

# Hydrogen Species in the Ionosphere of Mars



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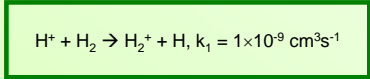
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## Abstract & Goals

A one dimensional model of the Martian ionosphere is used to explore the importance of H and H<sub>2</sub> chemistry in the upper atmosphere and ionosphere. Neutral and ionized H and H<sub>2</sub> undergo chemical reactions that lead to the production of several hydrogenated ions. Some of these ions (OH<sup>+</sup> and H<sub>3</sub><sup>+</sup>) are found to play a prominent role in the composition of the topside ionosphere. Sensitivity tests to unconstrained parameters in the model are done and results are validated using Viking ion density measurements as well as other published model results. Predictions are made for the ion composition and plasma escape measurements to be made by the Mars Atmosphere and Volatile Evolution mission (MAVEN).  
 In this poster, we use a 1-D model of the Martian ionosphere that includes a comprehensive hydrogen chemistry. The objective is to study the combined effects of atomic and molecular hydrogen chemistry at Mars, with particular attention to the topside ionosphere. Dominant species are analyzed and their fluxes predicted for comparison with the measurements made by MAVEN.

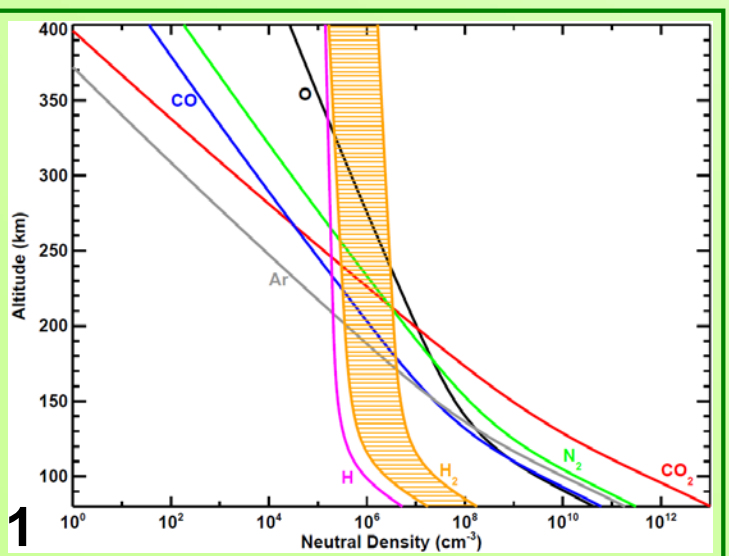
## Model Description & Sensitivity

Briefly, the model simulates the Martian ionosphere between 80 and 400 km using a neutral atmosphere from the Mars Climate Database (MCD) [Forget et al., 1999 and Lewis et al. 1999], photo-chemistry and plasma diffusion to yield ion densities and velocities as a function of height and time. We add H and Ar neutrals and expand the chemistry involving H and H<sub>2</sub>. Resulting ions: CO<sub>2</sub><sup>+</sup>, N<sub>2</sub><sup>+</sup>, O<sup>+</sup>, CO<sup>+</sup>, Ar<sup>+</sup>, H<sub>2</sub><sup>+</sup>, H<sup>+</sup>, O<sub>2</sub><sup>+</sup>, NO<sup>+</sup>, H<sub>3</sub><sup>+</sup>, OH<sup>+</sup>, HCO<sup>+</sup>, ArH<sup>+</sup>, N<sub>2</sub>H<sup>+</sup>, HCO<sub>2</sub><sup>+</sup> and HOC<sup>+</sup> are tracked individually through altitude and local time and summed to obtain an electron density profile. Results shown are for noon-time.  
 On Mars, H<sub>2</sub> neutral densities are not well constrained. Furthermore, the charge exchange reaction rate, k<sub>1</sub>, between H<sup>+</sup> and H<sub>2</sub> is not well constrained. The effect of the uncertainties in each of these two sensitivity parameters on the upper ionospheric composition of Mars is studied.



## Results

The neutral atmosphere adopted is shown in Figure 1 -- emphasizing the variability between the MCD H<sub>2</sub> and that of other models. In Figure 2 we show modeled electron and ion densities in cm<sup>-3</sup> vs. altitude in km for mid-day conditions. The reaction rate k<sub>1</sub> between H<sup>+</sup> and H<sub>2</sub> is 0 and the model is set for no vertical diffusion. Panel (a) shows the electron density profiles resulting from varying the H<sub>2</sub> mixing ratio from low, mid, to high values of 1.6, 9, to 16 ppm in dashed black, dotted red and solid blue respectively. Panel (b) shows the corresponding ranges in ion density between low and high mixing ratios of H<sub>2</sub>. Figure 3 is similar to Figure 2 but shows the effects of varying k<sub>1</sub> with the mixing ratio for H<sub>2</sub> fixed at 9 ppm and the model is set for no vertical diffusion. To demonstrate the effects of vertical diffusion on hydrogenated ionospheric composition, we show two extreme case in Figure 4. The variation shown in both panels if for electron and ion densities with both H<sub>2</sub> and k<sub>1</sub> set to their low limits and then both set to their high limits.



## Conclusion

Our 1-D model of the Martian ionosphere has been updated to include hydrogen chemistry and shows that the composition of the topside ionosphere is sensitive to the choice of neutral molecular hydrogen density, as well as to the charge exchange reaction rate between H<sup>+</sup> and H<sub>2</sub>. The resulting dominant ions at 350 km are a combination of OH<sup>+</sup>, O<sub>2</sub><sup>+</sup>, H<sub>3</sub><sup>+</sup>, H<sup>+</sup> and smaller quantities of O<sup>+</sup>, HCO<sup>+</sup>, H<sub>2</sub><sup>+</sup> and N<sub>2</sub>H<sup>+</sup> for the case of no vertical diffusion and O<sub>2</sub><sup>+</sup> and HCO<sup>+</sup> and smaller quantities of CO<sub>2</sub><sup>+</sup>, HCO<sub>2</sub><sup>+</sup>, OH<sup>+</sup> and N<sub>2</sub>H<sup>+</sup> for the case of vertical diffusion. The model presented here can offer an initial context for MAVEN NGIMS measurements between 150 and 400 km for O<sup>+</sup>, O<sub>2</sub><sup>+</sup>, CO<sub>2</sub><sup>+</sup>, OH<sup>+</sup> and other hydrogenated ions. It can therefore aid in the investigation of chemical and dynamical processes governing the upper atmosphere and ionosphere of Mars. These, in turn, offer insights to the escape rates of various atmospheric constituents.

## References

- Forget et al., JGR, 104 (1999)
- Lewis et al., JGR, 104 (1999)
- Mendillo et al., JGR, 116 (2011)

