Lecture 36
Chapter 11 Section 5
Chapter 12 Sections 1-2

- Crystal packing
- Solutions
Amorphous vs. Crystalline

- Amorphous solids have fixed shapes, but have irregular internal shapes – no regular structure
  - plastics
  - glass (SiO₂)
  - biological membranes

- Crystals have fixed shapes AND regular repeating structures.
  - NaCl
  - ice (H₂O)
  - quartz (SiO₂)
The Crystal Lattice and the Unit Cell

- Unit cell – the smallest unit from which the entire pattern can be assembled
Basic definitions

- **Lattice points** – the corners of the unit cell
- **Crystal lattice** – a group of identical unit cells
- **Cubic Unit Cell** – a unit cell which has edges of equal length \((l = w = h)\) and angles of \(90^\circ\)
Three basic cubic crystals

1. Simple cubic (sc) – layers of atoms stacked one directly above another, so that all atoms lie along straight lines at right angles.
2. Body-centered cubic (bcc) – simple cube with one entire atom in the center of the cube (in the body)
3. Face-centered cubic (fcc) – simple cube with atoms in the center of each face of the cube.
Simple cubic

# of atoms in unit cell
8 atoms (one in each corner)
Each atom is shared by 8 other cells, so 1/8 of the atoms are in the cell

# atoms = 8 atoms (1/8) = 1 atom
Body Centered Cubic

# of atoms in unit cell

8 atoms (one in each corner = 1/8 of each)
1 atom in the center

# atoms = 8 atoms (1/8) + 1 = 2 atoms
Face Centered Cubic

# of atoms in unit cell
8 atoms (one in each corner = 1/8 of each)
6 atoms are in the center of each side (shared by another cell = ½ of each)

# atoms = 8 atoms (1/8) + 6(1/2) = 4 atoms
Close-pack Crystals

- Close-packing maximizes intermolecular attractions.
- All empty space around the atoms or molecules is minimized.

Note two types of ‘dimples’ in (b)
1. Above the first-layer atom
2. Above the gap between first-layer atoms
Hexagonal close-packed (hcp) & Cubic close-packed (ccp)
Ionic Solids

- Ions of opposite charges alternate with one another to maximize attractions among ions.
- And, cations and anions are of different size. (cations are usually smaller)
- Often two separate packing arrangements interlaced together
Crystalline defects

- Defects can alter the properties of the solid material
- Examine what happens when carbon is added to iron to make steel.
- Iron is relatively soft, but adding carbon atoms reduces its ability to become deformed by filling in empty holes in the lattice.
Chapt 12: Nature of Solutions

- **Solution** – a homogeneous mixture of two or more substances, in which one is called the solvent and the other is the solute
  - **Solvent** – main medium, what is there in the largest quantity
  - **Solute** – dissolved in the solvent

<table>
<thead>
<tr>
<th>Solvent Type</th>
<th>Solute Type</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gas</td>
<td>Liquid</td>
</tr>
<tr>
<td>Diving gas</td>
<td>Humid air</td>
</tr>
<tr>
<td>(He, O₂)</td>
<td>(N₂, O₂, H₂O)</td>
</tr>
<tr>
<td>Carbonated water</td>
<td>Vodka</td>
</tr>
<tr>
<td>(H₂O, CO₂)</td>
<td>(H₂O, C₂H₅OH)</td>
</tr>
<tr>
<td>H₂ storage alloy</td>
<td>Plastic</td>
</tr>
<tr>
<td>(La, Ni, H₂)</td>
<td>(PVC, diocyclohexylphthalate)</td>
</tr>
<tr>
<td>Solid</td>
<td>Solid</td>
</tr>
<tr>
<td>Air move I₂</td>
<td>Saline solution</td>
</tr>
<tr>
<td>(N₂, O₂, I₂)</td>
<td>(H₂O, NaCl)</td>
</tr>
<tr>
<td>Steel</td>
<td>(Fe, C, Mn)</td>
</tr>
</tbody>
</table>
Solution Concentration

• Concentration units we have already mentioned:
  – Mole Fraction – useful for gases (see Section 5.5)
    \[ X_A = \frac{n_A}{n_{total}} \]
  – ppm and ppb – (see Section 5.5)

  – Molarity – measure for aqueous solutions (see Section 3.6)
    \[ M = \frac{n_{solute}}{V_{solution}} \]

• A new concentration unit:
  – Molality
Molality (m)

• Useful for applications where the temperature of a solution changes.

• Defined as the number of moles of solute divided by the mass of the solvent in kg

\[ c_m = \frac{n_{\text{solute}}}{m_{\text{solvent}}} \]

• Units are mol/kg
Concentrated aqueous ammonia is 14.8 M and has a density of 0.898 g/mL. What is the molality of ammonia in this solution? Use 17.0 g/mol as the molecular weight of NH₃.

- 25% 1. 0.280 m
- 25% 2. 0.389 m
- 25% 3. 16.5 m
- 25% 4. 22.9 m
Solubility

- Solubilities vary tremendously
- Chemists often use qualitative descriptions, for example:
  - Miscible: when two liquids mix in all proportions (Acetone and Water)
  - Immiscible: when two liquids DO NOT mix at all (Oil and water)
  - Insoluble: when a solid does not dissolve in a solvent (NaCl in gasoline)
  - Saturated: a solution that has dissolved the maximum possible solute.
Like Dissolves Like

• What does this mean?
  – Vinegar (acetic acid) dissolves in water, oil does not
• We are talking about polarity here…
  – Compounds with similar polarity will be soluble in each other.
  – In other words, substances that dissolve in each other usually have similar types of intermolecular interactions.
Which is the most soluble in hexane?

<table>
<thead>
<tr>
<th>25%</th>
<th>1. Hexanol</th>
</tr>
</thead>
<tbody>
<tr>
<td>25%</td>
<td>2. NaCl</td>
</tr>
<tr>
<td>25%</td>
<td>3. Octane</td>
</tr>
<tr>
<td>25%</td>
<td>4. Water</td>
</tr>
</tbody>
</table>
Example

Observe the following trend of alcohol solubilities in water:

<table>
<thead>
<tr>
<th>Alcohol</th>
<th>Molecular Formula</th>
<th>Solubility</th>
</tr>
</thead>
<tbody>
<tr>
<td>n-Propanol</td>
<td>CH$_3$CH$_2$CH$_2$OH</td>
<td>Completely Miscible</td>
</tr>
<tr>
<td>n-Butanol</td>
<td>CH$_3$CH$_2$CH$_2$CH$_2$OH</td>
<td>1.1 M</td>
</tr>
<tr>
<td>n-Pentanol</td>
<td>CH$_3$CH$_2$CH$_2$CH$_2$CH$_2$OH</td>
<td>0.30 M</td>
</tr>
<tr>
<td>n-Hexanol</td>
<td>CH$_3$CH$_2$CH$_2$CH$_2$CH$_2$CH$_2$OH</td>
<td>0.056 M</td>
</tr>
</tbody>
</table>
Solubility of Solids

Remember there are 4 basic solids?

1. Network solids (diamond, graphite) cannot dissolve without breaking covalent bonds.
2. Molecular solids – “like dissolve like”
3. Metals – do not dissolve in water (some will react, but not dissolve)
4. Ionic Solids – remember the solubility rules?
Example

Vitamins are organic molecules that are required for proper function but are not synthesized by the human body. Thus, vitamins must be present in the foods people eat. Vitamins fall into two categories: **fat-soluble**, which dissolve in fatty hydrocarbon-like tissues and **water-soluble**.
Alloys

• **Alloy**: a mixture of substances with metallic properties. (a solid solution)

• Some are true solutions \(\rightarrow\) homogeneous (brass)

• Others are heterogeneous (solder)
Solubility of Salts
Today

- Work on Chapt 12
- Start CAPA
- Review Exam

Wednesday

- Finish reading Chapt 12

Remember: You are done with the homework when you understand it!