^{10}Be AND ^{26}Al CONTENTS OF SMALL IRON METEORITES.

D. Aylmer, V. Bonanno and G.F. Herzog, Dept. of Chemistry, Rutgers University, New Brunswick, NJ 08903 and J. Klein and R. Middleton, Dept. of Physics, University of Pennsylvania, Philadelphia, PA 19104.

Iron meteorites have long exposure ages, typically 10^8-10^9 years. By comparing exposure ages based on various pairs of cosmogenic nuclides one may test the constancy of the cosmic ray flux over periods corresponding to the half-lives of the radioactive isotopes, from 10^6 to 10^9 y. Lipschutz et al. (Ref. 1) measured the ^{26}Al and noble gas contents of 10 iron meteorites. Calculated ^{26}Al/^{21}Ne ages agreed with published ^{40}K/^{41}K ages but not with ^{36}Cl/^{36}Ar or ^{39}Ar/^{38}Ar ages. In a similar study Hampel and Schaeffer (Ref. 2) found that ^{36}Cl/^{36}Ar, ^{39}Ar/^{38}Ar, and ^{26}Al/^{21}Ne ages agreed among themselves but not with ^{40}K/^{41}K ages. They concluded that the cosmic ray flux in the inner solar system was 50% more intense recently (<10 Ma B.P.) than in the more distant past.

The 50% differences in the ^{26}Al/^{21}Ne ages calculated by the two groups stem from two partially compensating factors: a deceptively small difference in a parameter of the age equations used (see Ref. 2) and what appears to be a systematic, 50-100% difference in the measured ^{26}Al contents. More generally, a review of the literature (3) reveals few determinations of ^{26}Al in irons and wide scatter among them. In this unsettled situation we thought it would be useful to determine ^{26}Al in some iron meteorites by using accelerator mass spectrometry, an independent method that allows one to measure the ^{26}Al present in less than one gram of an iron; in contrast decay counting normally requires at least 100 g of material.

Experimental

We obtained nine of the samples through the courtesy of Dr. H. Voshage; Dr. R. Schlotz sent us the Mundrabilla troilite. Voshage (4) summarizes the available rare gas and potassium isotope analyses. All the meteorites but Mundrabilla had preatmospheric masses estimated as less than 2×10^3 kg.

We isolated Al from 0.5-1.0 g samples by following procedures modified from those of Ref. 5. After addition of 1.5 mg of Al^{3+} carrier, dissolution of the sample in HNO_3 and HCl, and cation exchange on Dowex 50W-X8, Al was precipitated with NH_3(aq) at pH 6.4, dissolved in a small portion of 6<u>M</u> HCl, and reprecipitated. The resulting solid was dissolved a second time and diluted to a volume of 10.0 cm^3 from which we removed 0.5 cm^3 to check yield by atomic absorption spectrophotometry: Yields ranged from 79 to 103%. We took 7.0 cm^3 of each remaining solution, precipitated $Al(OH)_3$ in a quartz tube, and slowly raised the temperature to 700°C at which it remained for 2 hr.

We isolated Be from separate, 1-g samples of the irons. Samples were dissolved as above but in the presence of 200 µg of Be carrier, evaporated to dryness, and subjected to our usual separation procedures (6).

The accelerator mass spectrometry is described in Ref. 7. The results appear in Table 1.

Comparisons with other Work

Excluding Picacho, the ^{10}Be contents of Table 1 average 6.5 ± 0.8 dpm/kg. The average for 5 small falls analyzed by Chang and Wanke (8) is 5.05 ± 0.64 dpm/kg. The present results are higher by 25-30%. Shedlovsky (see 3) gives the ^{10}Be content of Bogou as 6.86 ± 0.20 dpm/kg in good agreement with our result. Honda et al. (9) obtain ^{10}Be contents for meteoritic metal ranging from 5 to 9 dpm/kg.

The ^{26}Al production rate in iron meteorites depends on shielding conditions. In order to compare the results of Refs. 1 and 2 with our own we have plotted ^{26}Al vs ^{4}He/^{21}Ne (Fig. 1). Included are several finds known or assumed to have terrestrial ages short compared to the ^{26}Al half-life (0.72 Ma). Their exclusion would have a minimal effect on the discussion below. We have excluded from the plot Skookum (Klondike) and Picacho because their ^{26}Al contents fall well below the field defined by the other data. We note that the errors in the ^{4}He/^{21}Ne ratios of Fig. 1 may be appreciable. The reason is that the samples counted for ^{26}Al were much larger than those analyzed for noble gases although the averaging of several sets of gas results may have helped in some cases. A second problem is the possible inconsistency of the noble gas standards used in different laboratories.

Inspection of Fig. 1 shows that our results occupy positions roughly intermediate between those of Refs. 1 and 2 with respect to both ^{26}Al contents and ^{4}He/^{21}Ne ratios. Taken as a set the data follow an expected trend: the ^{26}Al contents decrease with increasing ^{4}He/^{21}Ne ratio. Excluding only the outliers Kayakent and N'Goureyma, we get $^{26}Al = (7.98 \pm 0.55) - (0.0201 \pm 0.0024)\,^4He/^{21}Ne$ with $r = 0.92$. The trend should be regarded with some reserve because given the tendency toward grouping of data any significant interlaboratory bias could strongly influence the fit. Indeed, wherever direct comparisons are possible -Treysa, Aroos, Kayakent, and Mundrabilla troilite - the ^{26}Al contents reported by Hampel and Schaeffer (2) seem consistently higher, up to twofold, than ours and those of Ref. 1.

Terrestrial Ages

Picacho and Skookum have ^{26}Al contents that suggest long terrestrial ages. With ^{26}Al production rates in these two irons estimated from their respective ^{4}He/^{21}Ne ratios and the linear equation above, we arrive at terrestrial ages of 0.7 ± 0.5 and 1.0 ± 0.5 Ma. The latter age agrees well with one in Ref. (8).

^{26}Al/^{21}Ne Ages

The expression $511 \times {}^{21}Ne/^{26}Al \times R$ gives a ^{26}Al/^{21}Ne age. Hampel and Schaeffer (2) estimated the parameter R as 0.38 from semi-empirical nuclear calculations. We can estimate R independently. A plot of ^{21}Ne/^{26}Al vs ^{41}K/^{40}K exposure ages (4) should give a straight line through the origin with a slope related to R (Fig. 2). The data from Ref. 1 give R = 0.37 ± 0.02 (0.40 ± 0.02 without Aroos); those from Ref. 2 and this work yield R = 0.50 ± 0.02. The two values differ significantly and should not be sensitive to shielding effects.

Conclusions

1. For comparable shielding ($200 < {}^4He/{}^{21}Ne < 300$) we find ^{26}Al contents and hence production rates in iron meteorites intermediate between those of Refs. 1 and 2, i.e., in the range 2.2-3.2 dpm/kg.
2. Ages based on the equation $511 \times {}^{21}Ne/{}^{26}Al \times 0.38$ are 25% lower than accepted ^{40}K/^{41}K ages.
3. The maximum ^{10}Be production rate in iron metorites and by implication in the metal phases of stony meteorites appears to be at least 6.5 dpm/kg.

References

1. Lipschutz et al. (1965) J. Geophys. Res. 70, 1473-1489. 2. Hampel and Schaeffer (1979) Earth Planet. Sci. Lett. 42, 348-358. 3. Kohman and Bender (1967) in Nuclide Production by Cosmic Rays in Meteorites and on the Moon (ed. B.S.P. Shen). W.A. Benjamin. Pp. 169-245. 4. Voshage and Feldmann (1979) Earth Planet. Sci. Lett. 45, 293-308; Voshage et al. (1983) Z. Naturforsch. 38a, 273-280. 5. Horton and Thomason (1956) Anal. Chem. 28, 1326-1328. 6. Moniot et al. (1982) Nucl. Inst. Meth. 203, 495-502. 7. Klein et al. (1982) Nucl. Inst. Meth. 193, 601-616 Middleton et al. (1983) Nucl. Inst. Meth. 218, 430-438. 8. Chang and Wanke (1969) in Meteorite Research (ed. P.M. Millman) D. Reidel. Pp. 397-406. 9. Honda et al. (1983) Meteoritics 18, 315-316.

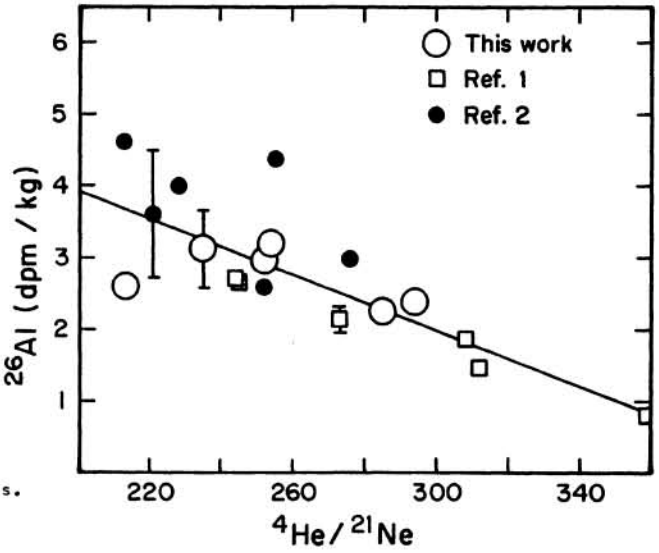

Fig. 1. ^{26}Al contents decrease with increasing ^{4}He/^{21}Ne ratio.

Fig. 2. ^{21}Ne/^{26}Al (10^{-8} cm^3 STP/g ÷ dpm/kg) vs. ^{40}K/^{41}K age. The slope of any fit is $(511)^{-1}$ P_{21}/P_{26} Ma^{-1}.

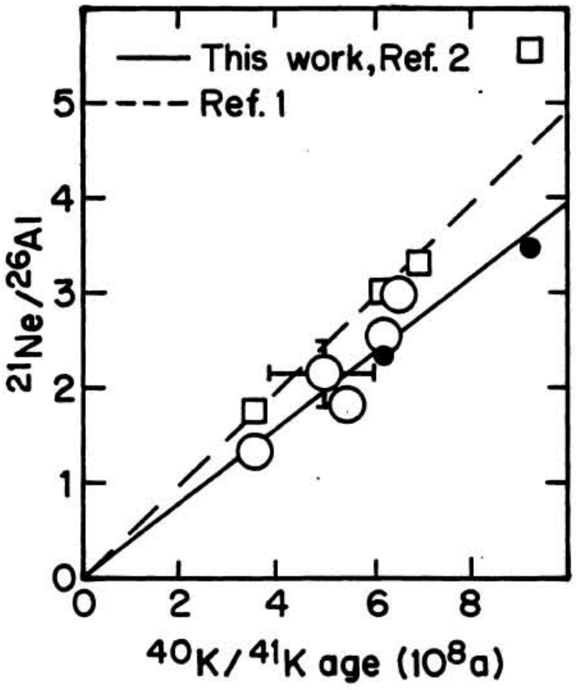

Table 1. ^{26}Al and ^{10}Be contents of iron meteorites

Meteorite[a]	ID[b]	^{26}Al (dpm/kg)	^{10}Be[c] (dpm/kg)	4/21[d]
Bogou(IA)	HV	2.21±0.38	7.30	285
Brownfield(IID)	H44.3	3.11±0.56	6.33	235
Calico Rock(IIA)	H70.2	3.20±0.47	7.55	254
Charlotte(IVa)	GMHU		7.03	219
Kayakent(IIIA)	OAS	2.59±0.49		222
Mayerthorpe(IA)	REF	2.36±0.36	5.21	294
Picacho(IIIA)	H237.5	1.18±0.25	5.83	283
Skookum(IVB)	81/1	0.82±0.14		286
Treysa(IIIB-an)	M	2.95±0.37	5.75	252
Mundrabilla Troilite(IR-an)	RS	6.8±1.3		

a. Falls underlined; classifications in parentheses; recovered masses <17 kg except Mundrabilla. b. H=American Meteorite Laboratory; M=Max-Planck Inst., Mainz (Dr. H. Wanke); GMNU=Geol. Mus. Harvard Univ. (Dr. C. Frondel); OAS=Prof. O. Schaeffer; REF=Dr. R.E. Folinsbee (Univ. Alberta) HV=Material Supplied by Drs. J. ARnold and P.S. Goel.; RS=Dr. R. Schlotz (Max-Planck Inst., Heidelberg). c. Uncertainty 5-10%. d. Refs. 2 and 4. 4/21 = ^{4}He/^{21}Ne.