a titanium getter at 950°C, condensed the xenon in a glass trap at liquid nitrogen temperature, and then trapped the argon and krypton on charcoal at liquid nitrogen temperature. The rare gases were measured in a high sensitivity mass spectrometer under static conditions [Schaeffer, 1959]. The mass spectrometer was calibrated before each measurement by adding known amounts of He^3, He^4, atmospheric neon and argon.

The sensitivity of the mass spectrometer varied less than 5% during the entire series of measurements. The calibrations for krypton and xenon sensitivity were determined from earlier measurements where a comparison could be made with radioactivity measurements on Ar^{37}, Kr^{79}, and Xe^{127}. The accuracy of the krypton calibration is 20%; the accuracy of the xenon calibration is 50%. The total xenon content was only measured in one stone sample and in one sample of the mineral fraction with specific gravity less than 2.4. We measured the ratios of the xenon isotopes in every sample.

We have presented our results in Tables 1 and 2, together with previous measurements on whole stone samples on Indarch by Reynolds [1960] and by Zähringer [1961]. Our results lead to several interesting conclusions. These are:

(1) The radiogenic argon-40 is highly concentrated in the s.g. 2.4 to 2.8 fraction. As a result, we conclude that potassium is concentrated in this fraction.

(2) The helium-4 content is surprisingly uniform. This indicates that there are no large variations in the uranium and thorium contents of the fractions and that there are no large variations in helium-4 diffusion loss.

(3) A large part of the cosmogenic helium-3 and neon-21 has been lost by diffusion from the tridymite and the 2.4 to 2.8 fractions. It appears that the helium-4 is not in the major mineral component of these fractions.

(4) The cosmogenic argon-38 is highest in the 2.4 to 2.8 fraction. Therefore a large percentage of the argon-38 is produced by cosmic ray interactions on potassium and calcium.

(5) The krypton is concentrated in the tridymite fraction. In view of the uniformity of the Ne^{20} and Ar^{36}, one can conclude that primordial krypton is concentrated in this fraction.

(6) The xenon-129 anomaly is highest in the enstatite fraction and lowest in the tridymite fraction. The xenon-132 contents of the whole rock and tridymite fractions are similar. This may support the xenon-129 to iodine correlation obtained in heating experiments by Jeffery and Reynolds [1961].

One of us, ELF, would like to express his thanks to the hospitality extended to him during his stay in the Brookhaven Chemistry Department in the course of this work.

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Table 1. Rare Gas Isotope Contents (10^{-8} cc/g) in Mineral Fractions of the Indarch Meteorite

	Sample Weight	Helium		Neon			Argon				
Specific Gravity	mg	3	4	20	21	22	36	38	40	Kr^{84} ‡	Xe^{132}
Whole stone	154	12.5	350	7.4	4.1	5.1	7.0	1.9	7,000	0.08	---
" "	92	12.5	390	6.7	3.9	4.6	6.7	1.6	6,000	0.08	0.06
Less than 2.4	45	1.49	530	---	0.35	0.5	5.2	1.36	2,200	0.21	---
" " "	48	1.07	575	---	0.43	0.5	5.3	1.47	2,300	0.24	0.08
2.4 to 2.8	79	4.64	880	6.1	1.68	2.3	7.4	3.9	23,800	0.04	---
2.8 to 3.3	182	13.3	340	5.5	5.6	6.1	6.2	1.7	5,900	0.04	---
Greater than 3.3	113	8.0	260	2.3	2.4	2.7	5.0	1.17	3,600	0.04	---
Magnetic	99	11.6	290	2.7	3.3	3.8	4.8	1.28	3,750	0.03	---
Whole stone, Zahringer [1962]	---	13	1270	7.7	3.6	4.5	6.3	1.6	5,620	0.04	0.07

‡ The krypton isotopes in each fraction have natural abundances.

Table 2. The Ratios, Xe^{i}/Xe^{132}, in Mineral Fractions of the Indarch Meteorite

	Sample Weight	Xenon Isotope Ratios					
Specific Gravity	mg	128/132	129/132	130/132	131/132	134/132	136/132
Whole stone	154	0.10	3.60	0.18	0.84	0.38	0.30
" "	92	0.1	3.30	0.17	0.82	0.38	0.32
Less than 2.4	45	0.1	1.65	0.17	0.80	0.45	0.31
" " "	48	0.1	1.73	0.22	0.86	0.52	0.35
2.4 to 2.8	79	0.11	2.96	0.21	0.84	0.38	0.30
2.8 to 3.3	182	0.15	4.93	0.19	0.89	0.35	0.29
Greater than 3.3	113	0.25	2.1	0.18	0.91	0.47	0.28
Magnetic	99	0.28	3.2	0.25	1.0	0.45	0.35
Whole stone, Reynolds [1960]	1830	---	3.43 ± 0.02	0.160 ± 0.001	0.808 ± 0.005	0.390 ± 0.002	0.334 ± 0.002
Whole stone, Zähringer [1962]	---	---	4.0	---	---	---	---
Atmosphere		0.0713	0.983	0.152	0.788	0.388	0.330