Properties of Aqueous Solutions
Definitions

A solution is a homogeneous mixture of two or more substances.

The substance present in smaller amount is called the *solute*.

The substance present in larger amount is called the *solvent*.

For now we will discuss only *aqueous solutions*. 
Electrolytes vs Nonelectrolytes

An electrolyte is a substance that, when dissolved in water, gives a solution that can conduct electricity.

A nonelectrolyte does not conduct electricity when dissolved in water.
the most important property of water when dealing with aqueous solution is its polarity.

Structure of water

O—H bonds are covalent but “polar”
Dipole Moments
a substance possesses a dipole moment if its centers of positive and negative charge do not coincide

\[ \mu = e \times d \]

Expressed in debye units

not polar

polar
examples

$\mu = 1.7 \text{ D}$

$\mu = 1.8 \text{ D}$

$\mu = 1.5 \text{ D}$
Solvation

Clustering of molecules of solvent around solute:

hydration is specific term for solvation when water is solvent
Water can solvate both cations and anions.
The breaking up of a compound into cations and anions

\[ \text{NaCl}_{(s)} + \text{H}_2\text{O} \rightarrow \text{Na}^{+}_{(aq)} + \text{Cl}^{-}_{(aq)} \]
Dissociation

(a) Ionic compounds like sodium chloride, NaCl, form ions when they dissolve.

1. H₂O molecules separate Na⁺ and Cl⁻ ions from solid NaCl.
2. H₂O molecules surround Na⁺ and Cl⁻ ions.
3. Na⁺ and Cl⁻ ions disperse throughout the solution.

Ionic compound dissolves in water.
Electrolytes vs Nonelectrolytes

Nonelectrolyte
- not ionized in water

Weak electrolyte
- incompletely ionized in water

Strong electrolyte
- completely ionized in water
**Electrolytes**

- A **strong electrolyte** dissociates completely when dissolved in water.
- A **weak electrolyte** only dissociates partially when dissolved in water.
Solutions

- An **electrolyte** is a substances that dissociates into ions when dissolved in water.
Solutions

- An **electrolyte** is a substance that dissociates into ions when dissolved in water.

- A **nonelectrolyte** may dissolve in water, but it does not dissociate into ions when it does so.

(b) Molecular substances like methanol, CH$_3$OH, dissolve without forming ions
The amount of solute that can be dissolved in a given amount of a saturated solution at a fixed temperature is the **solubility** of the solute in the solvent.
Solubility

Some compounds are very soluble: NaCl, KCl, NH₄Cl

Some are slightly soluble: AgCl

slightly soluble and insoluble can be used interchangeably
Strong electrolytes

Soluble Ionic compounds
Strong acids
Strong bases
Arrhenius definitions of acids and bases

An **acid** dissolves in water to yield protons

\[ \text{H—X} \rightarrow \text{H}^+ + \text{X}^- \]

A **base** dissolves in water to yield hydroxide ions

\[ \text{YOH} \rightarrow \text{Y}^+ + \text{HO}^- \]
Acids

- The Swedish physicist and chemist S. A. Arrhenius defined acids as substances that increase the concentration of $\text{H}^+$ when dissolved in water.
- Both the Danish chemist J. N. Brønsted and the British chemist T. M. Lowry defined them as proton donors.
There are only seven strong acids:

- Hydrochloric (HCl)
- Hydrobromic (HBr)
- Hydroiodic (HI)
- Nitric (HNO₃)
- Sulfuric (H₂SO₄)
- Chloric (HClO₃)
- Perchloric (HClO₄)
Strong Electrolytes Are…

- Strong acids
- Strong bases

**TABLE 4.2 • Common Strong Acids and Bases**

<table>
<thead>
<tr>
<th>Strong Acids</th>
<th>Strong Bases</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrochloric, HCl</td>
<td>Group 1A metal hydroxides [LiOH, NaOH, KOH, RbOH, CsOH]</td>
</tr>
<tr>
<td>Hydrobromic, HBr</td>
<td>Heavy group 2A metal hydroxides [Ca(OH)$_2$, Sr(OH)$_2$, Ba(OH)$_2$]</td>
</tr>
<tr>
<td>Hydroiodic, HI</td>
<td></td>
</tr>
<tr>
<td>Chloric, HClO$_3$</td>
<td></td>
</tr>
<tr>
<td>Perchloric, HClO$_4$</td>
<td></td>
</tr>
<tr>
<td>Nitric, HNO$_3$</td>
<td></td>
</tr>
<tr>
<td>Sulfuric, H$_2$SO$_4$</td>
<td></td>
</tr>
</tbody>
</table>
Weak electrolytes

- Weak acids
- Weak bases
A Weak Acid

Acetic acid:

$$\text{CH}_3\text{COH} \rightarrow \text{CH}_3\text{CO}^- + \text{H}^+$$

>99% <1%

Reversible reaction
the reaction can occur in both directions
A Weak Base

Ammonia:

\[ \text{H}_3\text{N} : + \text{H}_2\text{O} \rightleftharpoons \text{HO}^- + \text{NH}_4^+ \]

>99%  <1%
Nonelectrolytes

produce no ions when dissolved in water

- ethanol
- ethylene glycol
- sucrose
Concentration

Molarity (M)

moles of solute /1L of solution

What is the molarity of a solution made up by dissolving 9.52g of NaCl in enough H₂O to form 575 mL of solution?

\[ M = \frac{n}{L} \]

\[
\begin{align*}
9.52\text{g NaCl} &\times \frac{1\text{ mol}}{58.4\text{g NaCl}} \times \frac{1}{575\text{ mL}} \times \frac{10^3\text{ mL}}{1\text{ L}} \\
&= 0.284 \text{ mol/L}
\end{align*}
\]
Important point about concentration

Given: \( \text{Na}_2\text{SO}_4 \) concentration = 0.683 M

What is the concentration of \( \text{Na}^+ \)?

What is the concentration of \( \text{SO}_4^{2-} \)?

\[
\text{Na}^+ = 2 \times 0.683 \text{ M} = 1.37 \text{ M}
\]

\[
\text{SO}_4^{2-} = 0.683 \text{ M}
\]
Dilution of solutions
Dilution of solutions

Preparation of a less concentrated solution from a more concentrated one

\[ M_{\text{initial}} \times V_{\text{initial}} = M_{\text{final}} \times V_{\text{final}} \]

Moles of solute \(_{\text{initial}}\) = Moles of solute \(_{\text{final}}\)
The dilution of a more concentrated solution to a less concentrated one does not change the number of moles of solute
Dilution of solutions

How much concentrated HCl (12.5 M HCl) is required in order to prepare 1 L of a 1 M solution?

\[
M_{\text{initial}} \times V_{\text{initial}} = M_{\text{final}} \times V_{\text{final}}
\]

\[
(12.5 \text{ mole } / \text{ L}) \times V_{\text{initial}} = (1 \text{ mol } / \text{ L})(1 \text{ L})
\]

\[
V_{\text{initial}} = 0.080 \text{ L} = 80 \text{ ml}
\]