Hydrates and their Impact to the Habitability of the Icy Moons

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Introduction

Clathrate hydrates are proposed as constituents of the icy crusts and water rich reservoirs in the moons of the giant planets of the Solar System, e.g. as the source of CH\textsubscript{4} in Titan’s atmosphere, or in Enceladus as the origin of the geyser compounds. Remote measurements show CO\textsubscript{2} presence on the surfaces of giant moons of Jupiter, though it is unclear whether it is in the interior and interacts with water. In Ganymede, aqueous layers are suggested to be deep within the moon, between layers of different water ice phases. Geophysical models show that the pressure in the ocean is up to 1.3 GPa, so we need to understand the interactions between H\textsubscript{2}O and CO\textsubscript{2} under these conditions in order to constraint the carbon state in the aqueous layers. One way of interaction is forming clathrate hydrates.

From Pressures and Cavities to Densities

<table>
<thead>
<tr>
<th>Type</th>
<th>Symm</th>
<th>nH\textsubscript{2}O cell</th>
<th>Press. Range (GPa)</th>
</tr>
</thead>
<tbody>
<tr>
<td>sl</td>
<td>Pm3m</td>
<td>46</td>
<td>0—0.9 (CH\textsubscript{4})</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0—0.7 (CO\textsubscript{2})</td>
</tr>
<tr>
<td>slII</td>
<td>Fd3m</td>
<td>136</td>
<td>0—0.5 (CH\textsubscript{4})</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>metastable</td>
</tr>
<tr>
<td>sH</td>
<td>P6/mmm</td>
<td>34</td>
<td>0.9—1.6 (CH\textsubscript{4})</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>1.6—42* (CH\textsubscript{4})**</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td>0.7—1.0 (CO\textsubscript{2})**</td>
</tr>
</tbody>
</table>

* Max pressure studied but not decomposed
** Approximate values due to recent discovery

Effect of high pressure phases on the giant icy moons

High density of CO\textsubscript{2} clathrates might support a multilayered structure. However, it is not clear if high pressure clathrates can form at depth from its separate components. It is known that they can be transformed from low pressure phases in solid-solid phase transitions. Laboratory experiments are running to shed light on the former process.

The sl to FIS transition require a convective behavior of the icy layer in order to sink the sl phase to deeper levels. If it occurs, this transition is associated with a remarkable change in volume and other thermodynamical parameters.

Molecules containing essential elements for life, which would be released during early differentiation of the satellite, could have been retained at upper clathrate layers. Clathrate components would react in aqueous layers if they dissociate during further heating episodes.

Future JUICE mission will help to understand the structure and habitability of Ganymede.

References

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