The Major Classes of Chemical Reactions

4.1 The Role of Water as a Solvent

- Water participates actively in the dissolution process

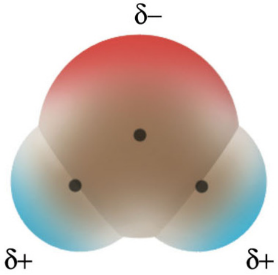
The dissolution process

- **Hydration** (solvation) of the solute particles in solution
  - The solute particles (ions, molecules, …) are surrounded by water (solvent) molecules
  - The solute particles are evenly spread throughout the solution

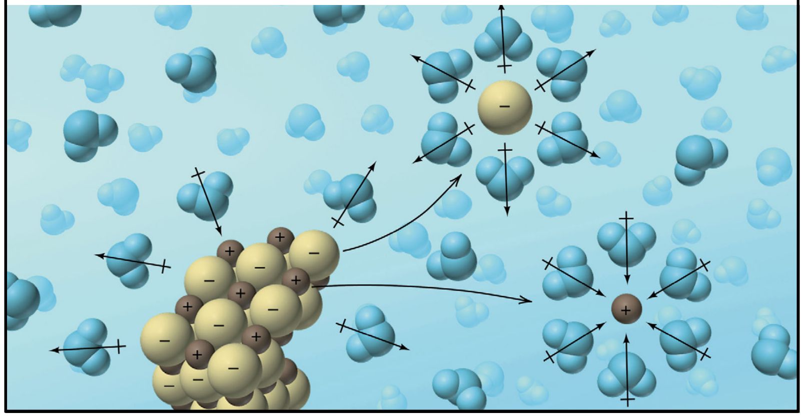
- **Electrolytes** – produce ions in solution (resulting solution conducts electricity)
  - **Strong electrolytes** – completely ionize in solution (soluble salts, strong acids and bases such as NaCl, HCl, KOH, ...)
  - **Weak electrolytes** – partially ionize in solution (weak acids and bases such as H_2S, NH_3, ...)
- **Nonelectrolytes** – do not ionize in solution (resulting solution does not conduct electricity)
  - Molecular compounds (except acids and bases) such as H_2O, sugar, acetone, methanol, …

- The molecule of water is **polar**
  - The O atom pulls the shared electrons stronger
  - The O is partially negative and the Hs are partially positive
  - The molecule is bent

$\Rightarrow$ The molecule has a positive and a negative pole $\rightarrow$ **dipole**



- The water dipoles surround the ions on the surface of an **ionic** compound and pull them away from the crystal → hydration → electrolyte solution



- The water dipoles surround the molecules on the surface of a **covalent** compound and interact with the polar bonds in it → hydration →
  - If the molecules do not dissociate (most covalent compounds) → non-electrolytes
  - If the molecules dissociate to ions (for example in acids which contain polar X–H bonds) → electrolytes
- The **solubility** of a compound depends in large part on the relative strengths of the attractive forces between its ions or molecules and the forces of hydration

Example:

How many Na^+ ions are present in 8.2 mL of a 0.15 M $Na_2SO_4(aq)$ solution?

Na_2SO_4 → strong electrolyte

$$\Rightarrow Na_2SO_4(s) \xrightarrow{H_2O} 2Na^+(aq) + SO_4^{2-}(aq)$$

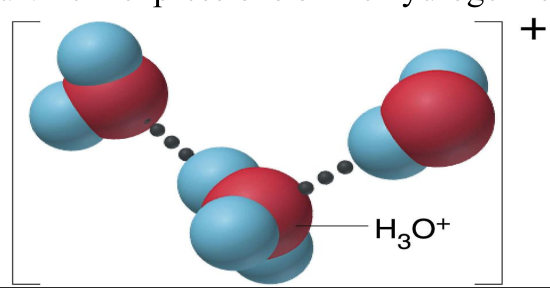
$$0.0082\ \cancel{L}\left(\frac{0.15\ \cancel{mol\ Na_2SO_4}}{1\ \cancel{L}}\right)\left(\frac{2\ \cancel{mol}\ Na^+}{1\ \cancel{mol\ Na_2SO_4}}\right)$$

$$\left(\frac{6.022\times10^{23}\ Na^+\ ions}{1\ \cancel{mol\ Na^+}}\right) = 1.5\times10^{21}\ Na^+\ ions$$

- The **H^+ ion** interacts very strongly with water and forms the **hydronium ion, H_3O^+**

$$H^+(aq) + H_2O(l) \rightarrow H_3O^+(aq)$$

  - H_3O^+ is strongly hydrated in water solutions by 1, 2 or even 3 H_2O molecules ($H_5O_2^+$, $H_7O_3^+$, $H_9O_4^+$)
  - H^+ and H_3O^+ (including the hydrated forms) are equivalent expressions of the hydrogen ion



4.2 Equations for Reactions in Aqueous Solution

- Overall **molecular equation** (all reactants and products in their undissociated form)

$AgNO_3(aq) + NaCl(aq) \rightarrow AgCl(s) + NaNO_3(aq)$

- **Complete** (total) **ionic equation** (all strong electrolytes are completely dissociated to ions (ionized) in aqueous solutions

[$NaCl(aq) \rightarrow Na^+(aq),\ Cl^-(aq)$]

$Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow$

$\rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$

- **Spectator ions** – present on both sides of the equation (can be canceled)

$Ag^+(aq) + NO_3^-(aq) + Na^+(aq) + Cl^-(aq) \rightarrow$

$\rightarrow AgCl(s) + Na^+(aq) + NO_3^-(aq)$

- **Net ionic equation** – no spectator ions

$$Ag^+(aq) + Cl^-(aq) \rightarrow AgCl(s)$$

- For simplicity, we can omit **(aq)** after the symbols of all ions in aqueous solutions (assume all ions in solution as aqueous)

$$Ag^+ + Cl^- \rightarrow AgCl(s)$$

Example:

Write the net ionic equation corresponding to the following molecular equation:

$Na_2CO_3(aq) + H_2SO_4(aq) \rightarrow$

$\rightarrow Na_2SO_4(aq) + H_2O(l) + CO_2(g)$

$\Rightarrow$Complete ionic eq:

$2Na^+ + CO_3^{2-} + 2H^+ + SO_4^{2-} \rightarrow$

$\rightarrow 2Na^+ + SO_4^{2-} + H_2O(l) + CO_2(g)$

$\Rightarrow$Net ionic eq:

$$CO_3^{2-} + 2H^+ \rightarrow H_2O(l) + CO_2(g)$$