

## Hydrogen, carbon, nitrogen and xenon depletion in terrestrial planets

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The  $^{40}\text{Ar}/^{36}\text{Ar}$  of MORB, OIB and well gases can be used to calculate the degree of degassing of primordial  $^{36}\text{Ar}$  from the total mantle as sampled, which can be shown to be >95% and was probably nearer to 99% given evidence for  $^{36}\text{Ar}$  recycling. On this basis a minimum primordial  $^{20}\text{Ne}$  budget of  $(2-7)\times 10^{13}$  kg can be calculated from upper mantle estimates assuming the lower mantle is if anything less degassed, and this is close to the atmosphere's  $6\times 10^{13}$  kg. A similar calculation for Xe using upper mantle estimates yields minimum degassing of  $3\times 10^{10}$  kg primary  $^{130}\text{Xe}$ , again close to the atmosphere's  $9\times 10^{10}$  kg. There is no evidence that the atmospheric pattern is fractionated relative to mantle. The primordial  $^3\text{He}$  budget can be calculated in the same way and an overall composition derived for the bulk silicate Earth's noble gases (BSE = total Earth minus core). When combined with updated budgets for  $^1\text{H}$ ,  $^{12}\text{C}$ ,  $^{14}\text{N}$ , Earth's composition correlates with that in chondrites. The noble gases  $^3\text{He}$ ,  $^{20}\text{Ne}$ ,  $^{36}\text{Ar}$  and  $^{84}\text{Kr}$  in particular are in chondritic proportions and provide evidence against models based on fractionated solar components. Relative to CI chondrites they are more abundant by 1 to 2 orders of magnitude than  $^1\text{H}$ ,  $^{12}\text{C}$ ,  $^{14}\text{N}$  and  $^{130}\text{Xe}$ . Normalised to CI chondrites carbon and nitrogen are the most depleted elements in the BSE. Venus and Mars display a similar primordial pattern (excluding  $^1\text{H}$  and  $^3\text{He}$ ). This reproducible feature cannot be explained with combinations of diverse protolith materials. For example, enstatite and CI chondrites have similar relative proportions of volatiles. Therefore, it appears that there was early removal of  $^1\text{H}$ ,  $^{12}\text{C}$ ,  $^{14}\text{N}$  and  $^{130}\text{Xe}$  relative to  $^3\text{He}$ ,  $^{20}\text{Ne}$ ,  $^{36}\text{Ar}$  and  $^{84}\text{Kr}$ . The present day budgets of carbon and nitrogen in Venus and Earth are strikingly similar, and similar in C/N to the budgets in Mars and CI chondrites providing evidence that they were subsequently replenished as veneers in proportion to planetary mass. More than half of Earth's water predates this veneer assuming a CI hydrogen budget. The mechanisms for preferential removal of  $^1\text{H}$ ,  $^{12}\text{C}$ ,  $^{14}\text{N}$  and  $^{130}\text{Xe}$  are unclear. They might all be depleted by core formation. Carbon, nitrogen and xenon also form low temperature species with first ionization potentials less than that of hydrogen. Therefore, depletion and possibly also xenon isotopic fractionation may relate to ionisation from solar EUV in the inner circumstellar disk [1].

[1] Zahnle *et al.* (2007) *Space Science Reviews* **129**, 35-78.

## Partitioning of hydrogen between plagioclase and basaltic melt

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The hydrogen in nominally anhydrous minerals (NAMs) can be an indicator of  $\text{H}_2\text{O}$  in silicate melts if the partitioning behavior of hydrogen between NAMs and melts is known. Plagioclase is one of the NAMs and igneous plagioclase accommodates hydrogen as OH [1]. We will report preliminary experimental results on the partitioning of hydrogen between Ca-rich plagioclase and arc basaltic melt.

Hydrous melting experiments of basaltic magma were carried out at 350 MPa using internally-heated pressure vessel. Starting material was powdered hydrous basaltic glass (50.5%  $\text{SiO}_2$ , 18.1%  $\text{Al}_2\text{O}_3$ , 4.9%  $\text{MgO}$ ) with 1 to 4 wt.%  $\text{H}_2\text{O}$ . A grain of Ca-rich plagioclase (about 1 mg,  $\text{An}_{95}$ ) and 10 mg of powdered glass were sealed in a  $\text{Au}_{80}\text{Pd}_{20}$  alloy capsule and kept at temperature slightly above crystallization temperature of plagioclase as a liquidus phase, in order to attain near equilibrium between plagioclase and melt. Oxygen fugacity during the experiments was estimated to be 3 log unit above Ni-NiO buffer. Experiments were terminated after 24 hours, which is long enough to attain equilibrium partitioning of hydrogen between plagioclase and melt. Concentration of  $\text{H}_2\text{O}$  in melt and concentration of OH in plagioclase was analyzed using FT-IR [2].

Linear correlation between  $\text{H}_2\text{O}$  concentration in melt and OH concentration in plagioclase is recognized. Obtained partition coefficient is  $\approx 0.008$  in molar basis, which is higher than the estimated partition coefficient using  $\text{H}_2\text{O}$  in dacitic melt inclusions and hydrogen in their host plagioclase,  $\approx 0.004$  [3]. This difference in partition coefficients between basaltic system and dacitic system may be explained by difference in crystallization temperature of plagioclase; we suggest that partition coefficient of hydrogen is higher at higher temperature. We are conducting further experiments to prove this hypothesis.

[1] Johnson & Rossman (2004) *Am. Mineral.* **89**, 586-600.

[2] Johnson & Rossman (2003) *Am. Mineral.* **88**, 901-911.

[3] Johnson (2005) *GCA* **69**, A743 (Goldschmidt Conference Abstracts 2005).