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Chondrites are primitive meteorites in that ratios of their major elements, Mg, Si and Fe, are similar (within a factor of two) to corresponding ratios obtained from the spectral analysis of sunlight (1). Remarkably, cosmochemical processes were ineffective in separating these elements one from another, even though, when combined with oxygen or sulfur, they form compounds which have different physical properties. Nonetheless, cosmochemical processes were of such a nature as to have resulted in the formation of three distinct sets of compounds manifest as the principal mineral assemblages of chondritic meteorites (Table 1). Elucidation of these processes is fundamental to understanding the origin and evolution of the solar system.

Most chondrites, including the frequently studied Allende meteorite, consist principally of the mineral assemblage characteristic of ordinary chondrites. Models have been presented which intend to explain this mineral assemblage as being the condensate of a gas phase of solar composition (2). However, boundary conditions for condensation (to which all such models are subject) require the ambient vapor phase to be depleted in hydrogen by a factor of ca. 10^3 relative to solar matter and also to be somewhat deficient in oxygen. It has been suggested that condensation progressed from a gas phase formed by the re-evaporation of condensed material which previously had been separated from the gaseous components of solar matter (3).

Experiments involving the volatilization of meteorite samples provide a direct approach to address the re-evaporation of condensed matter during the formation of the solar system. Recent partial vaporizations into vacuum of the Allende C3 chondrite (4), Kenna ureilite (5) and Holbrook L6 ordinary chondrite (6) provide data on vapor phase compositions. We report the results of laser-produced total evaporations of samples of the Orgueil C1 chondrite, Allende C3 chondrite, Ehole H6 chondrite, Bruderheim L6 chondrite and the Abee type I enstatite chondrite. Our investigations were made to study the oxidation state of the condensate, however, and not the composition of the vapor.

The process of transition from vapor to condensed phase is a ponderable subject. As emphasized by Donn and others, thermodynamics alone is inadequate for a complete theoretical description of that kinetic process. Experimental condensation investigations presently suffer from the difficulty in sustaining a controlled high temperature vapor for extended periods of time. The experimental results described below, obtained using state-of-the-art technology, should consequently be considered as preliminary measurements pending development of more sophisticated apparatus and analytical methods.

Meteorite samples, supported within a cylindrical pyrex chamber containing inert gas (He or Ar) at one atmosphere pressure, were evaporated by pulses from a solid-state laser (Nd^{3+} in glass) operating in the normal (non Q-switched) mode. A 500 μsec laser pulse, having 5 joules total energy, focused onto a 1mm^2 area of the target vaporizes ca. 200 μg of meteorite without detectable chemical fractionation. The vaporized material, moving away from the

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target surface into the ambient atmosphere, cools at a rate of ca. 10^5 deg/sec by expansion and mixing with the cool chamber gas. The vapor supersaturates in microseconds, nucleating ca. 1 μm droplets. These grow free of interaction with the chamber walls into tangled strings of condensate smoke which settle onto transmission electron microscope grids for examination, both by electron imaging and by selected area electron diffraction.

The condensate smoke, magnified by ca. 40,000X, appears as chain-aggregated particles, of similar morphology, for each vaporized meteorite. The major components of the condensate, resolved from electron diffraction patterns, are shown in Table 2 for comparison with similar data obtained from vaporization of pure compounds. Within limits of present analytical capability, our results indicate that iron metal and those pure compounds shown in Table 2 tend to remain essentially unchanged by evaporation and condensation in an inert atmosphere, except that silicate condensates suffer some chemical reduction. The condensate smoke of each vaporized meteorite consisted of ferrous sulfide and glass. The glass from the Allende vaporization devitrified to olivine upon annealing. Comparison of meteorite target compositions (Table 1) with condensate compositions (Table 2) suggests that, with the exception of Orgueil, the target mineral compositions are approximately preserved, although the silicate phases do change oxidation state somewhat, as did the pure silicate compounds. Such a circumstance appears to be an expression of the tendency of (essentially) an equilibrium mineral assemblage to remain (essentially) unchanged. The oxidation state of sulfur in the condensate of the Orgueil vaporization, on the other hand, had changed significantly from that of the target meteorite, going from a valence state of +6 to -2. Mason (7) and others have suggested that heating C1 chondrites to 600°C will cause their minerals to change to those characteristic of ordinary chondrites. On the basis of the experimental results presented here we venture a generalization of this concept, suggesting that complete vaporization and condensation of C1 chondrites in a chemically unreactive medium may yield minerals characteristic of the Allende meteorite and ordinary chondrites. Further investigations appear warranted.

- References: (1) Holweger, H., Earth Planet. Sci. Lett. 34, 152-154 (1977); (2) Grossman, L., Geochim. Cosmochim. Acta 36, 597-619 (1972); (3) Herndon, J. M., Proc. Roy. Soc. Lond. 363, 283-288 (1978); (4) Notsu, K., Onuma, N. and Nishida, N., Geochim. Cosmochim. Acta 42, 903-908 (1978); (5) Gibson, E. K. Jr., Geochim. Cosmochim. Acta 40, 1459-1464 (1976); (6) Gooding, J. L. and Musnow, D. W., Meteoritics 12, 401-408 (1977); (7) Mason, B., J. Geophys. Res. 65, 2965-2970 (1960).

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Table I. Mineral assemblages characteristic of the principal components of the chondritic meteorites

<u>CI chondrites</u>	<u>ordinary chondrites (including C2,C3,H, L and LL chondrites)</u>	<u>enstatite chondrites</u>
epsomite, $MgSO_4 \cdot 7H_2O$	troilite, FeS	complex mixed sulphides
complex hydrous layer-lattice silicates, e.g. $(Mg,Fe)_6Si_4O_{10}(OH)_8$	olivine, $(Fe,Mg)_2SiO_4$ pyroxene, $(Fe,Mg)SiO_3$	pyroxene $MgSiO_3$
magnetite, Fe_3O_4	metal (Fe-Ni alloy)	metal (Fe-Ni-Si alloy)

Table 2. Resolved major condensate components from meteorites and pure compounds laser vaporized in argon

<u>Target</u>	<u>Condensate</u>
Fe	α - Fe
FeS	FeS
$(Mg,Fe)_2SiO_4$	α - Fe + glass
$(Mg,Fe) SiO_3$	Fe-Si + glass
¹ Orgueil (c1)	FeS + glass
² Allende (C3)	FeS + glass
³ Bruderheim (L6)	FeS + glass
Ehole (H6)	FeS + glass
⁴ Abee (E.C.)	FeS + glass + Fe-Si

Notes:

1. Instead of Ar, He was used.
2. Annealing 18 hrs. in Ar @ 600°C produced olivine electron diffraction pattern.
3. Annealing produced spots which did not form a well defined diffraction pattern.
4. Annealing 3 hrs. in Ar @ 700°C produced enstatite pattern and some other which could be FeS.