

Experimental constraints on the light elements in the core

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The effect of pressure on the partitioning of S, Si, and O between molten Fe-alloy and molten silicate was investigated up to 16 GPa at 2000°C in a Walker multi-anvil device. The starting composition was the Homestead L5 ordinary chondrite, the sample capsule was MgO, and oxygen fugacity was estimated to be at approximately 2 log units below the iron-wüstite buffer. Chemical analyses were carried out with an electron microprobe. Figure 1 summarizes the pressure effect on defined by

$$D_S = \frac{C_S^{AL}}{C_S^{SL}}$$

where C_S^{AL} is the concentration in weight percent of S in Fe-alloy liquid and C_S^{SL} is the concentration in weight percent of S in silicate liquid.

In the range 3–16 GPa, D_S increases from 59 to 454 indicating that S becomes more ‘alloy-loving’

with pressure. For core formation models, this behaviour can be interpreted as an increasing affinity for the core, relative to the mantle, with depth in the Earth. In contrast to the pressure effect on D_S , we observed little, if any effect on D_{Si} and D_O . Figure 2 shows that the concentration levels of Si and O in Fe-alloy are far below 1 wt.% at all pressures investigated. Both Si and O remain strongly lithophile, with D_{Si} residing in the range 0.002–0.004 and D_O in the range 0.005–0.009. These results indicate that high pressure favours S over Si and O as the light element in the core. In other words, significant levels ($\gg 1$ wt.%) of Si and O will not be partitioned into the Earth’s outer core due to high pressure. Higher concentrations of Si and O may exist in core material if either very low or very high f_{O_2} , respectively, is invoked.

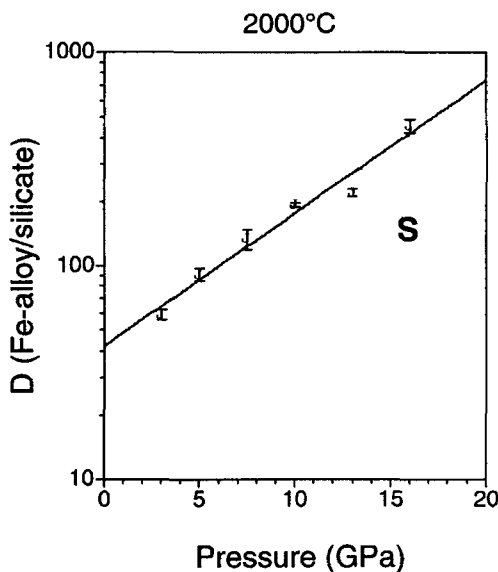


FIG. 1. Pressure effect on D_S .

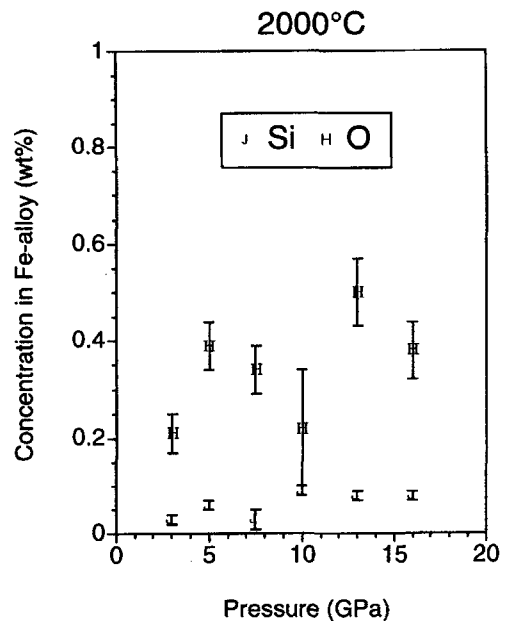


FIG. 2. Pressure vs concentration of Si and O in Fe-alloy.

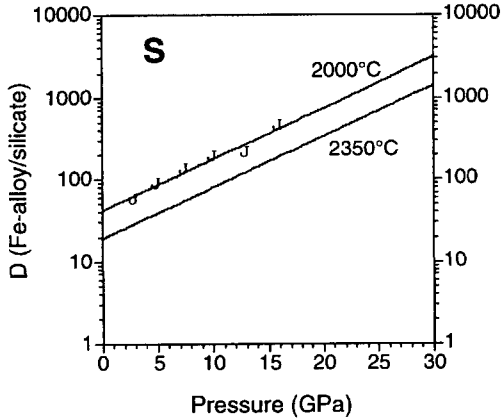
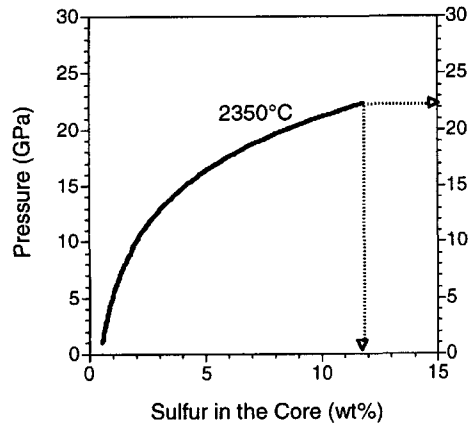
FIG. 3. Effect of pressure and temperature on D_S .

FIG. 4. Sulphur in the core vs pressure.

There are a number of factors that will effect estimates of S in the core, these include:

- 1) $P-T$ of core-mantle equilibration.
- 2) Pressure effect on D_S .
- 3) Temperature effect on D_S .
- 4) S content of the mantle.

The pressure and temperature effects on D_{Ni} and D_{Co} determined by Li and Agee (1996) and Li (1998) place the $P-T$ equilibration of core-mantle differentiation at ~ 22 GPa and 2350°C , giving factor #1. Data in Fig. 1 provide factor #2. Li (1998) carried out isobaric experiments in order to determine the effect of temperature on D_S which yield factor #3. The effect of temperature on D_S is shown in Fig. 3.

For factor #4, we adopt the value of 0.025 wt.% from McDonough and Sun (1995). We calculate

$$S_{\text{core}} = S_{\text{mantle}} \times D_S; S_{\text{mantle}} = 0.025 \text{ wt.}\%$$

Figure 4 gives solutions for 'sulphur in the core' over a range of pressures at constant temperature of

2350°C . The shape of the curve in Fig. 4 is a function of the pressure effect on D_S . For the pressure of equilibration during core-mantle differentiation of ~ 22 GPa, the solution for 'sulphur in the core' is slightly less than 12 wt.%. This S concentration is within the allowable range constrained by the geophysically observed density "deficit" in the Earth's outer core. Implicit in the calculation is the assumption that factor #4, S content in the mantle, is the S left in the mantle from core-mantle equilibration. If the S content of the mantle has changed since core-mantle equilibration, then the solution for 'sulphur in the core' is an apparent value.

References

- Li, J. (1998) Ph.D. Thesis, Harvard University.
 Li, J. and Agee, C.B. (1996) *Nature*, **381**, 686–9.
 McDonough, W.F. and Sun, S. (1995) *Chemical Geology*, **120**, 223–53.