

FORMATION CONSTRAINTS FOR TYPE IIA CHONDRULES.

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In [1], calculations were presented of the mineralogical, chemical and isotopic evolution of a C-, S-, H₂O-free chondrule precursor through non-equilibrium melting, evaporation, fractional crystallization and recondensation, during passage of a 7 km s⁻¹ nebular shock [2] in a closed system of solar composition except for enrichments of 300x in dust and of enough H₂O to yield initial ambient log fO₂=IW-2.1. This thermal history leads to formation of PO chondrules, as the peak T of 1859K is too low for dissolution of all olivine, even for equilibrium melting. Here, we explore the sensitivity of computed histograms of X_{Fa} and $\delta^{56}\text{Fe}$ (rel. to ⁵⁴Fe) of Type IIA chondrule olivine in such models to: evaporation coefficient of oxygen (α_o); fO₂ of ambient gas and precursor; fraction of the total metal (S) on the droplet surface; fraction of original olivine (R) that does not equilibrate with melt; fraction of crystallizing olivine that is isolated from the liquid (F); and quench T. The standard case is defined as $\alpha_o=0.3$, initial log fO₂ of the precursor and ambient gas of IW-3.1 and IW-2.1, resp., S=0.02 (corresponding to metal covering 12% of the surface area at the initial T=1398K), R=0.05, F varying from .05 at peak T to 0.5 at 1400K, and quench T=1050K. α_{Na} and α_{K} were derived from experiments in air at 1723K [3] and were assumed to fall by <50% by 1000K in order for Na and K to fully recondense in the standard case. In this case, 14% of the total olivine has X_{Fa}≤0.06 and falls from 14 at X_{Fa}=0.07 to 2 at X_{Fa}=0.27, 18% has X_{Fa}=0.29, and mean X_{Fa}=0.15. The mean $\delta^{56}\text{Fe}$ of olivine is -0.6‰ but 15% of the olivine has $\delta^{56}\text{Fe} \geq 6\text{‰}$, while the bulk droplet has $\delta^{56}\text{Fe} = -1.2\text{‰}$. At $\alpha_o=0.4$ and 0.5, oxidation of metal and redox equilibration of droplet and ambient gas are faster but the Fa and $\delta^{56}\text{Fe}$ histograms are virtually unchanged. When the quench T is 75K lower, more olivine fractionally crystallizes, the tail of the histogram extends to X_{Fa}=0.47, the high-Fa peak (representing olivine still in equilibrium with melt at the quench T) falls to <10% of the olivine, mean X_{Fa}=0.18, and mean $\delta^{56}\text{Fe}$ of olivine drops to -0.8‰ because more crystallizes from the melt whose $\delta^{56}\text{Fe}$ is becoming more negative. All else being equal, when S is lower, 0.005, or higher, 0.04, than the standard case, corresponding to initial metal surface areas of 3 and 24%, resp., mean X_{Fa} varies by <0.01, and mean $\delta^{56}\text{Fe}$ of olivine rises to -0.2‰ at S=0.04, due to more oxidation of more highly evaporated metal. At initial ambient log fO₂=IW-1.9, the high-Fa tail of the histogram extends to X_{Fa}=0.35, mean X_{Fa} increases to 0.18 and mean $\delta^{56}\text{Fe}$ of olivine is -1.0‰. In this case, increasing the degree of fractional crystallization of olivine by raising F from 0.5 to 0.7 at 1400K eliminates the high-Fa peak by producing more olivine with X_{Fa}≤0.15, reduces mean X_{Fa} to 0.13 and yields $\delta^{56}\text{Fe}$ of olivine =-0.3‰. The best match to actual Type IIA chondrules is obtained for F varying from 0.1 at peak T to 1.0 at 1600K; and initial precursor and ambient log fO₂ of IW-2.6 and IW-1.0, resp., for which 49% of total olivine has X_{Fa}=0.08-0.16, 32% has X_{Fa}=0.17-0.28, mean X_{Fa}=0.21 and mean $\delta^{56}\text{Fe}$ of olivine =0.1‰. At 300X dust enrichment, this ambient fO₂ requires enormous H₂O enrichment, ~700xsolar.

References: [1] Fedkin A. V. & Grossman L. 2007. Abstract #2014. 38th LPSC. [2] Desch S. J. & Connolly H. C. Jr. 2002. *MAPS* 37:183-207. [3] Fedkin et al. 2005. *GCA* 70:206-223.