

# Upper atmospheres of the Giant Planets

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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 ( $cm^3 s^{-1}$ )	$\alpha$

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
$j_1 = 10^{-9} s^{-1}$	$H_2 + hv \xrightarrow{j_1} H_2^+ + e^-$	-photoionization of $H_2$
$j_2 = 10^{-11} s^{-1}$	$H_2 + hv \xrightarrow{j_2} H^+ + H + e^-$	-dissociative photoionization of $H_2$
$k_1 = 10^{-8} cm^3 s^{-1}$	$H^+ + H_2O \xrightarrow{k_1} H_2O^+ + H$	-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 $H_2O$ )
$\alpha_1 = 10^{-12} cm^3 s^{-1}$	$H^+ + e^- \xrightarrow{\alpha_1} H + hv$	-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 $H_3^+$

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