MOLECULAR HYDROGEN EVOLUTION IN SMALL ICY PLANETESIMALS. J. A. Kammer[1], D. W. Sparks[1] and M. M. Tice[1], [1]Department of Geology and Geophysics, Texas A&M University, 3115 TAMU, College Station, TX 77843, sparks@geo.tamu.edu.

Introduction: We evaluate long term controls on the availability of hydrogen in the subsurface oceans of small icy planetesimals that existed in the early solar system. Previous research has suggested that serpentinization reactions in the rocky cores of such bodies were able to provide substantial dissolved hydrogen as a potential substrate for microbial communities. Our analysis suggests that the relative short duration of serpentinization and the low solubility of hydrogen in water ultimately limited the fraction of produced hydrogen available to any biosphere.

Serpentinization reactions in small icy planetesimals begin to occur when temperatures are high enough to allow the presence of liquid water. These temperatures are initially attained by heating from radiogenic sources, such as the decay of ^{26}Al[9]. Some of the liquid water reacts with rock, while the remainder rises to form a subsurface ocean, between the unmelted ice/rock crust above and the reacted rock core below. Serpentinization occurs very quickly at geologic timescales, releasing a large amount of energy and producing hydrogen gas in amounts based on the percentage of Fe in the original olivine. For Fo_{80}, or olivine containing 80% Mg and 20% Fe, the resulting balanced reaction would be[1]:

$$Fe_{0.4}Mg_{1.6}SiO_4 + 1.233\ H_2O = 0.5\ Mg_3Si_2O_5(OH)_4 + 0.1\ Mg(OH)_2 + 0.133\ Fe_3O_4 + 0.133\ H_2 \quad (1)$$

or,

Olivine (Fo_{80}) + water = serpentine + brucite + magnetite + hydrogen

This results in an amount of hydrogen that cannot all be dissolved in the ocean layer, and so would be released through cracks in the crust, eventually outgassing into space. How much of this hydrogen escapes in this way, and how much is maintained and in what concentration it exists within the water ocean is of particular interest in determining the likelihood of life developing that can take advantage of the hydrogen.

Reaction rates: The rate of the serpentinization reaction at the conditions within small icy rock bodies is important in determining how quickly the ice in the body melts and the layers differentiate, but also determines the rate of hydrogen production. On geologic timescales, even at 273K the rate of serpentinization is high enough that all of the rock within the melting radius of the body will react on the order of only 10,000 years[1,2]. This results in both an enormous amount of heat and hydrogen gas to be produced in a relatively short amount of time.

Reactions thermodynamics: Because serpentinization consumes water as the rock is hydrated, is it important to consider the relation between how much water is reacted to how much ice is being melted due to the heat released from the reaction. For an idealized serpentinization reaction, the amount of energy per unit mass of serpentine produced is 2.4×10^5 J/kg, which is equal to 6.6×10^4 J/mol, for serpentine having a molecular weight of 276 g/mol[4,9]. The latent heat of fusion for the water ice is 3.3×10^5 J/kg, or 5.9×10^3 J/mol, so for every mole of serpentine produced, the energy released will be able to melt about 11 moles of water ice. From equation (1), this means that for about every 2.5 moles of water consumed by the reaction, 11 moles of ice will be melted. This indicates a possibility for a thermal runaway, where heat from the reaction will be enough to melt the ice within the body much more quickly than it would have had the only heat available been due to radiogenic sources[9].

Hydrogen production: The hydrogen produced from serpentinization will initially be able to dissolve in the large excess of liquid water available from melting. Once the hydrogen reaches saturation, however, the hydrogen gas will bubble upwards through the ocean layer until it reaches the crust, where it potentionally starts to diffuse through cracks and can drive further crack propagation up to the surface. The ratio of hydrogen produced in this way to the amount that can ever be dissolved in the ocean layer is generally on the order of 20 to 50 times, depending on the size of the body and the corresponding volume of hydrogen produced and amount of liquid water available in the ocean layer. In all cases, there is simply no way to maintain crust stability without releasing most of the hydrogen produced.

Discussion and Conclusions: Serpentinization reactions within small rocky ice bodies play an important part in their evolution, especially in driving the internal differentiation of these bodies and overall thermal evolution. The production of hydrogen from this reaction is also potentially important in driving further development, however, as the build up of hydrogen will help to overturn the surface of the body as it escapes through cracks in the crust. Also important too is the hydrogen that remains behind in the ocean layer, available for possible use by any life that might form under these conditions [7].

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