CONDENSATION ORIGIN MODEL FOR CHONDRULES.

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Old Models: Chondrules are solidified, once molten silicate droplets. Their chemical and isotopic diversity apparently is incompatible with a simple nebular condensation origin as envisioned by, e.g., [1,2]. This is because it has been thought that liquids condensing from a homogeneous nebular gas should be chemically and isotopically homogeneous and that liquids cannot condense in the solar nebula. Because meteorites contain abundantly objects that obviously must have been fully or partly melted (chondrules, glasses), there is the widespread belief that these objects and in particular chondrules must form from melted solids. There is now growing evidence that liquids can indeed condense from a solar nebula gas, provided the gas/dust ratio is sufficiently low (e.g., 3,4]. However, the pre-conception still holds that condensates must be either all liquid or all solid. Here we sketch a way that leads to a simple model for chondrule formation via condensation.

Observations: In the course of our studies of glass inclusions in olivines of CC chondrites [5-8] we showed that these glasses must be remnants of a liquid that facilitated growth of the host. Such a liquid is a pre-requisite for growing crystals from the gas phase [e.g., 9], but only a thin film of liquid at the surface of the growing crystal is necessary for that **V**apor**L**iquid**S**olid (VLS) process. Bulk major and trace element patterns of such trapped liquids in olivines are all refractory, have solar relative abundances and clearly signal vapor fractionation and equilibrium with a gas that had solar relative elemental abundances. Matrix glasses of aggregates and chondrules of CC chondrites have trace element abundances indistinguishable from those in glass inclusions, indicating that they are samples of the very same liquid [e.g., 10]. These findings allow us to formulate a new chondrule formation model:

New Model: Olivines growing from the nebular gas by the VLS process either stayed single (isolated) or aggregated. The liquid film not only provided an accommodation site for the condensing elements but also a sticking agent for aggregate formation. Small amounts of liquids helped create irregularly shaped olivine (+/- pyroxene) aggregates, elevated amounts forced the formation of droplets of crystal-liquid mush. Solidification of the latter produced chondrules in a single step. Compositional variety is achieved by varying the proportions of olivines and trace element-rich liquid (refractory elements) and by metasomatic elemental exchange between solids and the gas (moderately volatile and volatile elements), e.g., [11]. Isotopic variations (e.g., O) are produced in the same way. Changes in the composition of the gas also allowed the late stage condensation of all-liquid droplets with an advanced chemical composition, the ROP chondrules [12,13]. Thus, chondrules can be produced in one single nebular cooling step with the help of the "universal liquid" [14] and derivatives thereof, no complex mixing of condensates and re-melting is necessary.

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