Ch 14 Mixtures and Solutions

Big Idea:
Nearly all of the gases, liquids and solids that make up our world are mixtures.

I CAN:
• Describe the concentration of solutions using different units;
• Compare properties of suspensions, colloids and solutions;
• Determine colligative properties of a solution

We all use Chemical Solutions

Average Family spends: $\underline{1200} / year on chemical solutions?

Make-up, laundry detergent, motor oil, gasoline, food preservatives, deodorant, lawn fertilizers & weed killers, shampoo, air fresheners, floor wax, furniture polish, toothpaste, mouthwash, oven cleaner, glass cleaner, etc.

Household Chemical Encyclopedia
Definitions

- **Solution** - homogeneous mixture
- **Solute** - substance being dissolved
- **Solvent** - present in greater amount

Solution = Solute + Solvent

- Solute - gets dissolved
- Solvent - does the dissolving
  - Aqueous (water)
  - Tincture (alcohol)
  - Amalgam (mercury)
  - Organic
    - Polar
    - Non-polar
Types of Solutions

<table>
<thead>
<tr>
<th>Solute</th>
<th>Solvent</th>
<th>Solution</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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<tr>
<td><strong>Gaseous Solutions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gas</td>
<td>gas</td>
<td>air (nitrogen, oxygen, argon gases)</td>
</tr>
<tr>
<td>liquid</td>
<td>gas</td>
<td>humid air (water vapor in air)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Liquid Solutions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>gas</td>
<td>liquid</td>
<td>carbonated drinks (CO₂ in water)</td>
</tr>
<tr>
<td>liquid</td>
<td>liquid</td>
<td>vinegar (CH₃COOH in water)</td>
</tr>
<tr>
<td>solid</td>
<td>liquid</td>
<td>salt water (NaCl in water)</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Solid Solutions</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>liquid</td>
<td>solid</td>
<td>dental amalgam (Hg in Ag)</td>
</tr>
<tr>
<td>solid</td>
<td>solid</td>
<td>sterling silver (Cu in Ag)</td>
</tr>
</tbody>
</table>

Factors Affecting the Rate of Dissolution

1. temperature  
   \[ \text{As } T \rightarrow \uparrow, \text{rate } \uparrow \]

2. particle size  
   \[ \text{As size } \downarrow, \text{rate } \uparrow \]

3. mixing  
   \[ \text{More mixing, rate } \uparrow \]

4. nature of solvent or solute
Making solutions

- In order to dissolve - the solvent molecules must come in contact with the solute.
- Stirring moves fresh solvent next to the solute.
- The solvent touches the surface of the solute.
- Smaller pieces increase the amount of surface of the solute.

Soluble, Insoluble, Immiscible, and Miscible

A substance that dissolves in a solvent is said to be **soluble** in that solvent (e.g. sugar in water).

A substance that does not dissolve in a solvent is said to be **insoluble** in that solvent (e.g. sand in water).

Oil and vinegar are said to be **immiscible**. They do not mix with one another.

Liquids that mix with one another are **miscible** with one another.
Dissolving of solid NaCl

Polar water molecules interact with positive and negative ions

Animation
Solubility

**Solubility** – the amount of solute that dissolves in a solvent at a specified temperature, expressed as “g of solute/100 g of solvent”

**Saturated Solution** – has dissolved as much solute as possible at a specified temperature

**Unsaturated Solution** – contains less solute than a saturated solution at a specified temp.

**Supersaturated Solution** – contains more dissolved solute than a saturated solution at a specified temp.
Pressure and Solubility of Gases

Ex: Carbonated beverages – bottled under high pressure; when bottle is opened, release pressure and CO₂ escapes (drink becomes flat)

Henry's Law: if increase P above a liquid, gas solubility increases;
If decrease P above liquid, gas solubility decreases.
A direct relationship!

\[ S_1 P_2 = S_2 P_1 \]
Concentrations of Solutions

Molarity (M) – the most common unit of solution concentration!

\[ M = \frac{\text{moles of solute}}{\text{liter of solution}} \]

The higher the molarity, the more concentrated the solution.

Examples: 1) Given moles and volume, find M

Molarity problems cont.

2) Given mass and volume, find M

3) Given mass and M, find volume

4) Given volume and M, find mass
CONCENTRATIONS OF SOLUTIONS cont.

Molality (m) = \( \frac{\text{moles of solute}}{\text{kg of solvent}} \)

Molality is useful because mass does not change with temp., but volume does, which alters the molarity of a solution.

Examples: 1) Given masses of solute and solvent, find m.

2) Given mass of solute and m of solution, find mass of solvent.
Percent Concentrations of Solutions

\[
\% \text{ by mass} = \frac{\text{mass of solute}}{\text{mass of solution}} \times 100
\]

\[
\% \text{ by volume} = \frac{\text{volume of solute}}{\text{volume of solution}} \times 100
\]

Example: 1) 4.5 g of NaCl are dissolved in 100.0 g H₂O

2) 25 mL of isopropyl alcohol are dissolved in 350 mL H₂O

Preparing Dilutions of Solutions

\[
\text{Molarity} \times \text{Volume before dilution} = \text{Molarity} \times \text{Volume after dilution}
\]

\[
M_1V_1 = M_2V_2
\]

Example: How much 12 M HCl would you need to prepare 250 mL of 1.5 M HCl?
Mole Fraction ($X$)

- The ratio of moles of solute or solvent to total moles of solution.

- $X_A = \frac{n_A}{n_A + n_B}$  \hspace{1cm} n = moles
  \hspace{1cm} A is solute, B is solvent

- $X_B = \frac{n_B}{n_A + n_B}$
• What is the mole fraction of NaOH in an aqueous solution which contains 25.0g NaOH in 150.0g H₂O?

Electrolytes and Colligative Properties

• Colligative properties are those properties that are changed by the number of dissolved particles in a solution, but not necessarily because of the specific solute (colligative means “depending on the collection.”)

• Colligative properties include:
  – Vapor pressure lowering
  – Boiling point elevation
  – Freezing point depression, and
  – Osmotic pressure
Nonelectrolytes and electrolytes in aqueous solution

- Sucrose in solution (nonelectrolyte)
  - Does not conduct electricity
- NaCl in solution (electrolyte)
  - Does conduct electricity

Pure water does not conduct an electric current

Source of electric power

Pure water
Ionic Solutions conduct a Current

Colligative Properties → depend on concentration of a solution

Compared to solvents... a solution with that solvent has a...
...normal freezing point (NFP) → ...lower FP

...normal boiling point (NBP) → ...higher BP
Applications (NOTE: Data are fictitious.)

1. salting roads in winter

<table>
<thead>
<tr>
<th></th>
<th>FP</th>
<th>BP</th>
</tr>
</thead>
<tbody>
<tr>
<td>water</td>
<td>0ºC (NFP)</td>
<td>100ºC (NBP)</td>
</tr>
<tr>
<td>water + a little salt</td>
<td>-11ºC</td>
<td>103ºC</td>
</tr>
<tr>
<td>water + more salt</td>
<td>-18ºC</td>
<td>105ºC</td>
</tr>
</tbody>
</table>

2. antifreeze (AF)_koolant

<table>
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<th>BP</th>
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<tr>
<td>water</td>
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<td>100ºC (NBP)</td>
</tr>
<tr>
<td>water + a little AF</td>
<td>-10ºC</td>
<td>110ºC</td>
</tr>
<tr>
<td>50% water + 50% AF</td>
<td>-35ºC</td>
<td>130ºC</td>
</tr>
</tbody>
</table>

Calculations for Colligative Properties

The change in FP or BP is found using... 

\[ \Delta T_s = K \cdot m \cdot i \]

\( \Delta T_s \) = change in Tº (below NFP or above NBP)

\( K_s \) = constant depending on... (A) solvent

(B) freezing or boiling

\( m \) = molality of solute = mol solute / kg solvent

\( i \) = integer that accounts for any solute dissociation

any sugar (all nonelectrolytes) \( i = 1 \)

table salt, NaCl \( \rightarrow \) Na\(^+\) + Cl\(^-\) \( i = 2 \)

barium bromide, BaBr\(_2\) \( \rightarrow \) Ba\(^+\) + 2 Br\(^-\) \( i = 3 \)

\[ K_b = \text{boiling point constant: } 0.52 \, ^\circ C/m \text{ (for water)} \]

\[ K_f = \text{freezing point constant: } 1.86 \, ^\circ C/m \text{ (for water)} \]
Heterogeneous Mixture

*Does not have a uniform composition; individual substances are distinct

Examples: suspensions and colloids

Remember: solutions are homogeneous mixtures!

<table>
<thead>
<tr>
<th></th>
<th>Particle Size</th>
<th>Characteristics</th>
<th>Examples</th>
</tr>
</thead>
<tbody>
<tr>
<td>Suspensions</td>
<td>&gt; 1000 nm</td>
<td>Particles can be filtered out or they can settle out</td>
<td>Muddy water, OJ with pulp</td>
</tr>
<tr>
<td>Colloids</td>
<td>1 nm – 1000 nm</td>
<td>Particles too small to be filtered; do not settle out</td>
<td>Milk, fog, paint</td>
</tr>
<tr>
<td>Solutions</td>
<td>&lt; 1 nm</td>
<td>Particles are &quot;atom&quot; sized</td>
<td>Air, salt water, steel</td>
</tr>
</tbody>
</table>

Suspensions and Colloids cont.

**Colloids** – when solute particles are observed under a microscope, they collide with the solvent particles and create jerky, random movements called **Brownian motion**. These collisions prevent the colloid particles from settling out.

How can you distinguish between colloids and solutions? Shine a beam of light on them….and observe the…

**Tyndall Effect** – the particles in colloids and suspensions scatter light; solutions never scatter light

Examples: a searchlight traversing the night sky;

using low beams when driving in fog
Tyndall Effect - colloid particles scatter light, solution particles do not

Solutions Notecard

Molarity: \( M = \text{mol solute} / \text{L solution} \)

Molality: \( m = \text{mol solute} / \text{kg solvent} \)

% by mass = \( \frac{\text{mass solute}}{\text{mass solution}} \times 100 \)

% by volume = \( \frac{\text{volume solute}}{\text{volume solution}} \times 100 \)

Dilution: \( M_1 V_1 = M_2 V_2 \)

Henry's Law: \( S_1 P_2 = S_2 P_1 \)

Mole Fraction:

\[ \chi_A = \frac{n_A}{n_A + n_B} \]

\[ \chi_B = \frac{n_B}{n_A + n_B} \]
\[ \Delta T_b = K_b \times m \times i \]

\[ \Delta T_f = K_f \times m \times i \]

\( K_b \) = boiling point constant: 0.52 \(^\circ\text{C}/\text{m}\) (for water)

\( K_f \) = freezing point constant: 1.86 \(^\circ\text{C}/\text{m} \) (for water)