

# Solubility of K in metal: Preliminary results of the effects of C, pressure, and temperature

N. L. Chabot  
M. J. Drake

Lunar and Planetary Laboratory, University of Arizona, Tucson,  
AZ 85721, USA

To determine the role of radioactive heating as an energy source in planetary cores, the solubility of K in metal has been examined experimentally. Previous experiments indicate S increases the solubility of K in metal, but the metal/silicate partition coefficients for K remain low. In these experiments, C, unlike S, is not found to enhance K solubility in metal, and pressure and temperature do not significantly affect the partitioning behaviour of K since experiments run at 15 to 100 kbars and 1400 to 1900°C all yield similar metal/silicate partition coefficients. Thus, current experimental results indicate a maximum metal/silicate partition coefficient for K of  $10^{-3}$ . Such a partitioning value suggests 140 ppb K in the Earth's core with a present day heat generation of  $10^9$  W, which is over 3 orders of magnitude lower than the power necessary to drive the Earth's geodynamo. The effect of silicate composition could affect K solubility in metal and has yet to be examined.

## Motivation

The decay of K has long been considered an important heat source for terrestrial planets. Generally, though, it is not considered a significant heat source for planetary cores, due to the tendency of K to form oxides and silicates and thus have a low solubility in metals. It follows that K would be concentrated in the silicate mantle and excluded from the metallic core during a core formation event.

However, the partition coefficients of elements are known to be dependent on a number of thermodynamic variables, such as pressure, temperature, oxygen fugacity, and silicate and metallic compositions. If the specific conditions of core formation did result in an increased solubility of K in the metallic core, this would have implications for the thermal history, geodynamo, and mantle dynamics of that planetary body. In the Earth's case, 300 ppm K in the core could supply enough energy to power the geomagnetic dynamo (Lister and Buffett, 1995).

Because of the significant consequences radioactive heating as a planetary core energy source could have, it is of interest to understand the

solubility of K in metal as a function of the relevant thermodynamic variables. Previous experiments (Chabot and Drake, 1998) conducted at 15 kbars and 1900°C with different concentrations of S in the metallic liquid indicate S increases the solubility of K in metal but still yields very low metal/silicate partition coefficients for K ( $D_K$ ); the resulting heat production in the Earth's core would be over 3 orders of magnitude too low to power the geodynamo. However, this calculation does not include the effects of other thermodynamic variables on  $D_K$  which could significantly affect the solubility of K in metal. Here we present preliminary results of the effects of C, pressure, and temperature on the metal/silicate partitioning behaviour of K.

## Experimental and analytical methods

For each experiment, ground K-feldspar was mixed in approximately a 1:1 ratio with an Fe, FeS metallic mixture which was designed to produce a metallic phase with about 25 wt.% S. The mixtures were contained in either an alumina or a graphite capsule. Experiments at 15 kbars were conducted in the piston cylinder, while experiments at pressures from 50 to 100 kbars were conducted in the multi-anvil. Run temperatures ranged from 1400 to 1900°C for durations of 26 hours to 30 minutes, respectively.

All experimental run products were analysed with the electron microprobe. The silicate phase quenched to a homogeneous glass, and a defocused beam of 10  $\mu$ m was used to minimize loss of K and Na by volatilization. Operating conditions were 15 kV and 20 nA with a counting time of 20 sec. The metallic phase quenched to Fe dendrites surrounded by FeS interstitial material. Operating conditions for the major elements Fe and S were 25 kV and 20 nA with a counting time of 20 sec. To measure concentrations of K as low as 20 ppm reliably, operating conditions of 25 kV and 300 nA with a counting time of 500 sec. were necessary (Chabot and Drake, 1998). It was also necessary to avoid secondary fluorescence effects from the neighbouring K-rich glass (Chabot and Drake, 1998). A 10  $\mu$ m raster beam was used for all

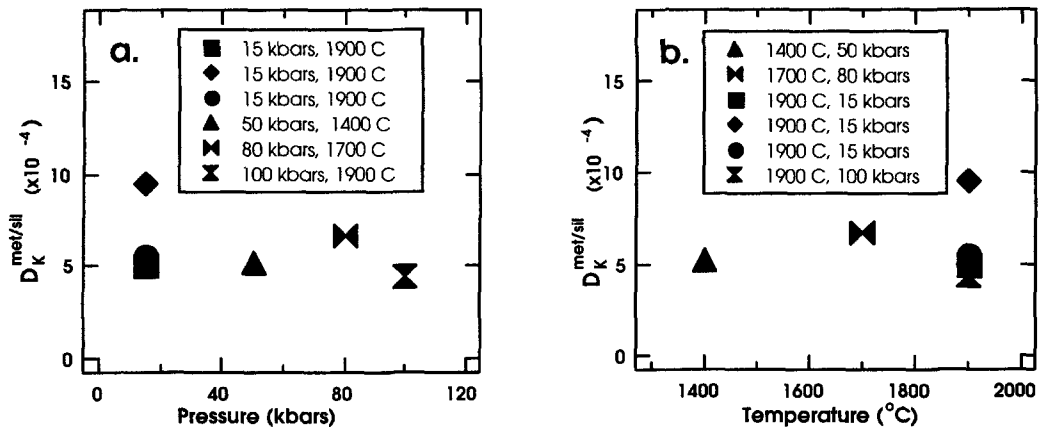


FIG. 1. The measured metal/silicate weight partition coefficients for K ( $D_K$ ) are plotted as a function of pressure (a.) and temperature (b.). No significant variations in  $D_K$  are shown over this pressure and temperature range.

measurements of the metallic phase due to its dendritic texture, and along with K, measurements of Na, Al, and Si were also made.

### The effect of C

An experiment run at 15 kbars and 1900°C in a graphite capsule produced two immiscible metallic liquids, one S-rich and one S-poor. The S-poor metallic phase was suspected to be C-rich, and identification of the presence of C was made by scanning the microprobe spectrometer over the wavelengths of the C peak and detecting a larger C peak in the S-poor metallic phase. Also, the C-Fe-S phase diagram indicates an S-rich liquid with 27 wt.% S, like the one produced in this experiment, could have a corresponding immiscible C-rich liquid with about 5 wt.% C; analysis of the C-rich phase indicated that 5 wt.% of its composition was not Fe or S.

The S-rich metallic phase was measured to contain 50 ppm K, yielding a  $D_K$  consistent with previous experimental results. However, the C-rich metallic phase did not contain any detectable K, giving a maximum K concentration of 10 ppm. Thus, the presence of C, unlike the presence of S, does not increase K solubility in metal to detectable levels.

### The effects of pressure and temperature

The measured  $D_K$  for experiments containing about 25 wt.% S in the metallic phase are plotted against pressure and temperature in Fig. 1. Too few microprobe measurements have currently been

made to determine error bars for each measured  $D_K$ , however, error bars representing two standard deviations are expected to be quite large due to the dendritic texture of the metallic phase and the low concentrations of K being measured. As illustrated in Fig. 1, the metal/silicate partitioning behaviour of K does not show any significant change over the pressure and temperature range of the experiments. As with the previous study (Chabot and Drake, 1998), the largest  $D_K$  obtained in the experiments is still only about  $10^{-3}$ .

### Conclusions

Using a primitive mantle abundance for K from Drake *et al.* (1989), a  $D_K$  of  $10^{-3}$  yields a concentration of only 140 ppb K in the Earth's core. This level of K would generate a present day heat production of  $10^9$  W, which is over 3 orders of magnitude lower than current estimates of the power necessary to drive the Earth's geodynamo (Lister and Buffett, 1995). This is the same conclusion that was reached in the previous study (Chabot and Drake, 1998). Over the range experimentally examined, pressure and temperature do not significantly change the solubility of K in metal, and the presence of C, unlike the presence of S, does not increase K solubility to a detectable level. However, the effect of silicate composition remains to be examined and could potentially have a significant effect on the partitioning of K between metal and silicate.

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