A Theoretical Investigation of Jovian Upperatmosphere. I

—Ionization and Dissociation—

Mikio Shimizu

Department of Physics, Ochanomizu University
Tokyo

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In previous papers,\textsuperscript{11,12} we discussed the upperatmosphere phenomena of Venus and Mars theoretically. Here we shall investigate the effect of the solar ionizing radiation on the Jovian upperatmosphere, as one of the series works on the solar planetary relationships. The Jupiter's microwave radiation may be separated into three components: the 130°K thermal radiation, the non-polarized non-thermal radiation (maybe due to a Jovian ionosphere), and the polarized non-thermal radiation (maybe due to the synchrotron radiation of electrons in a Jovian Van Allen belt).\textsuperscript{3,4} The radio-bursts from this planet have also been ascribed to the plasma vibration in the ionosphere caused by the impact of charged
particles fallen from the Van Allen belt.\(^5\)
In order to explain these features, the electron density of the ionosphere must be \(10^7 \sim 10^8 \text{ cm}^{-3}\), about 10\(^4\) times larger than that on the Earth. Rishbeth\(^5\) pointed out that the rapid ion molecular reaction

\[ \text{H}^+ + \text{H}_2 = \text{H}_3^+ + \text{H} \quad (1) \]

was prohibited energetically there and that electrons might recombine with ions through a very slow process (recombination rate \(\sim 10^{-12} \text{ cm}^3/\text{sec}\))

\[ \text{H}^+ + e^- = \text{H} + h\nu, \quad (2) \]

which may give the explanation of the dense Jovian ionosphere. His discussion is implicitly based on the assumption that \(\text{H}_2\) molecules are dissociated into \(\text{H}\) atoms to a large extent. The dissociation cross-section of \(\text{H}_2\) in the range of the Schumann-Runge radiation is, however, extraordinarily small, maybe less than \(10^{-21} \text{ cm}^2\), which causes some difficulties, not only to his conjecture but to other molecular mechanisms.\(^7\) In order to avoid the difficulty, we shall assume that the dissociation and ionization of \(\text{H}_2\) molecules may be done by the same solar ionizing radiation:

\[ \text{H}_2 + h\nu (\text{<804\AA}) = \text{H}_3^+ + e^-, \quad (3) \]
\[ \text{H}_2 + \text{H} = \text{H}_3 + \text{H}, \quad (4) \]
\[ \text{H}_3 + e^- = 3\text{H}, \quad (5a) \]
\[ \text{H}_3 + e^- = \text{H}_2 + \text{H}, \quad (5b) \]

together with the process (2) and

\[ \text{H} + \text{H} + \text{M} = \text{H}_2 + \text{M}, \quad (6) \]
\[ \text{H} + h\nu (\text{<912\AA}) = \text{H}^+ + e^-, \quad (7) \]

where \(\text{M}\) is the third body. As the Jovian atmosphere contains a considerable amount of \(\text{He}\), the following processes may be also useful for the dissociation of \(\text{H}_2\):

\[ \text{He} + h\nu (\text{<584\AA}) = \text{He}^+ + e^-, \quad (8) \]
\[ \text{He}^+ + \text{H}_2 = \text{HeH}^+ + \text{H}, \quad (9) \]
\[ \text{HeH}^+ + e^- = \text{He} + \text{H}. \quad (10) \]

According to Spinrad and Trafton\(^5\), the atmosphere may be composed of \(\text{H}_2 60\%\) and \(\text{He} 40\%\). Other species like \(\text{CH}_4\) and \(\text{NH}_3\) are scanty. The atmospheric pressure can be tentatively assumed to be 2.8 Atm. at the cloud top. The scale height was measured as 8 km by Baum and Code.\(^9\) The temperature may be assumed to be constant and taken as 130°K. We shall evaluate the distribution of constituent gas and electrons by adopting this model and also the hydrogen atmosphere model (\(\text{H}_2 100\%\)). By taking into account the processes (2) \(~\) (10) and neglecting the diffusion, the absorption of the solar ionizing radiation has been calculated downwards. The results of the calculation have been shown in Fig. 1. In the case of the hydrogen atmosphere (5b case), the total amount of \(\text{H}\) atoms is very small, only 0.01 cm STP, and the maximum electron density is \(1.6 \times 10^7 \text{ /cc at 170 km}\), which barely reach the value discussed so far. When the process (5a) is adopted, the dissociation of \(\text{H}_2\) has been increased, but the difference from the former case is not remarkable. In the case of ST model (5b case), the dissociation of \(\text{H}_2\) begins at a little lower
height than that of the dissociation layer of the hydrogen atmosphere. The effect of Schumann Runge radiation could be neglected even if the average dissociation cross-section of H₂ was taken to be $10^{-21}\text{cm}^2$, its upper limit value. The details will be published later.

2) M. Shimizu, Prog. Theor. Phys. to be published.
9) W. A. Baum and A. D. Code, Astron. J. 58 (1953), 108.