European Mineralogical Conference
Vol. 1, EMC2012-510, 2012
European Mineralogical Conference 2012

Experimental determination of alkali element evaporation rates from spherical melt drops of simple silicate compositions

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Introduction: The depletion of moderately volatile elements such as Na or K relative to solar or C1 chondritic abundances is characteristic of most materials of the inner solar system. The depletion occurs at all scales and comprises planets as well as bulk meteorites and chondrules. As chondrules make up to 80 vol. % of chondrites (1), and chondritic material provides the building blocks for larger planetary bodies, the evaluation of depletion processes in a small scale provides valuable information about the elemental distribution patterns of solid matter in the inner solar system and the origin of the depletions. Here we report results of evaporation experiments from Si-Al-Na-K bearing melt drops sized from 2-4 mm diameter.

Experimental procedures: Natural and synthetic silicate powders (albitic and peralkaline with Na and K) were heated by systematically varying temperature, oxygen fugacity (fO_2), heating time and sample size to evaluate volatilization rates of alkali elements. The runs were conducted in a vertical Gero gas mixing furnace at temperatures up to 1550 °C and fO_2 from air to IW -2. Heating times were up to 5.8 days. Samples' masses were from 12 to 56 mg. Sample fixing was performed by the wire loop method with glue (2) or by mounting pressed powder samples. The latter method enables the weight of the samples to be adjusted minutely and thus more accurate mass balance calculations and determination of evaporation rates are possible. The samples were rapidly quenched to glass beads.

Results: Albitic samples show no evidence of Na loss within a relatively wide range of experimental conditions: the albitic Na content persists independently of run temperature, heating time, fO_2 and derivation (natural or synthetic albite). Peralkaline samples lost Na and K with increasing temperature and run time. Reducing conditions force evaporation. Under oxidizing conditions losses of K are larger than those of Na. Samples' weights and alkali element losses are inversely correlated. Hence the evaporation rate, calculated from the slope of Arrhenius plots, is also a function of the sample radius.

Interpretation: The absence of Na losses from melts with plagioclase chemistry is supposed to be due to the melt structure, reflecting the unity molar Na/Al ratio implying that all of the Na is needed for charge compensation of tetrahedral Al. Thus Na is not available as network modifier and is not able to enhance the ratio of nonbridging oygens to tetrahedrons (NBO/T). The therefore strongly polymerized melt resists the evaporation of Na and keeps the Na/Al ratio locked at 1. So the evaporation of Na from chondrule precursors (Semarkona type II) stops exactly at a Na/Al ratio of 1:1 and cannot be considered as a strong argument for a closed system behavior of chondrites during their formation history, as argued by Hewins (3). Despite the dependence of sample size and evaporation rate in our experiments, a linkage of alkali element depletion and chondrule size has not yet been observed. Hence the depletion pattern of chondrules is supposed to be based on more complex and/or different processes than produced in our experimental setup. Further analyses with more complex sample compositions and under vacuum will be performed.

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3: Hewins, R. (1991): Retention of sodium during chondrule melting. GCA, 55: 935-942.