Condensation temperature, volatility and the abundances of volatile elements in the Earth

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The temperature of condensation of the elements from a gas of solar composition at low pressure is commonly used as a guide to understanding their abundances in silicate Earth. Earth has approximately constant abundances (ratioed to CI chondrites) of refractory lithophile elements which condense at high temperature and for more volatile elements a trend of decreasing abundance with decreasing condensation T. There are several notable anomalies, however, such as the overabundance of Indium and the high Zn/Pb ratio of silicate Earth despite similar condensation temperatures for Zn and Pb. In order to examine the meaningfulness of condensation temperature in this context we re-examined the results of Lodders [1] and find some significant differences largely due to the simplifying assumptions which she made about how volatile elements dissolve into Fe and FeS. Our approach leads to much lower condensation T's for Ag, Bi,Cd,Sb and Pb. Indium, however, remains stubbornly volatile with a similar relative abundance to Zn which is much less volatile in the solar gas.

One possible explanation for the In "anomaly" is that the abundances of moderately volatile elements in Earth were set not by condensation or equilibrium with H-rich solar gas, but by liquid-vapour equilibrium after disappearance of the solar gas. Melt-vapour equilibrium must have been important on many precursor bodies and during melting after the giant impact and we considered it possible that indium would be much less volatile in the absence of H, S and Cl, all of which form gaseous species with In. To test this idea we built a furnace in which the sample can be stirred in-situ at high temperature at fixed oxygen fugacity. By stirring we remove diffusion in the melt as a factor controlling volatile loss from our melt. We doped a natural basalt with a number of volatile and refractory elements and ran experiments at 1300ºC. We find that all elemental loss rates increase with decreasing oxygen fugacity and that, below Fe-FeO (IW) the relative volatilities of In, Zn and Cu are virtually identical. Thus, the similar relative abundances of In and Zn can be most simply explained by melt-gas equilibrium after disappearance of the nebular gas.

[1] Lodders, K. (2003): Solar system abundances and condensation temperatures of the elements. *Astrophys. J.*, **591**, 1220-1247.