Photochemistry in the Atmosphere of HD 209458b

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Abstract

Atomic hydrogen loss at the top of HD 209458b's atmosphere has been recently suggested by Vidal-Madjar et al. (2003). We have developed an one-dimensional model to study the chemistry in the upper atmosphere of this extrasolar "hot jupiter". The most abundant elements (other than He), as well as four parent molecules are included in this model, viz., H, C, O, H\textsubscript{2}, CO, H\textsubscript{2}O, and CH\textsubscript{4}. The higher temperatures (~1000 K) and higher stellar irradiance (6\times10\textsuperscript{5} W m\textsuperscript{-2}) strongly enhance and modify the chemical reaction rates in this atmosphere. The main result is that the production of atomic hydrogen in the atmosphere is mainly driven by H\textsubscript{2}O photolysis and reaction of OH with H\textsubscript{2}, and is insensitive to the exact abundances of CO, H\textsubscript{2}O, and CH\textsubscript{4}.

One-Dimensional Model

The model atmosphere is calculated based on the model developed by Seager et al. (2000). In the present model, the cloud and high temperature condensation are not considered in generating this model atmosphere. Our model is a simple derivative of the Caltech/JPL KINETICS model for the Jovian atmosphere. The model is started from four parent molecules, H\textsubscript{2}, CO, H\textsubscript{2}O, and CH\textsubscript{4}. A total of 253 chemical reactions involving C-H-O molecules is taken from the literatures.

Vertical Profiles of Temperature and Chemical Compositions

Chemical Abundances for Three Models

<table>
<thead>
<tr>
<th></th>
<th>Model A</th>
<th>Model B</th>
<th>Model C</th>
</tr>
</thead>
<tbody>
<tr>
<td>H\textsubscript{2}O</td>
<td>4.5x10\textsuperscript{-4}</td>
<td>4.5x10\textsuperscript{-5}</td>
<td>4.5x10\textsuperscript{-4}</td>
</tr>
<tr>
<td>CO</td>
<td>3.6x10\textsuperscript{-4}</td>
<td>3.6x10\textsuperscript{-4}</td>
<td>3.6x10\textsuperscript{-5}</td>
</tr>
<tr>
<td>CH\textsubscript{4}</td>
<td>3.9x10\textsuperscript{-8}</td>
<td>3.9x10\textsuperscript{-8}</td>
<td>3.9x10\textsuperscript{-8}</td>
</tr>
</tbody>
</table>

Results

The chemical processes are mainly driven by O and OH radicals, which are produced in the photolysis of H\textsubscript{2}O and CO.

CO\textsubscript{2} Production

\textit{OH + CO $\rightarrow$ CO\textsubscript{2} + H}

CH\textsubscript{4} Production

\textit{CO + h $\nu$ $\rightarrow$ C + O}
\textit{C + H\textsubscript{2} + M $\rightarrow$ 3CH\textsubscript{2} + M}
\textit{2 3CH\textsubscript{2} $\rightarrow$ C\textsubscript{2}H\textsubscript{2} + 2H}
\textit{C\textsubscript{2}H\textsubscript{2} + H + M $\rightarrow$ C\textsubscript{2}H\textsubscript{3} + M}
\textit{C\textsubscript{2}H\textsubscript{3} + H + M $\rightarrow$ C\textsubscript{2}H\textsubscript{4} + H}
\textit{C\textsubscript{2}H\textsubscript{4} + H + M $\rightarrow$ C\textsubscript{2}H\textsubscript{5} + M}
\textit{C\textsubscript{2}H\textsubscript{5} + H $\rightarrow$ 2C\textsubscript{2}H\textsubscript{3}}
\textit{CH\textsubscript{3} + H + M $\rightarrow$ CH\textsubscript{4} + M}

Conclusion

Using the one-dimensional Caltech/JPL KINETICS model, we found that the column density of the produced H is 10\textsuperscript{3} more abundant than that in Jupiter.

Reference