Upper atmospheres of the Giant Planets

Luke Moore
July 2014

1. **True/False.** Briefly explain your answer.
   (a) The more energetic an auroral electron, the deeper in the atmosphere it is likely to be thermalized.

   (b) The more energetic a solar photon, the deeper in the atmosphere it is likely to be absorbed.

   (c) The use of recombination coefficients is enough to derive the electron density from the electron production rate in a region where transport is dominant.

   (d) The solar flux at Neptune is 9 times less than at Saturn.

   (e) Photons of 180 nm are effective ionizers.

   (f) It is possible to define a temperature for a thermal electron population.

   (g) The profile in altitude of the electron density always peaks at the same altitude as the profile in altitude of the electron production rate.

   (h) Ion densities are roughly comparable to neutral densities near the ionospheric peak.

   (i) Both ionospheric electrons and photoelectrons are thermal.

   (j) The dominant loss process for H^+ in giant planet ionospheres is from radiative recombination.

2. **Saturn ring rain.** Assume in this problem that H^+ and H_3^+ are the only ions present, and that they are in the photochemical regime (i.e., photochemical equilibrium holds, and transport processes can be neglected). You may neglect hydrocarbons.

Common aeronomy notation:	Number density of species X^+ (cm^{-3})	$[X^+]$
	Photoionization rate (s^{-1})	j
	Charge exchange rate ($cm^3\ s^{-1}$)	k
	Recombination rate ($cm^3\ s^{-1}$)	α

For example, the reaction $H_2^+ + H_2 \xrightarrow{k_1} H_3^+ + H$ is a production reaction for H_3^+ and a loss reaction for H_2^+. Its value depends on the reaction rate, k_1, and on the number densities of H_2^+ and H_2. It would be written as:

$$L_{H_2^+} = P_{H_3^+} = k_1[H_2^+][H_2]$$

Values to use:

$[H_2] = 10^{10}\ cm^{-3}$		-molecular hydrogen number density
$j_1 = 10^{-9}\ s^{-1}$	$H_2 + h\nu \xrightarrow{j_1} H_2^+ + e^-$	-photoionization of H_2
$j_2 = 10^{-11}\ s^{-1}$	$H_2 + h\nu \xrightarrow{j_2} H^+ + H + e^-$	-dissociative photoionization of H2
$k_1 = 10^{-8}\ cm^3\ s^{-1}$	$H^+ + H_2O \xrightarrow{k_1} H_2O^+ + H$	-charge-exchange (H^+ and H_2O)
$k_2 = 10^{-8}\ cm^3\ s^{-1}$	$H_3^+ + H_2O \xrightarrow{k_2} H_3O^+ + H_2$	-charge-exchange (H_3^+ and H_2O)
$\alpha_1 = 10^{-12}\ cm^3\ s^{-1}$	$H^+ + e^- \xrightarrow{\alpha_1} H + h\nu$	-radiative recombination of H^+
$\alpha_2 = 10^{-7}\ cm^3\ s^{-1}$	$H_3^+ + e^- \xrightarrow{\alpha_2} OH + H$ (or $O + H_2$)	-dissociative recombination of $H3^+$

(a) Assume $[H^+] >> [H_3^+]$. The only loss for H^+ is radiative recombination. What is the electron density?

(b) Assume $[H^+] >> [H_3^+]$. Now also assume there is an influx of water from Saturn's rings into its atmosphere. What value of $[H_2O]$ would reduce $[H^+]$ to $10^4\ cm^{-3}$, the observed peak electron density?

(c) Finally, relax the $[H^+] >> [H_3^+]$ assumption. Using the values of $[H^+]$ and $[H_2O]$ from (b), find $[H_3^+]$. What is the dominant loss for H_3^+ under these conditions?