CHONDRULE FORMATION IN THE ACCRETIONAL SHOCK. T.V.Ruzmaikina, Inst.Phys. of the Earth Acad. of Sci., Moscow, USSR.

Similarity of the chemical composition of chondrites to the Sun, and an isotopic evidence for accumulation of chondrites soon after the element synthesis reveal that CHONDRITES PRESERVE MEMORY OF THE EARLY SOLAR SYSTEM. An abundance of chondrules in mainly all types of chondrites shows high efficiency of the energy sources at converting of precursor material into liquid droplets. The properties of chondrules are consistent with heating of chondrule precursors up to temperature about 1900 K in short high temperature events followed by cooling with rate 10 to 10^3 K/hr [1]. Collisions of planetesimals [2],lightning discharges in the solar nebula [3], and a heating of chondrule precursors by friction with the gas decelerated in accretional shock [4] were disscused recently as possible mechanisms for chondrule formation. An attribute of last mechanism for the chondrule formation is that a lot of the infalling dust material could be processed. However Wood [4] came to conclusion that, if accreting matter had the cosmic ratio of dust to gas and a mass of the solar nebula did not exceed two solar masses, then chondrule precursors could not be melted at the distances of asteroidal belt (2 to 4 AU).

THIS PAPER SHOWS THE POSSIBILITY OF MELTING OF SOLID PARTICLES (CHONDRULE PRECURSORS) EVEN AT DISTANCES OF ASTEROID BELT. The shock can be strong enough to melt silicates in the vicinity of centrifugal radius of the infalling matter

$$R = j^2 / GM ,$$

where j is a specific angular momentum about the rotational axis of the presolar nebula, M is a current mass of the protosun,G is the gravitational constant.

An abnormal intensification of the shock near the centrifugal radius is possible due to remarkable increasing of density of the infalling gas near R_K . It is necessary also that the accreting gas and dust should infall nearly normal to the shock front as ,e.g.,in the equatorial plane at the edge of the disk.

MAXIMAL TEMPERATURE OF SOLID PARTICLES is determined by balance of their heating in the shock front and cooling via the thermal radiation. In the vicinity of shock front solid particles are heated due to absorption of ultraviolet radiation form the front, thermal collisions with gas atoms and molecules, and drag associated with an inertial motion of the particles through the decelerated gas.
As a result the temperature of big particles (larger than wave-length of maximum intensity of their thermal radiation, which is of the order of 10^{-2} cm) reaches [5]

$$T = 20 (\rho v^3)^{1/4} K, \qquad (1)$$

where ρ is the density of the infalling preshock gas, v is the normal to the shock front component of velocity of the infall.

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CHONDRULE FORMATION

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In the limit of hypersonic flow onto an infinitely thin disk,i.e. then an internal thermal pressure in the gas is neglected, the density becomes infinite at the heliocentric distance $R = R_k$ [6]. In fact, the singularity is absent because the internal pressure gradient begins dominate in the infalling envelope, hindering its further compression, when the density reaches

$$\rho = \frac{M}{4\pi t_a (R c_s)^2} \left(\frac{G M}{R}\right)^{1/2} \qquad (2)$$

where c_s is the sound speed in the preshock gas, t_a is the current time scale of accretion, G is the gravitational constant. Besides, a disk radius is usually greater R_k due to transport of the angular momentum and an internal pressure within the disk. An estimatimation of the temperature of dust particles (1) for ρ from (2) and v = sqrt {G M \ R}, which is equal to the radial velocity of infall at the equatorial plane, gives

$$T = 3\ 10^3 \left(\frac{R}{1\ AU}\right)^{-1} \left(\frac{M_\odot}{M} \frac{c_s}{10^5\ cm/s}\right)^{-1/2} K \qquad (3)$$

It follows from (3) that the particles could be heated to the liquidus temperature (of about 1500 K) even if the accreting matter is optically thin for the thermal radiation of particles. It takes place, at least, in the inner part of asteroidal zone and closer to the Sun.

Particles are placed in the region transparent for the ultraviolet emission of the shock front over the time scale t $10^2 - 10^3$ s. The time scale of cooling of the solid particles are between t and time scale of the gas cooling which is not greater than 10^5 to 10^6 s.

Thus, the conditions in the shock front at the edge of the forming disk (solar nebula) with the radius $R_d \simeq R_k$ can be appropriate for the chondrule formation by melting of precursors, at least, as long as $R_d \leqslant 2$ AU.

The condition R_k= 2 to 4 AU at a final stage of formation of the Sun and disk results in restriction of the angular momentum of presolar nebula is between about $3\ 10^{52}$ to 10^{53} g cm^2/ s .

Formation of the chondrule precursors of radius and mass similar to those for chondrule is possible when the sonic turbulence is exited within infalling envelope and the precursors are formed as flabby fractal agregates.

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