CHEMICAL COMPOSITIONS OF SILICATE INCLUSIONS IN IAB IRON METEORITES.

T. Fukuoka and R. A. Schmitt, Department of Chemistry and the Radiation Center, Oregon State University, Corvallis, OR 97331.

Silicate inclusions are contained in many group IAB iron meteorites. The petrographic studies and microprobe analyses for the inclusions were reported by several workers (e.g. 1). Bulk chemical analyses were also published by Olsen and Jarosewich (2) etc. Recently, Bild(3) had reported chemical analyses of major, minor and trace elements (especially siderophiles) in silicate inclusions in three IAB iron meteorites.

In this study, 31 major, minor and trace element abundances were determined via sequential INAA (instrumental neutron activation analysis) and RNAA (radiochemical neutron activation analysis) in four silicate inclusions in IAB iron meteorites. Campo del Cielo and Linwood were classified in the Odessa class, and Four Corners and Woodbine are in the Copiapo class (1). The results are shown in Table 1 and the chondritic normalized Na, K, Sr, Ba, REE, Sc, V and Mn abundances of these silicate inclusions are plotted in Fig. 1.

All samples were powdered in an agate mortar and metal phases were separated by a hand magnet. The FeO content in Woodbine is considerably higher than observed in other silicate inclusions; also, higher values for the siderophile elements Co, Ni and Ir were found in Woodbine which indicates incomplete separation of the metal phase. The Cr_2O_3 content in Linwood is at least three times higher than in other inclusions. Bunch et al. (1) found chromite in the Linwood inclusion, but did not observe chromite in Four Corners and Woodbine inclusions. The highest V content in Linwood is consistent with the existence of chromite, in which V is concentrated (1). In ordinary chondrites, Zn is mostly concentrated in chromite (4) and FeS. The high Zn content in the Linwood inclusion relative to Campo del Cielo and Four Corners is also consistent with the existence of chromite in the Linwood inclusion. However, the highest Zn content was found in Woodbine, in which no chromite was observed (1). Such a high Zn abundance may be attributed to excessive FeS in the inclusion.

Ratios of Al_2O_3/Na_2O and Na_2O/K_2O in four inclusions are almost constant at 1.9-2.2 and 12-18, resp. This suggests that Al, Na and K were not fractionated significantly in any high temperature metamorphic or other events.

Our abundance values (except discussed above) for Woodbine generally agree with the values previously reported (1,3). Differences between our values for Campo del Cielo and those observed by Bild (3) in two chips support his contention that significant heterogeneity exists in the Campo del Cielo silicate inclusions.

The Ba abundance in Campo del Cielo is similar to the value (2.37ppm) by Eugster et al. (5). Fig. 1 shows apparent high positive Ba anomalies for all four inclusions. Moore and Brown (6) observed that chondritic finds showed higher Ba abundances relative to chondritic falls. Also, the Melrose-b howardite (find) showed a large positive Ba anomaly (7). Since the four meteorites of this work are all finds, the observed positive Ba anomalies very likely reflect terrestrial contamination. Higher Sr abundances relative to La in Four Corners and Campo del Cielo may also indicate some terrestrial contamination. The chondritic normalized REE pattern for Woodbine is similar to that observed by Bild (3), but different from that reported by Masuda (8) in which enrichment

of the heavy REE (Tb to Lu) was observed.

Except for Campo del Cielo, the minor and trace element data shown in Fig.1 are generally similar to ordinary chondrites although V and Mn in Woodbine inclusions seem to be slightly depleted. Aℓ, Ca and Mg abundances in these inclusions are also similar to those in ordinary chondrites. Zn contents except for Woodbine are similar to Cl chondritic abundance and 4-8 times higher relative to ordinary chondritic abundance. Cr_2O_3 contents except for Woodbine are depleted by a factor of 0.2 to 0.3 relative to the ordinary chondritic abundance. Co, Ni and Ir contents are depleted compared to ordinary chondritic abundances by factors of 0.1 to 0.2 except for Co in the Campo del Cielo inclusion and those in the Woodbine inclusion (because of metal phase contamination). But The Ir/Ni and Co/Ni ratios except for Campo del Cielo and Woodbine are similar to H, L and C chondrites.

The chondritic normalized REE pattern for Campo del Cielo shows a fractionated pattern which might indicate some differentiation had occured. However, the similar chondritic normalized K (volatile LIL) and La (refractory LIL) abundances observed would suggest such a process is restricted to a mild igneous differentiation of this inclusion, since K is depleted relative to La in most basaltic achondrites (e.g., 9). The Linwood inclusion is more depleted in Na and K relative to Woodbine but is more enriched in REE (Fig. 1). This may suggest a smaller plagioclase content in the Linwood inclusion.

Bild (3) suggests that the Campo del Cielo inclusion may have experienced some partial melting. The fractionated REE pattern with some apparent loss of plagioclase are consistent with the above interpretation of a limited degree of partial melting that may have occurred in a non-equilibrium manner (see 10). The REE pattern in Campo del Cielo is similar in some respects to that found in the Kesen (H4) chondrite (11). The monotonic REE pattern (La/Lu $\simeq$0.5) in the Four Corners inclusions also suggests a mild fractionation event.

In conclusion, the bulk, minor and trace element data of this work support previous observations that silicate inclusions in iron meteorites are very similar in composition to chondrites and that significant exposures to partial melting of these silicate phases were absent. The Zn data does favor the predominance of Cl or C2 chondrites as the primary silicate inclusions over the ordinary chondritic classes for such inclusions. Studies of other strongly depleted elements in uncontaminated inclusion specimens should test this hypothesis.

REFERENCES (1) Bunch T. E. (1970) Contr. Mineral Petrol. 25, 297-340. (2) Olsen E. and Jarosewich E. (1970) Earth Planet. Sci. Letters 8, 261-266. (3) Bild R. W. (1977) Geochim. Cosmochim. Acta 41, 1439-1456. (4) Curtis D.B. (1974) Ph.D. thesis, Oregon State University. (5) Eugster O., Tera F. and Wasserburg G. J. (1969) J. Geophys. Res. 74, 3897-3908. (6) Moore C. B. and Brown H. (1963) J. Geophys. Res. 68, 4293-4296. (7) Starzyk P. M. et al.(1978) (in preparation). (8) Masuda A. (1969) Nature 224, 164-165. (9) Fukuoka T. et al. (1977) Proc. Lunar Sci. Conf. 8th, 1, 187-210 (10) Fukuoka T. F. et al. (1978) In Lunar Science IX. (11) Masuda A. et al. (1973) Geochimica Cosmochim. Acta 37, 239-248.

CHEMICAL COMPOSITIONS OF SILICATE . . .

T. Fukuoka et al.

Table 1. Chemical abundances in silicate inclusions of iron meteorites by INAA and RNAA.

Sample	Campo del Cielo(1)		Four Corners		Linwood		Woodbine		Error(2) (%)
Method(3)	I	R	I	R	I	R	I	R	
Wt,mg	69-75	69	189-347	189	54-61	54	197-209	197	
TiO_2 %	0.21		0.21		0.16		0.15		25-42
Al_2O_3	1.28		3.4		1.59		2.1		2-5
FeO (4)	5.9		3.7		7.7		32.3		2-3
MgO	31.8		31.5		22.3		19.5		2-4
CaO	1.3		3.0		2.4		1.7		10-17
Na_2O	0.63		1.53		0.82		0.94		2-3
K_2O		0.035		0.118		0.059		0.076	2
MnO	0.313		0.208		0.207		0.137		1
Cr_2O_3 %	0.181		0.116		0.49		0.159		1
Sc ppm	9.6		13.8		7.9		8.0		2
V	47		31		53		25		10-12
Co	383		71		103		1220		1
Ni	1190		1520		1630		9950		2-3
Ir	0.150		0.127		0.121		0.26		2-4
Zn	217		206		438		699		2-3
Sr		9.3		48		14		11	5-12
Ba		3.4		8.6		16.6		13.5	3-10
La		0.114		0.29		0.49		0.38	5-7
Ce		0.30		1.1		1.4		1.2	10-23
Pr		0.06		0.12		0.21		0.14	15-75
Nd		0.21		0.68		0.74		0.74	6-22
Sm		0.096		0.250		0.35		0.27	6-7
Eu		0.044		0.124		0.079		0.080	3-4
Gd		0.11		0.34		0.44		0.29	11-25
Tb		0.024		0.069		0.085		0.058	5-8
Dy		0.195		0.48		0.54		0.40	6-9
Ho		0.043		0.106		0.116		0.076	4-10
Er		0.14		0.37		0.35		0.24	12-23
Tm		0.024		0.051		0.047		0.032	8-12
Yb		0.177		0.37		0.32		0.22	2-3
Lu ppm		0.030		0.052		0.046		0.029	3-5

(1) Also known as El Taco
(2) Errors were estimated due to counting statistics.
(3) I=INAA; R=RNAA
(4) Analyzed total iron expressed as FeO.