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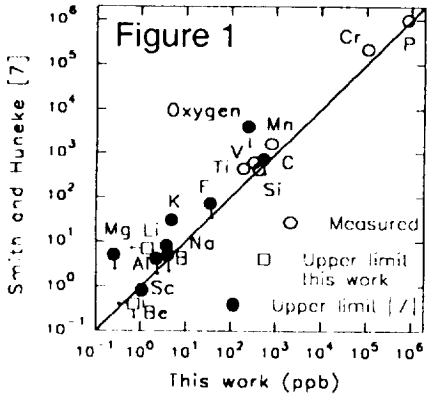
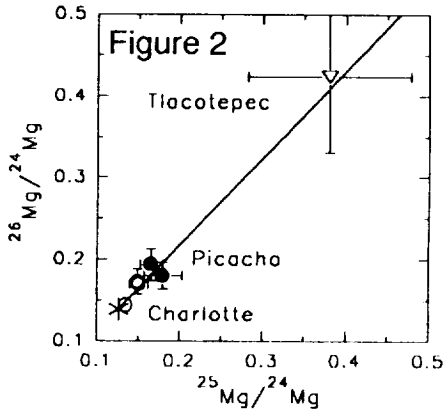
^{26}Al-^{26}Mg AGES OF IRON METEORITES: G.F. Herzog[1], A.E. Souzis[2], S. Xue[1], J. Klein[3], D. Juenemann[3], and R. Middleton[3]. 1) Dept. Chemistry, Rutgers Univ., New Brunswick, NJ 08903; 2) US Army Research Lab., EPSD, Fort Monmouth, NJ 07703-5601; 3) Dept. Physics, Univ. Pennsylvania, Philadelphia, PA 19104.

Introduction. An exposure age for an iron meteorite can be calculated from measurements of a radioactive nuclide and a stable nuclide that are produced by similar sets of nuclear reactions, provided that the stable nuclide is present with low initial abundance. The standard methods rely on either ^{40}K ($t_{1/2}$ = 1.26 Gy), ^{39}K, and ^{41}K (e.g., [1,2]) or on a shorter-lived radionuclide and a stable, noble gas isotope. Widely used pairs of this type include ^{36}Cl/^{36}Ar and ^{26}Al /^{21}Ne (e.g., [3] and [4]). Other pairs may serve the purpose for iron meteorites contain many stable isotopes besides those of K and the noble gases that are produced partly by cosmic rays [5-8]. We consider here the calculation of exposure ages, t_{26}, from measurements of ^{26}Al ($t_{1/2}$ = 0.7 My) and (stable) ^{26}Mg. Ages based on ^{26}Al/^{26}Mg ratios, like those based on ^{36}Cl/^{36}Ar ratios, are "buffered" against changes in relative production rates due to shielding because decay of the radioactive nuclide accounts for a good part of the inventory of the stable nuclide.

Experimental Methods. Encouraged by the work of [7] and [8], we decided to apply the method of glow-discharge mass spectrometry to the analysis of stable isotopes in iron meteorites. This method is capable of part-per-trillion (ppt) detection limits at high mass resolution (> 4000). Samples were introduced into the VG 9000 spectrometer as "pins," i.e., rectangular solids ~ 20 x 2 x 2 mm trimmed to size with a diamond-studded saw. The sample of Tlacotepec was taken adjacent to the one analyzed by Smith and Huneke [7]. Before data acquisition began, the samples were subjected to 0.5-1 h of sputtering at 1 kV and 5 mA (Ar^+) in order to remove surface contamination. Data were then acquired using discharge conditions of 1 kV and 3 mA. Initially, a broad elemental survey requiring ~3 h and covering the mass range from 6 to 59 AMU was taken for each sample. This survey was followed by longer (4 h) and more detailed measurements of the isotopic magnesium concentrations (24-26 AMU). Each mass window was scanned 200 times and the resulting signals were summed and averaged. Each window consisted of 100 channels with a dwelltime/channel of 100 ms. In separate experiments, the ^{26}Al activities of 4 iron meteorites were measured by accelerator mass spectrometry [9].

Results. Figure 1 shows the results obtained for minor and trace elements from the elemental scan for Tlacotepec. Concentrations were calculated from the raw data using *R*elative *S*ensitivity *F*actors (RSFs) developed from previous analyses using NBS standards. For those elements for which we had no standard, the RSFs supplied by VG with their software were used. The uncertainties estimated from the reproducibility of the measurements for Tlacotepec and the other irons vary considerably: from ~2% for the major elements Fe and Ni, to ~10% for the minor elements, to 30-100% for the trace elements. Also shown in Figure 1 are the results of Smith and Huneke [7] for Tlacotepec. Agreement is good for the major elements (Fe = 84.0% vs. 82% and Ni = 15.9% vs. 17%). For the other elements, the concentrations of ref. [7] typically exceed ours by 5% to 100%, perhaps because a different library of RSFs was used. Table 1 and Figure 2 show the





magnesium isotopic data for Charlotte, Picacho, and Tlacotepec. The errors plotted in Figure 2 are conservative. The isotopic ratios for Tlacotepec agree well with those of ref. [7]. The experimental points plot (within error) on a line defined by terrestial Mg and cosmogenic Mg, taken here to have the composition $^{24}Mg/^{26}Mg$ = 0.90 and $^{25}Mg/^{26}Mg$=0.95 in analogy with cosmogenic neon. The irons studied contain between 2% and 30% of cosmogenic ^{26}Mg ($^{26}Mg_c$). The ^{26}Al activities, which are only in fair agreement with results reported previously [4] are given in Table 2.

Table 1. Mg (ppt) in iron meteorites.

Sample	^{24}Mg	^{25}Mg	^{26}Mg	$^{26}Mg_c$	$^{24}Mg_p$
Charlotte (4A)	1533± 20	231 ± 17	261 ± 10	47 ± 12	1488 ± 23
	2041 ± 26	304 ± 15	353 ± 30	69 ± 35	1975 ± 42
	3385 ± 67	458 ± 23	487 ± 25	1 ± 31	3383 ± 73
Picacho (3A)	1242 ± 44	207 ± 15	239 ± 22	70 ± 26	1175 ± 50
	1074 ± 37	193 ± 24	193 ± 16	45 ± 20	1031 ± 42
Tlacotepec (4B)	257 ± 41	98 ± 20	109 ± 16	83 ± 20	178 ± 45

$^{26}Al/^{26}Mg$ Ages. To calculate $^{26}Al/^{26}Mg$ ages, t_{26} (Table 2), we assume single-stage irradiations at production rates, P(^{26}Mg) and P(^{26}Al) [atom/My], that are constant for each meteorite. In addition, we can plausibly assume that the exposure ages and the terrestrial ages of the iron meteorites are long and short, respectively with respect to the half-life of ^{26}Al so that the measured ^{26}Al activity equals P(^{26}Al) in each case. Under these conditions it can shown that

$$t_{26} = \frac{44.1 \times {}^{26}Mg(ppt)/{}^{26}Al(dpm/kg)}{[1 + P({}^{26}Mg)/P({}^{26}Al)]}$$

Table 2. $^{26}Al/^{26}Mg$ ages of four iron meteorites.

Meteorite	^{26}Al (dpm/kg)	$^{26}Mg_c$ (ppt)	t_{26} (My)	$t_{K\text{-}K}$ (My)
Cape of Good Hope	1.6	138[7]	1360	775±70[1]
Charlotte	4.4	41±12	148±45	365±80[1]
Picacho	3.2	56±16	273±81	635±50[2]
Tlacotepec	2.1	83±20	622±157	945±55[1]
		250[7]	1130[7]	

where the factor 44.1 converts the ratio of measurement units in the numerator to My. The term in brackets allows for the fact that ^{26}Al decays to give ^{26}Mg. A production rate ratio P(^{26}Mg)/P(^{26}Al) = 1.79 (atom/atom) was calculated from the work of Silberberg and Tsao [10], assuming production rates for iron and nickel are the same; for comparison we note that P(^{21}Ne)/P(^{26}Al), the ratio needed for the calculation of $^{26}Al/^{21}Ne$ ages, is 2.70 [4]. Our $^{26}Al/^{26}Mg$ ages are 35-60% smaller than the ^{40}K-K ages. A discrepancy in this direction and of this approximate magnitude is expected based on short-lived radionuclides (see [4]). We note, however, that the $^{26}Al/^{26}Mg$ ages calculated from the $^{26}Mg_c$ concentrations given by Smith and Huneke [7] are appreciably larger.

Conclusions $^{26}Al/^{26}Mg$ ages are in fair agreement with ages for iron meteorites based on noble gases and other short-lived radionuclides. The largest uncertainty in the $^{26}Al/^{26}Mg$ ages, now about 30%, is associated with the the determination of the cosmogenic ^{26}Mg. The uncertainty arises partly because cosmogenic Mg comprises at most 30% of the total Mg observed and partly because the calibration factors for Mg are not well known. The variations in the observed concentrations of non-cosmogenic Mg are large and appear to be associated with the samples. The Mg may occur in crystallites or as contamination. It would be of interest to investigate the Mg systematics in iron meteorites.

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