OLDHAMITE AS AN INDICATOR OF DISEQUILIBRIUM DURING ENSTSTITE CHONDRITE ACCRETION   Petaev M.I. - Vernadsky Inst. Geochem. Analyt. Chem., USSR Acad. Sci., Moscow, USSR

According to modern ideas, high-temperature minerals of enstatite chondrites which are in disequilibrium with nebula gases of solar composition have condensed under reduced conditions due to increased C/O or H/O ratios. The possibility of condensation of accessory sulfides and nitrides in cooling Supernova envelope [1] and in solar nebula with increased C/O [2-4] has been argued by thermodynamical calculations. But within both environments high-temperature minerals characteristic for enstatite chondrites must react with residual gas and form oxides of these elements under the temperature range of condensation of main enstatite meteorite minerals. This fact has often been noted early. Nevertheless, mineralogical [5] and chemical [6] data (Table 1) evidence that the major contributions of Ca (up to 96%), Cr (up to 93%), Mn (up to 98%) and Ti (up to 97%) into the bulk contents of these elements are by sulfides. Enrichment of sulfide phase in Mn is in agreement with stability of MnS relative solar gases even under solar C/O [15], but the chalcophile behaviour of Ca, Cr and Ti suggests whether disequilibrium conditions during accretion of enstatite chondrite material or postaccretional redistribution of these elements between sulfide and silicate phases.

In principle, such redistribution of Ca, Cr and Ti may take place during thermal metamorphism of enstatite chondrites followed by high temperatures and high sulfur fugacities [4,16], however mineralogical evidence of total sulfurization are not observed yet. Futhermore, many EH chondrites having clear evidence of chemical disequilibrium are enriched in oldhamite having no reaction relations to silicates. Recent data on oldhamite chemistry and isotopy [17-20] reveal its substantial enrichment in REE and Ca isotope anomaly in some grains. These observations suggesting the primitive nature of oldhamite grains are obviously difficult to conform with the postaccretional Ca redistribution. For this, the oldhamite contribution to the bulk Ca content is relatively high (Table 1) and varies from 12 (Abee EH4, Hvittis EL6) to 64 % (St.Mark's EH5).

Consequently, the chalcophile behaviour of Ca, Cr and Ti in enstatite chondrites should be considered as primary feature indicating the conditions of condensation and accretion of dust in the region of enstatite chondrite formation. At present it is difficult to determine a place and a time of formation of these minerals so far as an effective mechanism of C enrichment or O depletion in any region of solar nebula is unknown. Nevertheless, recent papers reporting on discovery of tiny grains of SiC and diamond in the acid residues of C, O and E chondrites support the idea on presence of Supernova condensates in the solar nebula. Ca isotope anomaly observed in some oldhamite grains from EH chondrite Qingzhen [19] may also be interpreted as the evidence of its condensation in the cooling Supernova envelope. But in spite of a place of condensation of high-temperature minerals of enstatite chondrites these may be preserved in the nebula only under reduce conditions. This is especially important for oldhamite which is easily oxidized by water vapor even under low temperatures. Thermodynamical calculations [3,4] suggest that in the nebula with C/O close to 1 the oldhamite is stable only under high temperatures when main minerals of enstatite chondrites don't condense yet. Consequently, if major enstatite meteorite minerals were in equilibrium with nebular gases during accretion that neither oldhamite nor other high-temperature accessories must be preserved. This demand is not so critical for carbides and nitrides which chemical inertness is well known. But if such conclusion is true that the accretion of enstatite meteorite minerals must be followed whether effective isolation of high-temperature condensates from the cooling gas or even more reduce conditions than those characteristic for nebuba with C/O close to 1. The enrichment of oldhamite in Se (15-20 x CI) was considered by [20] as the evidence of low-temperature equilibrium between oldhamite and solar gas but this suggestion has some problems with buffering of high sulfur and low oxygen fugacities which are necessary for oldhamite stability. Futhermore, observed low Se contents in oldhamite might condense under high temperatures as solid solution of CaSe in CaS so far as it may expect even higher condensation temperature of CaSe than CaS. Whether or no, this evidence is not decisive and demands thermodynamical verification.

The suggestion on oldhamite isolation during nebula cooling has also some problems. Indisputable mineralogical evidence of isolation is unknown and that may result from later cnodrule formation or thermal metamorphism. Isolation is probable to proceed due to condensation of Mn-Mg-Fe sulfide on oldhamite grains and such isolation might be a reason of diopside missing in the condensation sequence. Diopside which is condense just after oldhamite is not abundant in enstatite chondrites while it is ordinary minor mineral of

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aubrites. Moreover, an isolation of Ca and Al high-temperature condensates under 0.8 < C/O < 1, when SiC is not first condensate, will lead to initial condensation of forsterite which will be followed oractically simultaneous condensation of enstatite. But if Mg/Si ratio in gas was decreased relative to solar, for example, due to patrial MgS condensation, that enstatite may condense before forsterite.

Thus, irrespective of oldhamite genesis, its presence in the enstatite chondrites suggests disequilibrium during their accretion caused by isolation of high-temperature minerals. Considering the oldhamite as an example of these minerals we may conclude that the degree of isolation was relatively high (Table 1). It means that such isolation should be taken into consideration in thermodynamical modelling of enstatite chondrite formation.

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Table 1
Sulfides contribution to the bulk Ca of enstatite chondrites

		1	2	3	4	5
Indarch	EH4	0,811	[7]	0,39	27 %	86.2 %
Pilistfer	EL6	0,976	[7]	0,70	40 %	-
Abee	EH4	0,872	[8]	0,19	12 %	-
Adhi-Kot	EH3	0,87	[9]	0,89	60 %	-
St.Mark's	EH5	0,87	[9]	1,0	64 %	95,5 %
St.Sauveur	EH5	0,80	[10]	0,85	59 %	94,3 %
Daniel's Kuil	EL6	0,74	[11]	0,55	41 %	30,2 %
Hvittis	EL6	0,882	[8]	0,21	13 %	-
Hvittis	EL6	0,98	[12]	0,21	12 %	-
Hvittis	EL6	0,53	[13]	0,21	22 %	-
J. d. K. Lalu	EL6	0,96	[9]	0,87	50 %	-
Khairpur	EL6	0,53	[14]	0,52	55 %	58.5 %
Khairpur	EL6	1,04	[11]	0,52	28 %	58.5 %

1 - bulk Ca content (wt.%), 2 - reference,
3- modes of oldhamite (wt.%) [Keil, 1968],
4- oldhamite contribution, 5- sulfides
contribution [Easton, 1985]