The Role of Chlorine in the Degassing of Alkalies During Flash Melting of Chondrules

G. USTUNISIK[1], D. S. EBEL[1] AND H. NEKVASIL[2]

[1]Department of Earth and Planetary Sciences, AMNH, New York, NY, 10024, gustunisik@amnh.org,

[2]Department of Geosciences, Stony Brook University, Stony Brook, NY 11794-2100

The variability of chondrule volatile element contents may provide information about the processes that shaped the early solar system and its compositional heterogeneity. An essential observation is that chondrule melts contain very low alkalies and other volatile elements (e.g., Cl). The reason for this depletion is the combined effects of cooling rates (10 to 1000K/h), the small size of chondrules, and their high melting temperatures (~1700 to 2100 K) resulting in extensive loss of volatiles at canonical pressures (e.g., 10^{-4} bar). However, we observe some chondrules with significant concentrations of volatiles (Na, Cl), that differ markedly from chondrules dominated by refractory elements. Could such heterogeneity arise from loss of alkalis and Cl to a gas phase that itself later condenses, thereby yielding variations in volatile enrichments in chondrules? Does Cl enhance volatility of the alkalis to varying extents?

Experiments on Cl-bearing and Cl-free melts of equivalent composition for 10 min, 4 h, and 6 h reveal systematic effects of Cl on alkali volatility. Cl-bearing melts lose 48% of initial Na_2O, 66% of K_2O, 96% of Cl within the first 10 minutes of degassing. Then the amount of alkali loss decreases due to the absence of Cl. Cl-free melts loses only 15% of initial Na_2O and 33% K_2O. After 4 hours, melts lose 1/3 of initial Na_2O and 1/2 of K_2O. For both systems, Na_2O is more compatible in the melt relative to K_2O. Therefore, the vapor given off has a K/Na ratio higher than the melt through time in spite of the much higher initial Na abundance in the melt. Enhanced vaporization of alkalis from Cl-bearing melt suggests that Na and K evaporate more readily as volatile chlorides than as monatomic gases. Cl-free initial melts with normative plagioclase of $An_{50}Ab_{44}Or_6$ evolved into slightly normal zoned ones ($An_{49}Ab_{50}Or_1$) while Cl-bearing initial melts normative to albitic plagioclase ($An_{46}Ab_{50}Or_4$) evolved to reverse zoned ones ($An_{54}Ab_{45}Or_1$).

The vapor phase over Cl-bearing chondrule melts may have a bimodal character over time. The heterogeneous volatile contents of chondrules may result from quenching melt droplets at different stages of repeated heating, chondrule fragment recycling, and recondensation of exsolved volatiles.