Overview of Chapter 13

• Intermolecular Forces
• Liquids and their Properties
• Solids and Their Properties
• Phase diagrams

Questions to consider:

• Why is water usually a liquid?
• Why does water boil at 100°C and not 30°C?
• Why does ice float?
• Do all snowflakes have 6 sides?

Intermolecular Forces

• Dipole-Dipole
  – Hydrogen bonding
• Dipole-Induced dipole
• Induced dipole-Induced dipole
• Ionic Bonds
• Network Bonds

Dipole-Dipole Forces

Dipole-dipole forces occur between molecules having permanent dipoles.

<table>
<thead>
<tr>
<th>Compound</th>
<th>Mol. Wt</th>
<th>Boiling Point</th>
</tr>
</thead>
<tbody>
<tr>
<td>N₂</td>
<td>28</td>
<td>-196°C</td>
</tr>
<tr>
<td>CO</td>
<td>28</td>
<td>-192°C</td>
</tr>
<tr>
<td>Br₂</td>
<td>160</td>
<td>59°C</td>
</tr>
<tr>
<td>ICl</td>
<td>162</td>
<td>97°C</td>
</tr>
</tbody>
</table>

Hydrogen Bonding

A special form of dipole-dipole attraction, which enhances dipole-dipole attractions.

H-bonding is strongest when X and Y are N, O, or F
Hydrogen Bonding Between Methanol and Water

Hydrogen Bonding in H₂O

H-bonding is especially strong in water because
- the O—H bond is very polar
- there are 2 lone pairs on the O atom

H-bonding accounts for many of water’s unique properties.

Hydrogen Bonding in H₂O

Ice has open lattice-like structure.

Ice density is < liquid, so ice floats on water.

One of the VERY few substances where solid is LESS DENSE than the liquid.

Hydrogen Bonding in H₂O

Hydrogen Bonding

Hydrogen bonds lead to abnormally high boiling point of water.

Boiling Points of Simple Hydrogen-Containing Compounds
Boiling Points of Hydrocarbons

Note linear relation between boiling point and molar mass.

Forces Involving Induced Dipoles

How can non-polar molecules such as O\(_2\) and I\(_2\) dissolve in water?

The water dipole INDUCES a dipole in the O\(_2\) electric cloud.

Solubility increases with mass of the gas

<table>
<thead>
<tr>
<th>Table 13.2</th>
<th>The Solubility of Some Gases in Water*</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Molar Mass (g/mol)</td>
</tr>
<tr>
<td>H(_2)</td>
<td>2.01</td>
</tr>
<tr>
<td>N(_2)</td>
<td>28.0</td>
</tr>
<tr>
<td>O(_2)</td>
<td>32.0</td>
</tr>
</tbody>
</table>