Water
The solvent of life
• Why is water essential for life?

• How does water influence life (at the molecular level)?
Which environment is best suited to the development of life?

- Too unstable
- Too limited
- Just right!
Liquid water is essential for life because it provides stability and richness

**Stability of temperature**

**Stability of state (liquid)**

**Richness of dissolved cpds and chemistry**

**Why?**

- High heat capacity
- Large heat of fusion
- Large heat of vaporization

**H-bonding!**

- Large liquid range
- Floating ice insulates water below; large bodies stay liquid

**How?**

- Good solvent
- Protic, amphoteric
Many of water’s unique properties are due to the extent of its hydrogen bonding

Water contains only H-bonding groups
  Compare with methanol, ethanol

Water has 2 H-bond donors and 2 acceptors
  Compare with ammonia
• Why is water essential for life?

• How does water influence life (at the molecular level)?
Water interacts with biomolecules, influencing their chemistry

Water dissolves polar and ionic compounds

*Adds richness, hinders access*

Water forms electrostatic or H-bonding interactions with polar & ionic groups

*May stabilize structure, link interactors*

Water pushes nonpolar compounds together

*Creates ‘order’*
The hydrophobic effect is driven by changes in entropy

<table>
<thead>
<tr>
<th>Process</th>
<th>( \Delta H ) (kJ \cdot mol^{-1})</th>
<th>(-T\Delta S) (kJ \cdot mol^{-1})</th>
<th>( \Delta G ) (kJ \cdot mol^{-1})</th>
</tr>
</thead>
<tbody>
<tr>
<td>( \text{CH}_4 ) in ( \text{H}_2\text{O} ) ( \rightleftharpoons ) ( \text{CH}_4 ) in ( \text{C}_6\text{H}_6 )</td>
<td>11.7</td>
<td>-22.6</td>
<td>-10.9</td>
</tr>
<tr>
<td>( \text{CH}_4 ) in ( \text{H}_2\text{O} ) ( \rightleftharpoons ) ( \text{CH}_4 ) in ( \text{CCl}_4 )</td>
<td>10.5</td>
<td>-22.6</td>
<td>-12.1</td>
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<tr>
<td>( \text{C}_2\text{H}_6 ) in ( \text{H}_2\text{O} ) ( \rightleftharpoons ) ( \text{C}_2\text{H}_6 ) in benzene</td>
<td>9.2</td>
<td>-25.1</td>
<td>-15.9</td>
</tr>
<tr>
<td>( \text{C}_2\text{H}_4 ) in ( \text{H}_2\text{O} ) ( \rightleftharpoons ) ( \text{C}_2\text{H}_4 ) in benzene</td>
<td>6.7</td>
<td>-18.8</td>
<td>-12.1</td>
</tr>
<tr>
<td>( \text{C}_2\text{H}_2 ) in ( \text{H}_2\text{O} ) ( \rightleftharpoons ) ( \text{C}_2\text{H}_2 ) in benzene</td>
<td>0.8</td>
<td>-8.8</td>
<td>-8.0</td>
</tr>
<tr>
<td>Benzene in ( \text{H}_2\text{O} ) ( \rightleftharpoons ) liquid benzene(^a)</td>
<td>0.0</td>
<td>-17.2</td>
<td>-17.2</td>
</tr>
<tr>
<td>Toluene in ( \text{H}_2\text{O} ) ( \rightleftharpoons ) liquid toluene(^a)</td>
<td>0.0</td>
<td>-20.0</td>
<td>-20.0</td>
</tr>
</tbody>
</table>

\(^a\)Data measured at 18°C.

Water entropy is the major contributor to the hydrophobic effect

Reduction in nonpolar surface area = reduction in ordered water
Water also participates in biochemical reactions

- ATP hydrolysis drives muscle contraction
  - \[ \text{ATP} + \text{H}_2\text{O} \rightarrow \text{ADP} + \text{HPO}_4^{2-} \]

- Proteins and polysaccharides are hydrolyzed into component amino acids or sugars

- Water adds to alkenes to form alcohols
  - Ex: fumarase reaction of citric acid cycle
    \[ \text{-OOC-CH=CH-COO}^- + \text{H}_2\text{O} \rightarrow \text{-OOC-CHOH-CH}_2\text{-COO}^- \]