NICKEL–IRON SPHERULES IN A LUNAR GLASS SPHERE; J. A. O'Keefe, Lab. for Astronomy & Solar Physics, NASA/GSFC, Greenbelt, MD 20771, R. Ganapathy., J. T. Baker Co., Phillipsburg, NJ 08865

Lunar Sample 14425 is from the Apollo 14 bulk fines, in the pre-numbered sample bag 1N. It is a glass sphere, 8.01 mm in diameter, with a mass of 0.784 g. X-rays (1) show that it contains numerous metallic inclusions, up to 7 mm in diameter, accompanied by sulfide inclusions or coatings (2). K, U, and Th were determined by J. E. Keith (3) by passive γ-ray counting as 3000, 2.2, and 7.2 ppm respectively. Keith noted the resemblance to typical Apollo 14 samples. Glass and O'Keefe (4) found, by energy-dispersive x-ray analysis, that the composition resembles that of a noritic breccia such as 14068; their K agreed with Keith's.

In the present work, the abundances of 17 elements were determined at the Research Laboratory, J. T. Baker Co., by neutron activation. Two samples were studied: a metallic sphere, 14425.4, mass 0.469 mg, and a glass chip, 14425.6, mass 10.687 mg. The glass chip was sealed into a quartz tube of high chemical purity, and exposed to an integrated neutron flux of 4×10^{19} n cm^{-2} at the University of Missouri. The metallic sphere was similarly treated, except that radiochemical purification was first used in order to make it possible to study some of the rare elements.

The results are shown in Table 1. Some of the measures can be compared with (4); Fe and Cr are in agreement; but Na is lower in these measurements by a factor 3, as feared by (4), and Ni is, unexpectedly, about 20 times higher in these measurements on the glass than in (4). On the metal, the Ni is similar to that of (2).

The same data is shown in Fig. 1, referred to carbonaceous chondrites (5) and normalized to Ni. The relative abundances in metal and glass are similar (using the neutron-activation figure for Ni); and both are in reasonable agreement with chondritic relative abundances, except for a 30-fold excess of W.

Discussion

Are the spherules the residue of an impacting meteorite or are they exsolved from the glass? The measured W/La is 0.0155; the usual lunar ratio is 0.02, in reasonable agreement. Since the REE are much to high for a meteoritic origin, it follows that at least the W is probably lunar, and got into the spherules from the glass.

The physical phenomena at the interface between the cloudy and the clear glass resemble those of phase separation in the glass (6). There is first a bluish cloud corresponding to the nucleation of a new phase, not necessarily metallic, and perhaps a sulfide as mentioned by Glass (5). The cloud grown in intensity and loses the blue color, as if the nuclei were growing. A maximum is reached about 30 micrometers from the edge, and then the brightness diminishes, as if the larger particles were growing at the expense of the smaller (Ostwald ripening, (6, p. 66)). Finally the metallic spherules appear, but only in the cloudy region. These phenomena suggest that the cloudy region is advancing into the clear region, and hence the spherules are exsolving from the glass.

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System

O'Keefe, J. A., and Ganapathy R.

Table 1. Elemental Concentrations in the Metal Sphere and Glass from the Apollo-14 Mission

	Metal (14425, 2, 4) (469 micrograms)	Glass (14425, 2, 6) (10.687 mg)	Metal / Glass	Metal / C1	Glass / C1	C1 Chondrites (Anders & Ebihara 1982)
Ir (ppb)	6562 ± 12	167 ± 4	39	13.9	0.35	473
Au (ppb)	1282 ± 10	43 ± 4	30	8.84	0.30	145
Ni (%)	13.1 ± 0.2	0.35 ± 0.02	37	11.9	0.32	1.10
Co (ppm)	5494 ± 13	192 ± 2	29	10.8	0.38	509
Re (ppb)	658 ± 105 (±125)	-	-	17.8	-	36.9
Os (ppb)	7290 ± 1090	-	-	10.4	-	699
Ru (ppb)	7000 ± 3400	-	-	9.80	-	714
As (ppm)	12.3 ± 0.6	0.37 ± 0.23	33	6.44	0.19	1.91
W (ppm)	26.9 ± 0.8	0.98 ± 0.31	27	302	11	0.089
Fe (%)	85.8 ± 0.6	12.0 ± 0.4	7.2	4.64	0.65	18.51
Cr (ppm)	268 ± 8	2307 ± 7	0.12	0.101	0.87	2650
Sb (ppb)	-46 ± 323	140 ± 164	-	1.8	0.90	155
Na (ppm)	4.1 ± 0.9	1875 ± 5	0.0022	-	0.39	4830
La (ppm)	-	63.4 ± 0.2	-	-	270	0.236
Sm (ppm)	≤0.013	24.1 ± 0.08	≤0.00054	-	170	0.142
Eu (ppm)	-	2.09 ± 0.15	-	-	39	0.0543
Yb (ppm)	-	25.2 ± 0.3	-	-	150	0.166
(Ir/Au)	5.12	3.88	-	1.57	1.19	3.26
$(Ir/Ni)10^{-5}$	5.00	4.77	-	1.16	1.11	4.30

On the other hand, it is difficult to believe that the moon could produce metallic spherules which, over such a wide range in concentration, simulate meteoritic relative abundances. In any case, it is clearly seen that, apart from W, the abundance bear little resemblance to those observed in tektite metallic spherules (7).

References: (1) J. A. O'Keefe and B. P. Glass (1985) Science 227, 515-516. (2) B. P. Glass (1986) Geochim Cosmochim Acta, 50, 111-113 (3) J. E. Keith (1984) Johnson Space Center Memo SN 3-84-269. (4) B. P. Glass and J. A. O'Keefe (1985) Science 229, 1410. (5) E. Anders and M. Ebihara (1982) Geochim. Cosmochim Acta, 46, 2363-2380. (6) R. H. Doremus (1973) Glass Science, Wiley-Interscience, New York. (7) R. Ganapathy and J. W. Larimer (1983) Earth Planet Sci. Lett. 65, 225-228.

Figure 1

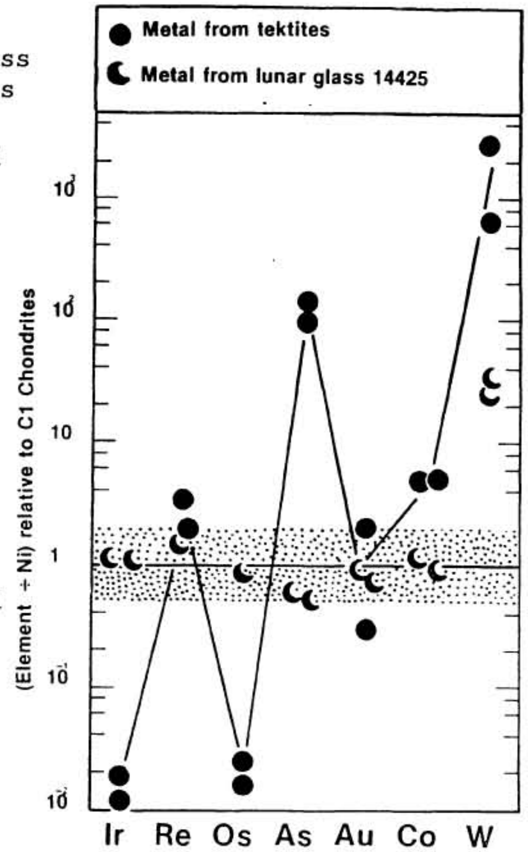

Figure 1

© Lunar and Planetary Institute • Provided by the NASA Astrophysics Data System