Determining the metal/silicate partition coefficient of Germanium: Implications for core and mantle differentiation.

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Current hypotheses:

- shallow magma ocean[1]
- deep magma ocean[2]
- Heterogeneous Accretion (no magma ocean)[3]

$$D_{Ge} = \frac{C_{metal}}{C_{silicate}}$$

D_{Ge} = partition coefficient of Ge

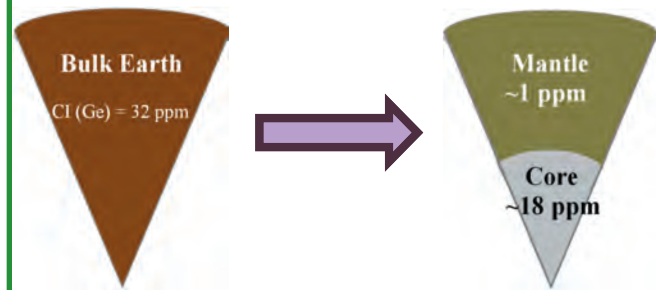
c = concentration of Ge in metal and silicate, respectively

In this study, results from 14 different data points are reported from high temperature, high pressure experiment

Run Label	Temperature	Duration (mins)	Capsule	ΔIW	Ge_{metal}	$Ge_{silicate}$	D(Ge)
Ge62509b	1500	180	Graphite	-1.72	3.95	120	328
Ge72409	1600	90	Graphite	-1.77	4.55	119	382
Ge72009	1700	45	Graphite	-1.73	4.10	213	192
Ge62409b	1800	15	Graphite	-1.74	4.20	270	155
Ge93009	1900	15	Graphite	-1.72	4.30	655	64
Ge72109	1500	180	MgO	-1.97	4.21	171	246
Ge61509	1600	90	MgO	-2.22	4.69	153	307
Ge62409	1700	45	MgO	-2.36	4.33	101	428
Ge61909	1800	15	MgO	-2.30	4.86	79	617
Ge72309	1900	10	MgO	-2.24	4.50	235	191

Table 1: Summary of experiments in this study performed at 1.0 GPa. Two different series were performed – two temperature series each with a different capsule (MgO and graphite), from 1500 to 1900 °C.

Figure4: This diagram illustrates Ge partitioning for early Earth. We assume bulk composition similar to that of CI carbonaceous chondrites, and can measure Ge composition in the mantle[11].

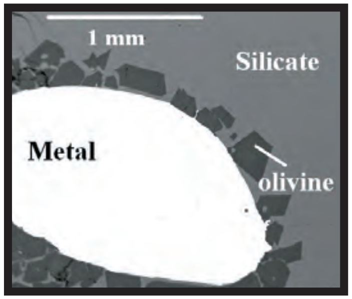


We can estimate the D(Ge) in Earth's mantle assuming Ge was set by early metal silicate equilibrium. We assumed the bulk composition for early Earth is roughly the same as CI carbonaceous chondrites (32 ppm), core=32 mass%, and mantle=68 mass% (see *figure4*).

Using these assumptions, and correcting for Ge volatility according to McDonough and Sun [11] results in $\mathbf{D_{Ge} = 18}$ (Figs. 2 and 3).

Factors affecting the Partition Coefficient

- Pressure
- Temperature
- Oxygen fugacity
- Metal and silicate melt composition



BSE image of sample Ge72109

SAMPLE

(powdered)

- 70 wt.% Knippa Basalt
- 30 wt.% Fe, Ge mixture
  - 95 wt.% Fe
  - 5 wt.% Ge

EQUIPMENT & METHODS

- MgO and graphite capsules
- Piston Cylinder Apparatus (see picture)
  - 1.0 GPa
  - 1500 – 1900°C
- Time and temperature series

Piston Cylinder Apparatus

RESULTS

- Samples in MgO capsules show a general increase of D_{Ge} as temperature increases.
- Graphite samples show a decrease of D_{Ge} as temperature increases.

(see figure1)

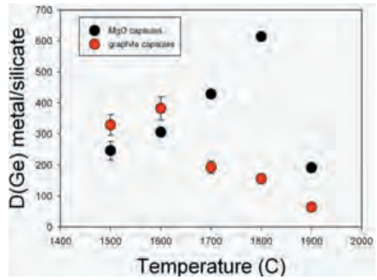


Figure1: Results of MgO and graphite capsule series experiments.

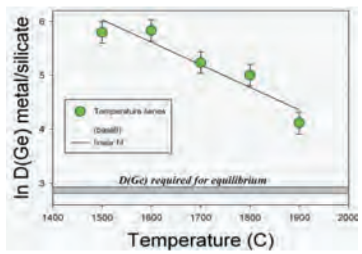


Figure2: ln D(Ge) versus temperature for the graphite capsule series. A linear fit to the data shows a close to factor of 10 decrease across 400ºC.

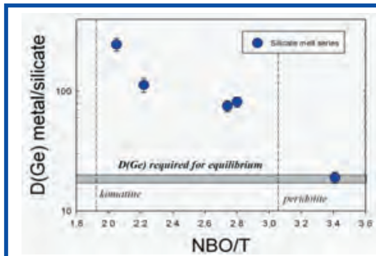


Figure3: D(Ge) vs. NBO/T – the degree of melt depolymerization- for the MgO capsule series. D(Ge) is lowered substantially in peridotite melts. D(Ge) has been corrected for temperature and fO_2 to isolate the effect of melt composition alone.

ANALYSIS

All samples were analyzed for major element composition using the Cameca SX100 for electron microprobe analysis at NASA-JSC, however the Ge content of the glasses was lower than the detection limit of the EMPA, therefore samples were analyzed for trace element composition using LA-ICP-MS at Rice University.

DISCUSSION

- Graphite: D(Ge) met/sil decreases by a factor of nearly 10 from 1500 to 1900 °C (Fig. 2) with a few constraints from previous work [8, 9]
  - Pressure, silicate and metallic melt compositions are constant
  - Assume valence of Ge is 4+
- MgO: D(Ge) met/sil decreases from magnesian basalt (NBO/T=2.1) to peridotite (NBO/T=3.4) [10]
  - Pressure and metallic melt composition are constant
  - Corrections made for fO_2 and temperature (from the graphite series)

CONCLUSIONS

- D(Ge) approaches ~18 at temperatures near 2000°C and peridotite melt.
- S decreases D(Ge) [9, 12].
- Indicative of a shallow magma ocean and extremely high temperatures are not necessary.

Effects of pressure should also be considered

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