

The chemical composition of dark inclusions from the Allende meteorite.

A. Bischoff¹, H. Palme², B. Spettel², R.N. Clayton³, and T.K. Mayeda³. ¹Institut für Planetologie, Wilhelm-Klemm-Str.10, and Institut für Mineralogie, Corrensstr. 24, 4400 Münster; ²Max-Planck-Institut für Chemie, Saarstr.23, 6500 Mainz, F.R.G.; ³Enrico Fermi Institute, University of Chicago, Chicago, IL 60637, USA.

Dark inclusions (DIs) are common constituents in the Allende meteorite. They appear macroscopically black and featureless and consist predominantly of tiny subhedral to euhedral olivine crystals. DIs do not contain true chondrules. Almost spherical components that appear to be chondrules, turn out to be olivine aggregates that lack interstitial mesostasis material. DIs contain some Ca-pyroxene and a few very small CAIs consisting of spinel, perovskite and Ca-pyroxene. Fragments within the fine-grained olivine matrix include olivine (with variable FeO-contents), irregularly-shaped Ca-pyroxene-andradite inclusions, sulfide-rich aggregates and chromites.

In this abstract we report major and trace element data on 7 large 'dark inclusions from Allende. All elements were determined by INAA-procedures. Oxygen isotopes were determined on four of these inclusions. The results are given in Tables 1 and 2.

The major chemical characteristics of the dark inclusions are:

- 1) Somewhat higher contents than bulk Allende in Fe (+17%) and Mn (+12%) (Fig.1)
- 2) Higher Ca and lower Al contents than bulk Allende, leading to Ca/Al ratios as high as 4.5 (cosmic 1.08)
- 3) Large depletions in Na and K (up to a factor of 5)(Fig.2)
- 4) Some depletions (20-35%) in refractory lithophile and refractory siderophile elements (e.g. Sc, Fig.2, Ir, Fig.3).
- 5) Most other elements have abundances indistinguishable from bulk Allende (Table 1, Fig.3). This is especially remarkable for the rather volatile elements Zn and Se (Fig.2). These elements are diagnostic for C3-meteorites. The similar abundances of Zn and Se in dark inclusions and in Allende (i.e. C3-meteorites) show that they ultimately came from a C3-reservoir.

It can be shown from these data, that dark inclusions basically contain the same components as Allende. Their modal proportions are however quite different.

- 1) The higher FeO and MnO contents are due to the low abundance of iron poor phases; dark inclusions contain no chondrules and few forsteritic fragments.
- 2) The low alkali contents and simultaneously low Al-contents reflect the complete lack of Na-Al-silicates (plagioclase, sodalite, nepheline). The elevated Ca-values are caused by a relatively high modal content of Ca-rich pyroxene.
- 3) Dark inclusions contain no large Ca,Al-rich inclusion. Occasionally, small (< 200 μm) CAIs were encountered. Dark inclusions consequently have lower abundances of refractory elements.

Elements that are largely contained in metal, sulfide or in the fine grained olivine matrix have rather similar abundances as in bulk Allende (Ni, Co, As, Ga, Zn, Se), independent of volatility. Only Au shows some scatter. This is also observed in bulk Allende samples. It therefore appears that the abundances of sulfide and metal in dark inclusions and in bulk Allende are very similar. DBA-analyses of our suite of inclusions show indeed a S content of about 2% for the DIs (2.1% S in bulk Allende).

Oxygen isotopic compositions of dark inclusions plot on the upper end of the Allende mixing line (Fig.4). The lack of components low in $\delta^{18}\text{O}$ and $\delta^{17}\text{O}$ (CAIs) may be in part responsible for the extreme position of the dark inclusions.

The simplest and most straightforward interpretation of these data is that during aggregation of DIs larger components (chondrules, fragments, CAIs,

Na-rich aggregates) were not accreted, probably because they were absent from the formation region, perhaps due to some type of grain size sorting. Our data also exclude formation of DIs by regolith processes.

Clayton et al. (1977), EPSL 34, 209-224; Clayton et al. (1983), Chondrules and their Origins; edited by E.A. King, 37-43, Lunar and Planetary Institute, Houston; Jarosewicz et al. (1985), Natl. Museum of Natural History, Smithsonian Institution, Washington, D.C. 20560; Kallemeyn and Wasson (1981), GCA 45, 1217-1230.

Table 1: Allende dark inclusions

	Allende Bulk	Pa	ABS1	D-1	D-2	D-3	D-4	D-7	stand
%									
Mg	14.83*	13.98		13.33	10.68	13.69	13.78	13.71	5
Al	1.74*	1.19		1.09	0.75	1.28	1.02	1.19	5
Ca	1.84*	1.70	2.3	2.25	3.41	2.37	2.35	1.45	5
Fe	23.57*	26.32	28.48	28.4	29.39	26.96	26.28	27.28	3
ppm									
Na	3400*	770	567	720	590	820	624	1315	3
K	289**	85	48	106	62	89	66	67	10
Sc	11.5**	9.7	6.04	8.13	5.44	7.60	6.93	9.21	5
V	92*			68.4	48.9	64.6	65.0	80.9	5
Cr	3580**	2530	3100	3020	2475	3170	3050	4320	3
Mn	1472**	2050	1615	1710	1715	1770	1697	1680	3
Co	640**	706	605	653	530	615	638	820	3
Ni	13500**	16300	15500	14900	13700	14600	21300	19300	6
Cu	125**		113	130	130	<120	145	<150	10
Zn	110*	160	124	130	96	140	128	147	10
Ga	6.1**	8.3	6.31	6.97	6.55	8.49	6.5	8.49	10
As	1.33**	1.8	1.93	2.47	1.50	1.39	2.50	1.82	5
Se	8.6**	9.1	11.1	11.1	11.4	8.41	12.5	11.1	10
Br	1.6**	0.87	0.68	1.1	0.95	0.83	0.69	0.92	15
Mo	1.6**		1.4	1.2	1.4	1.8	1.2	<1.5	25
Sb	0.083†	0.13	0.13	0.18	<0.1	0.13	<0.2	0.084	20
La	0.52*	0.39	0.256	0.38	0.26	0.35	0.27	0.35	12
Sm	0.34*	0.24	0.158	0.22	0.131	0.200	0.204	0.253	5
Eu	0.11*	0.083	0.058	0.080	0.052	0.078	0.069	0.087	10
Dy	0.42*		0.22	0.20	0.34	0.37	0.37	0.37	15
Yb	0.3*	0.27	0.15	0.18	0.22	0.23	0.18	0.27	20
Lu	0.052*	0.039	0.03	0.032	0.033	0.035	0.027	0.049	20
Os	0.75*	0.75	0.95	0.75	0.98	0.77	0.73	0.46	20
Ir	0.74*	0.72	0.753	0.650	0.702	0.500	0.652	0.464	5
Au	0.15*	0.144	0.093	0.162	0.043	0.114	0.157	0.162	5

* Jarosewicz et al. (1985)
** average of 4 Allende samples (MPI Mainz)
† from Kallemeyn and Wasson (1981)
‡ calculated from CI-ratios

Table 2: Oxygen isotopes

Sample	$\delta^{18}O$	$\delta^{17}O$
D-1	+3.75	+1.08
D-2	+4.60	+0.18
D-3	+3.23	-0.60
D-4	+3.74	+1.09

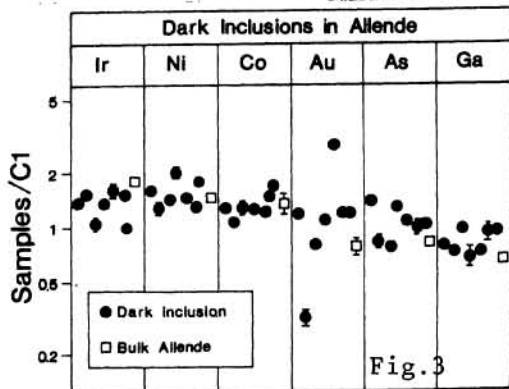


Fig. 1

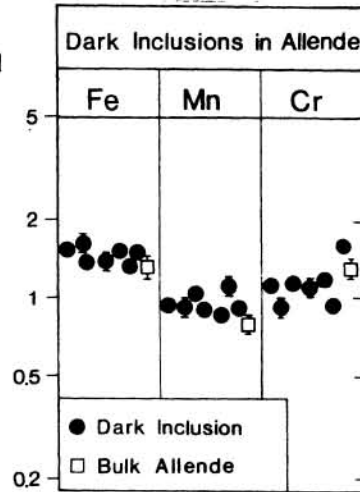


Fig. 2

