

THE EFFECT OF PRESSURE AND TEMPERATURE ON MOLYBDENUM SOLUBILITY IN SILICATE MELTS. L. K. Burkemper¹ and C. B. Agee¹, ¹Institute of Meteoritics, Department of Earth and Planetary Sciences, 1 University of New Mexico, MSC03 2050, Albuquerque, NM 87131; burkeml@unm.edu.

Introduction: Molybdenum is a refractory element; therefore its abundance in the bulk Earth is assumed to be chondritic. Molybdenum is also moderately siderophile and would consequently partition into the Fe-rich metal phase during differentiation of the Earth's core. As a result, molybdenum is depleted in the bulk silicate Earth (as estimated from upper mantle abundances) relative to chondritic abundances, and the rest of the molybdenum presumably resides in the core [1]. This provides a way to study core formation mechanisms by experimentally trying to reproduce the proportions of molybdenum in the core (a metal phase) and mantle (a silicate phase) through varying conditions, i.e. pressure, temperature, oxygen fugacity, and composition. Previous investigations of core formation mechanisms suggest that the core formed through equilibrium separation from a silicate magma ocean [2, 3], that may have been caused by one or more large impacts [4]. Therefore, understanding the behavior of molybdenum in silicate melts is fundamental to understanding core formation.

Molybdenum can occur in multiple oxidation states and molybdenum solubility as a function of oxygen fugacity has been examined [5, 6]. These studies were performed at low pressure and relatively low temperature. In the present study, we examined the effects of pressure and temperature on molybdenum solubility in multiple silicate melts in order to obtain results more relevant to core formation.

Experimental: Starting materials consisted of a synthetic Apollo-14 black glass (high-Ti basalt), a natural basalt, and a synthetic peridotite (KLB-1). Powdered starting materials for the desired experiment were loaded into a molybdenum capsule and capped with a friction fit lid. The molybdenum capsule served as the pure metal phase in equilibrium with the silicate phase. All experiments were conducted in a Walker-type multi-anvil press in the High Pressure Laboratory at the Institute of Meteoritics. The experiment was brought up to pressure and temperature and held from 2-60 minutes (longer time for lower temperature runs). The experiment was quenched by cutting power to the system. A drawback of using this set-up is the oxygen fugacity of the experiments can only be estimated because the system has no direct way of measuring it. However, oxygen fugacity relative to an oxygen buffer, e.g. iron-wustite, would not change much over a suite of constant composition experiments.

Run products were analyzed for major and trace elements on a JEOL 8200 electron microprobe (Institute of Meteoritics). Molybdenum was measured as MoO₃ and the element totals were near (+/-0.8 on average) 100. During the quench, the silicate formed a glass that was interspersed with quench crystals, therefore a 20 μm broad beam was used to obtain bulk compositions on all samples. Some samples had small blebs of the metal phase that infiltrated the silicate so analyses with a point beam were used to confirm no metal phase was included in the silicate broad beam analysis.

Results and Discussion: Over 15 experiments were performed and the results of the pressure and temperature studies on the black glass composition can be seen in Figures 1 and 2. A temperature range of 1585-2100 °C was investigated. Toward the low temperature end, molybdenum solubility increases with increasing temperature; though this increase appears to level off at higher temperatures. This is the opposite of what [5] showed over the temperature range of 1350-1436 °C using an anorthite-diopside eutectic starting composition. Over the pressure range investigated, 2.5-9.7 GPa, there is no pressure effect (within error) on molybdenum solubility. This is an important observation because the effect of pressure on molybdenum solubility had been only narrowly examined to date.

To determine the effect of silicate composition on molybdenum solubility, a peridotite and basalt composition were also investigated. Table 1 shows the molybdenum concentration in the silicate melt for all three compositions at the same pressure and temperature. The black glass and peridotite have similar concentrations of molybdenum; however, the basalt composition has an order of magnitude less molybdenum dissolved in the silicate. Slight temperature ranges were looked at with these compositions as well. With the basalt, an experiment was performed at 1800 °C and 2.5 GPa that yielded 1.12 wt.% MoO₃ in the silicate, which is within error of the concentration at 2100 °C. With the peridotite, an experiment performed at 2000 °C and 2.5 GPa yielded a MoO₃ concentration of 4.91 wt.% which is similar to the silicate concentration at 2100 °C. Hence, there appears to be no temperature effect in the basalt and peridotite compositions either, but a larger temperature range need to be investigated. Furthermore, the effect of pressure on molyb-

denum solubility in these compositions should be examined.

The results of the present study can be compared to the literature data on molybdenum partitioning between Fe-rich metal and liquid silicate. [7] and [8] found the amount of molybdenum in the silicate to increase slightly (causing the partition coefficient, D , to decrease) with increasing pressure and temperature. Both studies concluded that the observed upper mantle molybdenum abundances can be obtained from equilibrium core formation in a magma ocean. Our results do not dispute this conclusion but rather suggest that pressure and temperature are less significant to molybdenum partitioning than previously thought. Furthermore, composition has a large effect on molybdenum solubility, as shown above, as does oxygen fugacity [5, 6]. As a result, molybdenum is an ideal element to help further constrain these conditions during core formation.

Summary and Future Work: This study determined that pressure and temperature have a negligible effect on molybdenum solubility in silicate melts over the pressure and temperature range examined. However, varying the silicate composition can change the concentration of molybdenum in the melt by an order of magnitude. These results can be related to partitioning studies; however, when [9] attempted to directly compare the D values of molybdenum partitioning experiments to their D values calculated from solubility experiments, discrepancies were found. Therefore, as future work we will perform molybdenum partitioning experiments between silicates and Fe-rich metal, and compare the results to our solubility studies, to help remedy the present sporadic results.

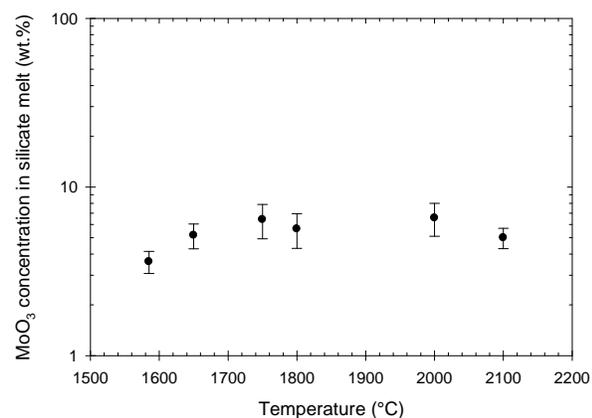


Figure 1. Plot of molybdenum concentration in the silicate melt versus temperature for the black glass starting silicate composition. All experiments were run at 2.5 GPa. Error bars are standard deviations.

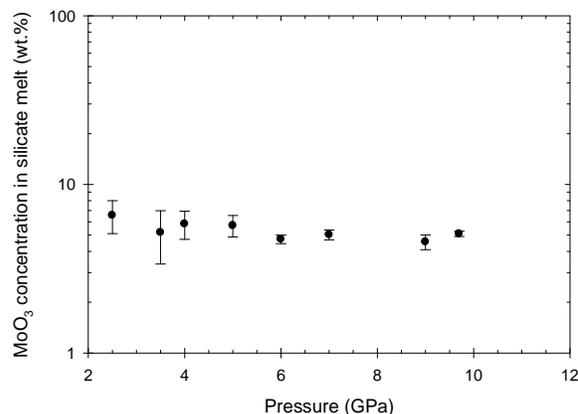


Figure 2. Plot of molybdenum concentration in the silicate melt versus pressure for the black glass starting silicate composition. All experiments were run at 2000 °C. Error bars are standard deviations.

Table 1. MoO₃ concentration in three different silicate melt compositions at the same pressure (2.5 GPa) and temperature (2100 °C). Numbers in parentheses are standard deviations.

	black glass	peridotite	basalt
wt.% MoO ₃	5.00 (0.69)	4.88 (0.92)	0.91 (0.12)

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