

HYDROGEN FORMATION AND PHASE PARTITIONING DURING PARENT BODY ALTERATION OF CHONDRITES: A THERMODYNAMIC QUANTIFICATION. M. Yu. Zolotov¹, E. L. Shock^{1,2} and M. V. Mironenko³ ¹Department of Geological Sciences, ²Department of Chemistry and Biochemistry, Arizona State University, Tempe, AZ 85287; ³Vernadsky Institute, Russian Academy of Sciences, Moscow, 119991, Russia. E-mail: zolotov@asu.edu.

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 H₂O (accreted as ice) and was likely to be accompanied by H₂ production [1-3]. H₂ 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 CO₂. 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°C), pressure (*P*) and alteration progress on H₂ production and partitioning between liquid and gas phases. Formation of CH₄ is suppressed, consistent with observations. Calculated H₂ 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* H₂ can form in the presence of solution, which exists at *WRR* greater than ~0.1-0.4. At elevated *WRR*, H₂ production is limited by the mass of rock and H₂O is present at the end of reaction progress. The amount of H₂ formed increases with *T* and *WRR* and is mostly accounted for by magnetite formation. Below ~100°C and *WRR* of 0.1-1, which may characterize CI and CM chondrites, 4-6 *m* H₂ can form. The ratio H₂(aq.)/H₂(gas + aq.) varies from 10⁻¹⁰ (low *T* and *WRR*) to 1 (high *T* and *WRR*), and H₂ solubility also increases with increasing *P*.

Significantly lower H₂ amounts form in H₂O-depleted conditions without solution. However, H₂ dominates in the gas phase. At *WRR* < ~0.1, H₂ production is limited by the mass of H₂O, the instability of magnetite and the stable existence of saponite. At *WRR* < ~0.01, saponite becomes insignificant and H₂ forms mostly through oxidation of organic polymer and Cr⁰ in metal. At *WRR* = 0.001-0.01, up to 0.05-0.1 *m* H₂ forms at 0°C, 0.14-0.26 *m* forms at 100°C and 0.15-0.42 *m* forms at 350°C. The amounts of H₂ 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 H₂ formation. Lower ratios favor hydration, which limits H₂ generation through oxidation. Pressure above that of water-gas saturation permits high *P*(H₂) and may limit H₂ formation through mineral buffering.

Sequential involvement of new portions of rock during the aqueous stage of alteration increases the amount of H₂ formed, consumes solution and contributes to *P* growth. Although consumption of solution marks the conversion of H₂O-H₂ gas into H₂-rich gas, H₂ can be partially consumed through reduction of magnetite and other minerals formed in the presence of solution. At this stage, H₂ abundance can be maintained by buffering reactions that involve magnetite, ferrous silicates, silica, troilite, pyrrhotite, pentlandite and metal.

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