Ordinary and carbonaceous chondrites are oxidized compared to the redox state of the canonical solar nebula. Oxidation of chondrites mainly occurred on their parent bodies through reactions with H$_2$O (accreted as ice) and was likely to be accompanied by H$_2$ production [1-3]. H$_2$ is the expected product of redox reactions that led to formation of Ni-rich metal alloys, chromite, magnetite, tochilinite, pyrrhotite, pentlandite, ferrous silicates, phosphates, sulfates, carbides, carbonates and CO$_2$. Here we model isochemical parent body alteration through equilibrium calculations in multicomponent systems [4] in order to evaluate effects of composition, water/rock mass ratio ($WRR$), temperature ($T$, <350$^\circ$C), pressure ($P$) and alteration progress on H$_2$ production and partitioning between liquid and gas phases. Formation of CH$_4$ is suppressed, consistent with observations. Calculated H$_2$ amounts in moles (m) are referenced to alteration of 1 kg of water-free ordinary or carbonaceous chondrites.

Results show that, depending on rock composition, up to 6-13 m H$_2$ can form in the presence of solution, which exists at $WRR$ greater than ~0.1-0.4. At elevated $WRR$, H$_2$ production is limited by the mass of rock and H$_2$O is present at the end of reaction progress. The amount of H$_2$ formed increases with $T$ and $WRR$ and is mostly accounted for by magnetite formation. Below ~100$^\circ$C and $WRR$ of 0.1-1, which may characterize CI and CM chondrites, 4-6 m H$_2$ can form. The ratio H$_2$(aq.)/H$_2$(gas + aq.) varies from 10$^{-10}$ (low $T$ and $WRR$) to 1 (high $T$ and $WRR$), and H$_2$ solubility also increases with increasing $P$.

Significantly lower H$_2$ amounts form in H$_2$O-depleted conditions without solution. However, H$_2$ dominates in the gas phase. At $WRR$ < ~0.1, H$_2$ production is limited by the mass of H$_2$O, the instability of magnetite and the stable existence of saponite. At $WRR$ < ~0.01, saponite becomes insignificant and H$_2$ forms mostly through oxidation of organic polymer and Cr$^0$ in metal. At $WRR$ = 0.001-0.01, up to 0.05-0.1 m H$_2$ forms at 0$^\circ$C, 0.14-0.26 m forms at 100$^\circ$C and 0.15-0.42 m forms at 350$^\circ$C. The amounts of H$_2$ at higher temperature may characterize alteration on parent bodies of CV3 and unequilibrated ordinary chondrites.

Higher (Fe, Ni, Cr, P, S, C)/(Mg, Ca, Si, Al, Na, K) ratios, as in CI chondrites, support oxidation and H$_2$ formation. Lower ratios favor hydration, which limits H$_2$ generation through oxidation. Pressure above that of water-gas saturation permits high $P$(H$_2$) and may limit H$_2$ formation through mineral buffering.

Sequential involvement of new portions of rock during the aqueous stage of alteration increases the amount of H$_2$ formed, consumes solution and contributes to $P$ growth. Although consumption of solution marks the conversion of H$_2$O-H$_2$ gas into H$_2$-rich gas, H$_2$ can be partially consumed through reduction of magnetite and other minerals formed in the presence of solution. At this stage, H$_2$ abundance can be maintained by buffering reactions that involve magnetite, ferrous silicates, silica, troilite, pyrrhotite, pentlandite and metal.