Evaporation Loss of Light Elements as a Function of Cooling Rate: Logarithmic Law.

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Introduction: Knowledge about the evaporation loss of light elements is important to our understanding of chondrule formation processes. The evaporative loss of light elements (such as B and Li) as a function of cooling rate is of special interest because recent investigations of the distribution of Li, Be and B in meteoritic chondrules have revealed that Li varies by 25 times, and B and Be varies by about 10 times [1-5]. Therefore, if we can extrapolate and interpolate with confidence the evaporation loss of B and Li (and other light elements such as K, Na) at a wide range of cooling rates of interest based upon limited experimental data, we would be able to assess the full range of scenarios relating to chondrule formation processes. Here, we propose that evaporation loss of light elements as a function of cooling rate should obey the logarithmic law.

Logarithmic Law: In the following series of figures, the observation that evaporation loss of light elements as a function of cooling rate at constant peak temperatures obeys a logarithmic law is demonstrated based on our experimental results.

Figure 1 displays the evaporation loss of boron as a function of cooling rate at three peak temperatures and at oxygen fugacity half a logarithmic unit below that of iron-wustite buffer (IW–0.5). In Figure 1, $B_{(o)}$ refers to the initial concentrations of boron. It is obvious that the evaporation loss of boron as a function of cooling rate obeys the logarithmic law.

Similarly, Figure 2 displays the evaporation loss of boron as a function of cooling rate at four peak temperatures and at IW–1.0. The evaporation loss of boron as a function of cooling rate at this oxygen fugacity also follows the logarithmic law.

Figures 3 and 4 show the evaporation loss of lithium as a function of cooling rate at IW–0.5 and IW–1.0, respectively. It seems that the logarithmic law fits the data well.

To further test if the evaportation loss of other elements as a function of cooling rate obeys the logarithmic law too, the experimental data of Yu and Hewins [6] on the evaporation loss of sodium as a function of cooling rate were plotted in Fgure 5. It is significant that the evaporation loss of sodium as a function of cooling rate also follows the logarithmic law we proposed. That of K does too [7] Cohen, 2002)

As we have experimental data for the evaporation loss of both boron and lithium, it is interesting to see if the fractionation of boron and lithium can be fitted to logarithmic law. Figures 6, 7, and 8 depict the fitting of the fractionation of boron and lithium at peak temperatures of 1450°C, 1470°C, and 1490°C, respectively, using a logarithmic law. These figures clearly demonstrate the fractionation as a function of cooling rate at constant peak temperature and oxygen fugacity can be successfully modeled by applying the logarithmic law.

Implications and Conclusions: The above experimental observations that the evaporation loss of light elements as a function of cooling rate at constant peak temperature and oxygen fugacity obey the logarithmic law may have a wide range of applications and implications. As a cooling rate is a deritive (dT/dt), it should be emphasized that this relation is fundamently different from the evaporation loss of chemical elements as a function of time at constant peak temperature and oxygen fugacity, which follows the first order of kinetics. An immediate application of the above relation is to obtain the evaporation loss at cooling rates of interest by extrapolation and interpolation according to the logarithmic law derived from limited experimental data. The successful modeling of the fractionation of boron and lithium as a function of cooling rate at constant peak temperature and oxygen fugacity by employing the logarithmic law may imply that the fractionation of other elements also obeys the logarithmic law.

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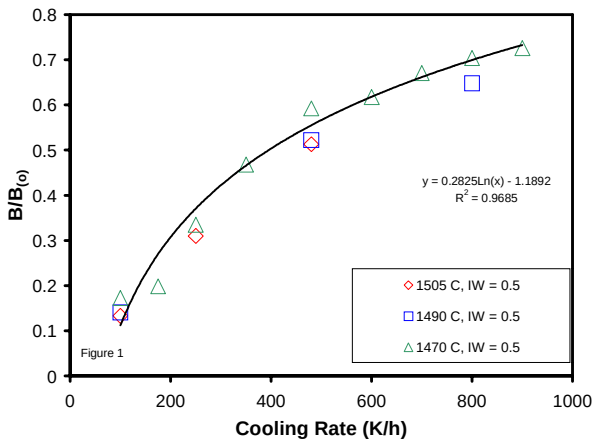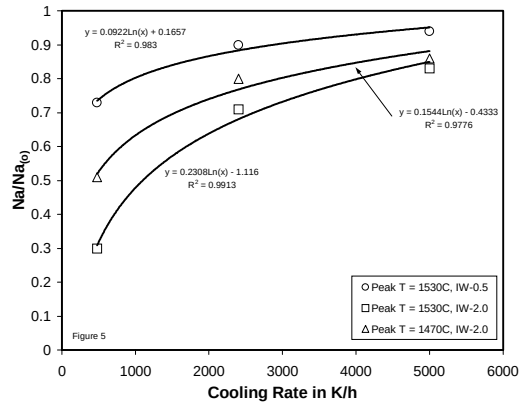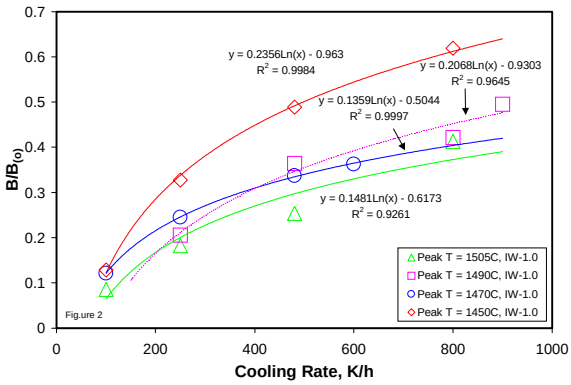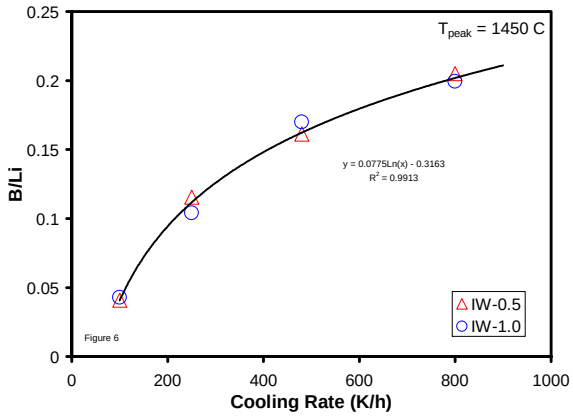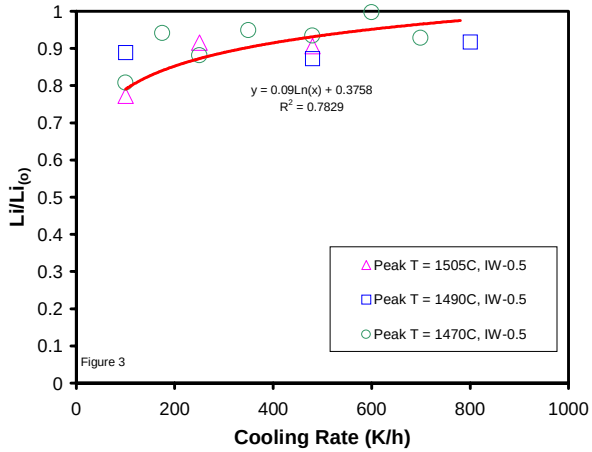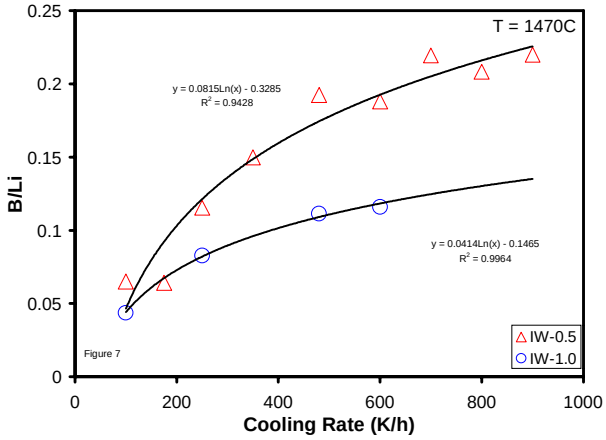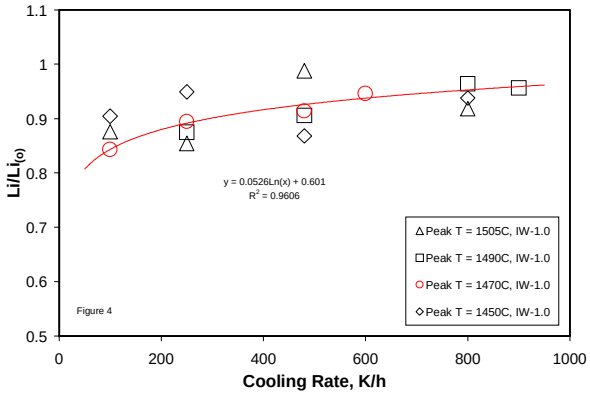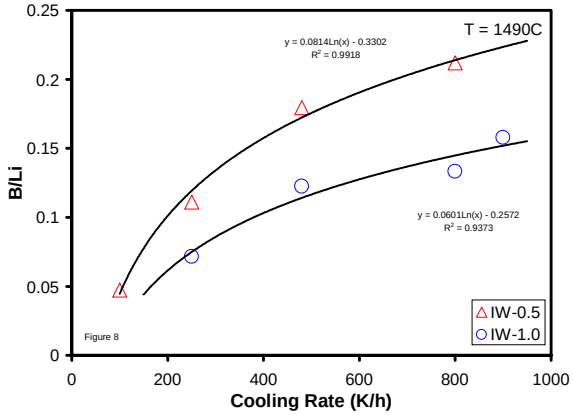
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