

H₂ solubility in silicate melts and the origin of hydrogen in planetary interiors

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Molecular hydrogen (H₂) may have been a major component of the primordial atmosphere in equilibrium with a magma ocean on the early Earth and on other terrestrial planets. Recently, it was suggested that the dissolution of H₂ in the magma ocean may have been a major source of Earth's volatile interior. However, current experimental studies on hydrogen solubility in silicate melts are usually based on the quantification of dissolved H₂ by infrared spectroscopy using an extinction coefficient that was calibrated with rather questionable methods for pure silica glass. We have therefore re-determined the infrared extinction coefficient of H₂ in silicate glasses using two independent methods. They yielded a value of 2.12 liter mol⁻¹cm⁻¹, one order of magnitude larger than the previously used coefficient. Accordingly, previous studies likely have overestimated H₂ solubility in the magma ocean by about one order of magnitude. H₂ solubility measurements in our laboratory (Chaudhari et al. in prep.) agree with previous data if they are re-calculated using the revised extinction coefficient. They suggest a solubility of H₂ in basaltic melt of 206 ppm (by weight) /GPa at Fe-FeO buffer conditions. This solubility law can be used to calculate the possible maximum contribution of H₂ to the interior volatile inventory of the early Earth. If one assumed Earth to have formed from ordinary chondrite material without any loss of volatiles and with all hydrogen being converted to H₂, this would create a hydrogen partial pressure in the atmosphere of 138 MPa, corresponding to just 52 ppm H₂ by weight being dissolved in the magma ocean. For a bulk composition equivalent to 95 % ordinary chondrite and 5 % carbonaceous (CI) chondrite, these values would increase to 220 MPa and 90 ppm. In any case, however, these values are far too low to account for the total amount of hydrogen contained in the present-day Earth, if one assumes that the oceans formed by outgassing of the crystallizing magma ocean. The main source of hydrogen in the Earth very likely was the dissolution of H₂O, not of H₂, in the magma ocean.