

Origin and evolution of C-O-H volatiles in terrestrial magma ocean, Earth's Hadean mantle and atmosphere

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The dissolution of C-O-H volatiles in silicate melt plays an important role in determining the distribution of volatiles and fluids throughout the whole Earth system from core to the atmosphere. However, our understanding of solubility of these volatiles in silicate magma remain mostly limited to oxidized conditions relevant for the shallow mantle and crust of the modern Earth, i.e., in equilibrium with CO₂-H₂O vapor phase. But the conditions of core-forming magma ocean (MO) and those of Earth's Hadean mantle, with recent memory of equilibrium with Fe-rich alloy, must have remained several log units more reduced than at present. Here we use data from recent high *P-T* experiments that constrain the solubility of C-O-H volatiles in basaltic melt at graphite saturation at a range of oxygen fugacity equivalent to 5-log unit below iron-wustite (IW) buffer to 1 log-unit above IW buffer and also at various degree of hydration of silicate melt with bulk 'water' varying between few hundreds of ppm to ~1-2 wt.%. Our data suggest that to achieve the abundance of carbon approaching the estimate for BSE or Earth's present day mantle, C and H should have been delivered along with reduced impactor bodies. This allows the partition coefficient of carbon between core (alloy melt) and mantle (silicate melt), D_C (metal/silicate) to approach ~100, irrespective of depth and temperature. If carbon is delivered with oxidized impactors, perhaps at a late stage of accretion, and decoupled from delivery of 'water', D_C (metal/silicate) could approach values of ~10⁵ for deep terrestrial MO and effectively all C in bulk Earth could be partitioned to the core.

Using a subset of the available experimental data at conditions between ~IW-1 and ~IW+1, we also developed a parameterization to calculate bulk C solubility and relative concentration of CO₂ and CH₄ in mafic melts as a function of *P*, *T*, XH₂O, melt composition, and *f*O₂. This model allows us to calculate the extent of carbon release, either in the form of CO₂ and/or CH₄, by partial melting of reduced and graphite-bearing planetary mantles including that of the Earth. Using this model and with the knowledge of conditions of mantle melting for Earth, Mars, and the Moon, we quantify the extent of CO₂ and CH₄ degassing and the impact of such on the composition of protoatmospheres for different planetary bodies at time soon after magma ocean crystallization.