

PARTITIONING OF Xe AMONG PHASES RELEVANT TO THE UPPER MANTLES OF THE EARTH AND MARS. J.H. Jones* and D. Walker**. *SN4, NASA/JSC, Houston, TX 77058. **Lamont-Doherty Earth Observatory, Palisades, NY 10964.

Previous studies have suggested that, compared to the other noble gases, Xe may be quite compatible in solid silicate phases during partial melting in the Earth's upper mantle [1,2]. Conceivably, if Xe is compatible in some major silicate phase, such as olivine, the observed Xe depletion of the Earth's atmosphere [3] could be simply explained by retention of Xe in the mantle. Consequently, we have attempted to partition Xe between olivine, pyroxene, spinel, graphite, and silicate liquid at igneous temperatures and pressures. We find that Xe is highly incompatible in olivine, pyroxene, and spinel, but that it is slightly compatible in graphite. We suggest that the carbon-rich phases observed in mantle xenoliths [4] are the most likely hosts for Xe in the mantle. Alternatively, graphite in crustal rocks such as shales or other pelites could also serve as a host for Xe. Whether graphite in crustal materials could also explain the depletion of Xe in the martian atmosphere is problematical.

Experimental. Basaltic silicate starting materials Eg1 [5] and MO695 [Longhi, unpublished] were either added to graphite capsules and mechanically sealed in Pt or were simply sealed in Pt directly. These sample capsules were then run in a piston cylinder at 10 kbar using the sample assembly of [6]. Temperature histories of the experiments and phase assemblages are given in Table 1. In theory, Eg1 should have only low-Ca pyroxene on the liquidus at 10 kbar, and the liquidus phase of MO695 should be olivine.

Xenon was added to the charges as crystals of XeF_2 . In the case of Eg1-4 the XeF_2 was placed outside the graphite capsule but within the enclosing Pt. An earlier experiment that had started with XeF_2 and silicate enclosed in graphite subsequently had no Xe in the quenched glass. Consequently, we concluded that graphite was permeable to Xe. Therefore, the Eg1-4 arrangement gave us a means of introducing Xe to the silicate charge without the concomitant addition of F. The F was expected to react with MgO (placed just under the graphite capsule as a holder for the XeF_2) to form MgF_2 and O_2 , with the latter reacting with the graphite to form CO_2 . As can be seen from Table 1, though, no Xe was subsequently found in the silicate charge.

This observation led us to the hypothesis that the graphite capsule might act as a Xe sink. We therefore removed all graphite from the Pt container in the MO695-2 experiment, since at this juncture our primary interest was still olivine/pyroxene/silicate liquid partitioning. But we concluded that if, indeed, graphite could adsorb significant Xe, this should be better quantified. Consequently, we performed a graphite-partitioning experiment Eg1-6 with ~80 mg Eg1, ~15-20 mg XeF_2 , and ~1 mg of graphite, all encapsulated in Pt. Unlike our other experiments, the vesicularity of Eg1-6 is indicative of vapor (and possibly Xe) saturation.

Analytical. Xenon was detected using a Cameca Camebax electron microprobe (either at Lamont-Doherty or JSC), operated at 15 keV accelerating voltage and a beam current of 100 nA. Because we did not know the exact location of the Xe x-ray peak, qualitative analysis was performed by conducting wavelength scans using the PET crystal across the Xe L_α peak. The position of the Xe L_α was within ~20 motor steps ($\sin\theta$) of theoretical. The location of the Xe L_α also agreed with the position interpolated from the deviation of the Sn and Ba L_α peaks from theoretical. When clearly resolved from background, the peak was broad (~200 motor steps) and resembled the shape of the Ba L_α peak, as measured on benitoite.

The identification of the peak as belonging to Xe was done in two ways. The first we have already mentioned: the generally good agreement of the peak location with both the theoretical location and a location determined empirically. Additionally, for the Eg1-6 experiment, the Xe L_β peak was also identified.

We currently have no Xe standard. But because x-ray yield/sec/nA is a smooth function of atomic number, it is theoretically possible to standardize by interpolating from nearby elements

XE PARTITIONING BETWEEN GRAPHITE AND SILICATE: Jones J.H. and Walker D.

such as Ba and Sn. However, for partition coefficients, we have used a more classical approach, that of peak integration by tracing, cutting, and weighing.

Results. Wavelength scans over all silicate and oxide crystals generated in our experiments indicate no detectable Xe. Therefore, while we have not yet quantified these results in terms of partition coefficients, they are small. Therefore, we conclude that at 10 kbar and 1300-1400°C, olivine, pyroxene, silica, and spinel are not important hosts for Xe. Our inability to detect Xe in olivine is in qualitative agreement with the results of Musselwhite, who reports a $^{forsterite/liq}D_{Xe}$ of $\sim 0.03 \pm 0.02$ [7].

Our experiment Eg1-6 indicates that the same is not true for graphite. The $^{gr/liq}D_{Xe}$ that we derive by integration of the Xe peaks from graphite and glass is 1.3. Application of a standard ZAF correction to the graphite and silicate glass changes this value only marginally, to 1.4.

Discussion. We conclude that, if present in the upper mantle, graphitic carbon could be an important host for Xe. Since we presently have no data for other noble gases, it is not known if graphite also could account for the depletion of Xe, relative to other noble gases, observed in the atmospheres of the Earth and Mars. However, at low pressures and temperatures, graphite clearly prefers Xe over the other noble gases [8]. And this observation raises another possibility: Although shales have been considered as a possible source of the terrestrial "missing Xe" [3], to the best of our knowledge, samples analyzed for noble gases have seldom been characterized in terms of their modal graphite, a common accessory mineral in pelitic sediments. It seems to us that this should at least be done to evaluate the "shale hypothesis."

References. [1] Broadhurst C.L. et al. (1988) *Lunar Planet. Sci. XIX*, 138-139. [2] Hiyagon H. and Ozima M. (1986) *Geochim. Cosmochim. Acta* **50**, 2045-2057. [3] Ozima M. and Podosek F.A. (1983) *Noble Gas Geochemistry*, Cambridge. [4] Mathez E.A. and Delaney J.R. (1981) *Earth Planet. Sci. Lett.* **56**, 217-232. [5] Longhi and Pan (1989) *Proc. Lunar Planet. Sci. Conf. 19th.*, 451-464. [6] Jones J.H. et al. (1995) *Geochim. Cosmochim. Acta* **59**, 1307-1320. [7] Musselwhite D.S. (1995) Ph.D. Thesis, U. Arizona. [8] Göbel R. et al. (1978) *J. Geophys. Res.* **83**, 855-867.

Experiment	Homogenization		Equilibration		Phase Assemblage	Graphite?	Xe in Glass?
	Temperature*	Time ⁺	Temperature*	Time ⁺			
Eg1-4	1400	2	1275	20	pyx, liq, gr	Capsule	No
MO695-2	—	—	1400	24	ol, pyx, sp, liq	No	Yes
Eg1-6	—	—	1300	19	pyx, qtz, liq, sp, gr, v	Smidgen	Yes

Table 1
Summary of 10 kbar Experiments

*Temperature in °C; +Time in hours. Abbreviations: ol, olivine; pyx, low-Ca pyroxene; gr, graphite; liq, silicate glass; qtz, silica polymorph; sp, spinel; v, vapor.