

## EARLY OUTGASSING OF THE EARTH'S MANTLE: IMPLICATIONS OF MINERAL/MELT PARTITIONING OF I.

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**Introduction:** The excess  $^{129}\text{Xe}$  found in mantle-derived materials is often assumed to be primordial. Allègre *et al.* [1] proposed a two-layer mantle: The upper mantle (as sampled by MORBs) degassed early in Earth history while  $^{129}\text{I}$  was still alive, thereby enhancing its I/Xe ratio. The residual  $^{129}\text{I}$  in the upper mantle decayed to  $^{129}\text{Xe}$  ( $t_{1/2} = 17$  m.y.), thereby enhancing the  $^{129}\text{Xe}/^{130}\text{Xe}$  ratio there. The lower mantle (as sampled by OIBs) is undegassed and, therefore, has a low I/Xe ratio and thus a low  $^{129}\text{Xe}/^{130}\text{Xe}$  ratio.

Caffee and Hudson [2] proposed that fission of  $^{238}\text{U}$  could produce enough  $^{129}\text{I}$  to account for the  $^{129}\text{Xe}$  excess in the MORB source. Ozima *et al.* [3] suggested that the excess  $^{129}\text{Xe}$  in MORBs originated in a reservoir of different composition that accreted earlier than the atmospheric source region.

A poorly constrained factor in discussions of this problem has been the partitioning of I relative to Xe in mantle melting events. Knowledge of partition coefficients is important since [1] and [2] rely on different partitioning behaviors for I and Xe in order to fractionate them. An implicit assumption of [1] is that Xe is less compatible than I -- an assumption which has no experimental basis. This work reports the results of experimental mineral/melt partitioning of I.

**Methods:** Iodine partitioning experiments are being carried out in the system diopside-anorthite-forsterite at 1 bar following the approach of [4]. 100 mg aliquants of mixtures of various component oxides ( $\text{MgO}$ ,  $\text{SiO}_2$ ,  $\text{Al}_2\text{O}_3$  and  $\text{CaO}$ ) along with 2 wt. % I (as KI) are sealed into 2 cm lengths of 3 mm diameter platinum tubing. These capsules are suspended in alumina buckets in a cylindrical muffle furnace. The sample charges are then brought up to superliquidus temperature ( $1380^\circ\text{C}$ ) and held there for one half to one hour, after which the temperature is reduced to the crystallization temperature ( $1300^\circ\text{C}$ ) for 24 to 120 hours. The charges are quenched in air by removal from the furnace. The resulting crystal/glass assemblage is analysed by electron microprobe and by the Proton Induced X-ray Emission (PIXE) probe.

Some problems have been encountered in keeping I in solution during the experiments resulting, in some cases, in bursting of the capsule. To eliminate the problem of bursting capsules, in some experiments open platinum capsules containing oxide mixtures fused to a glass by being held at  $1380^\circ\text{C}$  for one hour are sealed inside of evacuated silica tubes along with 0.5 grams of KI, then brought to and held at the crystallization temperature ( $1300^\circ\text{C}$ ) for 24 to 120 hours. These are then quenched and analysed.

**Results and Discussion:** Results are given in Table 1. We have determined upper limits on mineral/melt partition coefficients for I,  $D(\text{I})$ , for diopside/melt pairs of 0.003, anorthite/melt pairs of 0.015 and forsterite/melt pairs of 0.035. Only upper limits are available because I has not been reliably detected in any crystals. Comparison of our data with  $D(\text{Xe})$  [5,6] (Table 2) indicates that I is not more compatible than Xe in the mantle. It follows that I and Xe cannot be significantly fractionated during partial melting of the mantle. Furthermore, since I has a low solubility in silicate melts at one bar, it will be outgassed along with Xe and other noble gasses during eruption of basaltic lavas. The similarity in mineral/melt partitioning behavior of I and Xe, thus, sheds doubt on the early outgassing model of [1] and the fission model of [2].

Since the excess  $^{129}\text{Xe}$  found in the Earth's upper mantle is most likely the result of  $^{129}\text{I}$  decay, the problem of fractionating I from Xe remains. Given the relative partitioning

behavior of I and Xe in silicates and their relative solubilities in silicate melts[6] and in water[7], a possible mechanism for fractionation of I from Xe is to erupt mantle melts into ocean water. Both I and Xe would be partitioned into the melt and outgassed upon eruption. Iodine would go into solution in seawater whereas Xe would outgas significantly from seawater at the ocean surface. The dissolved I would subsequently become incorporated into ocean sediments and/or hydrothermally altered ocean crust. The  $^{129}\text{I}$  would then decay to  $^{129}\text{Xe}$  which would remain trapped in the sediment and/or crust and would subsequently be subducted back into the previously degassed mantle, thereby enhancing the  $^{129}\text{Xe}$  content relative to other Xe isotopes.

**References:** (1) Allègre, C.J. *et al.* (1983) *Nature* 303, 762-766. (2) Caffee, M.W. and G.B. Hudson (1987) *LPS XVIII*, 145-146. (3) Ozima *et al.* (1985) *Nature* 315, 471-474. (4) Malvin, D.J. and M.J. Drake (1987) *GCA* 51, 2117-2128. (5) Hyagon, H. and M. Ozima (1986) *GCA* 50, 2045-2057. (6) Broadhurst, C.J. *et al.* (1988) *LPS XIX*, 138-139. [7] *Handbook of Chemistry and Physics*, R.C. Weast ed., p. B-100 and B-156, Cleveland, Ohio, Chemical Rubber Company Press, 1975.

Table 1  
Composition of Experimental Run Products\*

	Diopside	Glass (Di) <sup>†</sup>	Forsterite	Glass (Fo) <sup>†</sup>	Anorthite	Glass (An) <sup>†</sup>
MgO	19.64	15.45	58.57	13.87	0.39	10.10
Al <sub>2</sub> O <sub>3</sub>	2.33	11.45	0.04	15.55	35.63	16.34
SiO <sub>2</sub>	54.82	50.10	43.31	53.40	44.48	47.81
K <sub>2</sub> O	0.0	0.41	0.0	0.32	0.11	0.55
CaO	24.51	23.24	0.45	16.46	20.10	23.61
I (ppm)	≤8.6 <sup>P</sup>	3490±42 <sup>P</sup>	≤8.2 <sup>P</sup>	320±44 <sup>P</sup>	≤120 <sup>e</sup>	8000±170 <sup>e</sup>

\* -- Composition of oxides in %, I composition in ppm

† -- Abbreviation in ( ) are phases in equilibrium with the glass: Di = diopside, Fo = forsterite, An = anorthite

<sup>P</sup> -- Iodine analysis by PIXE

<sup>e</sup> -- Iodine analysis by electron probe

Table 2  
Mineral/Melt Partition Coefficients

Mineral	I	Xe
Diopside	≤0.003	0.73 <sup>[6]</sup>
Anorthite	≤0.015	0.046 - 1.9 <sup>[6]</sup>
Forsterite	≤0.035	0.015 - 0.60 <sup>[5,6]</sup>

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