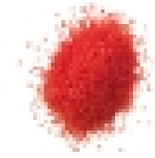
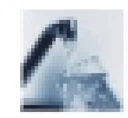
Chapter 4: Types of Chemical Reactions and Solution Stoichiometry

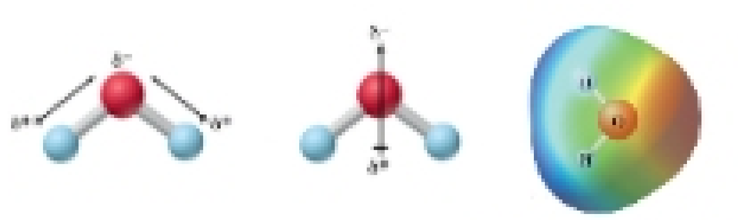
Definitions – Solutes, Solvents and Solutions

- Solute
  - Substance being dissolved, mixed, diluted.
  - Example: sugar
- Solvent
  - Substance doing the dissolving, mixing, dilution.
  - Example: water
- Solution
  - Final combination of dissolution, mixing, and dilution.
  - Example: Kool-Aid


Water as a Solvent

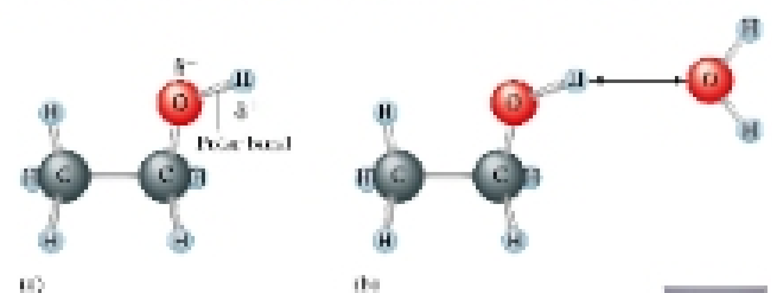
- Water is an important solvent – dissolves many substances
- "Aqueous" means a solution in which water is the solvent
- Water is a POLAR molecule



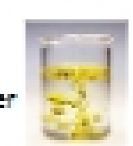
Red: more electron density
Blue: less electron density

Polar and Nonpolar Solutes

- Water dissolves some non-ionic substances if they are polar (ethanol-water)
- Ethanol molecules are polar (contain directional O-H bond)

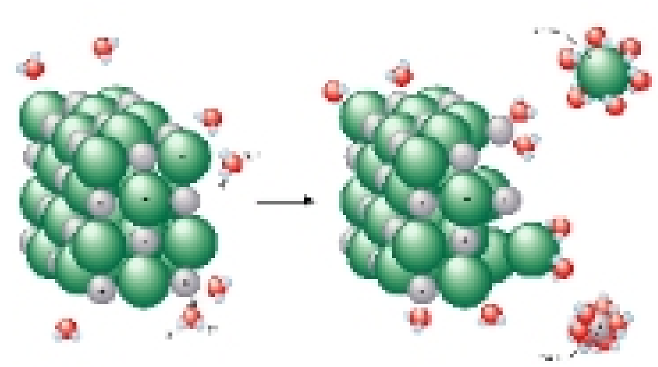


Nonpolar substances (e.g., octane (C_8H_{18}), benzene (C_6H_6), fats, oils) will not dissolve in water



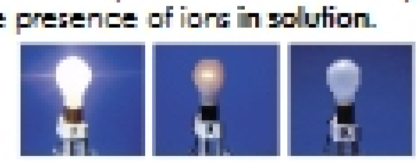
Ionic Solutes

- Polar water molecules dissolve ionic compounds (salts)
- "Hydration" breaks ionic compounds into anions and cations
- Water dissolves different ionic compounds to different degrees (more in Ch. 8)



The Role of Water as a Solvent: Dissolution of Ionic Compounds

Electrical conductivity: the flow of electricity in a solution indicates the presence of ions in solution.



Electrolyte: a substance that conducts a current when dissolved in water.

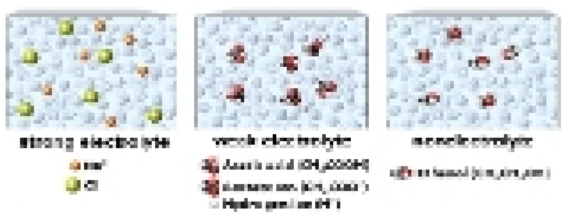
$$NaCl\ (s) + H_2O\ (l) \longrightarrow Na^+\ (aq) + Cl^-(aq)$$

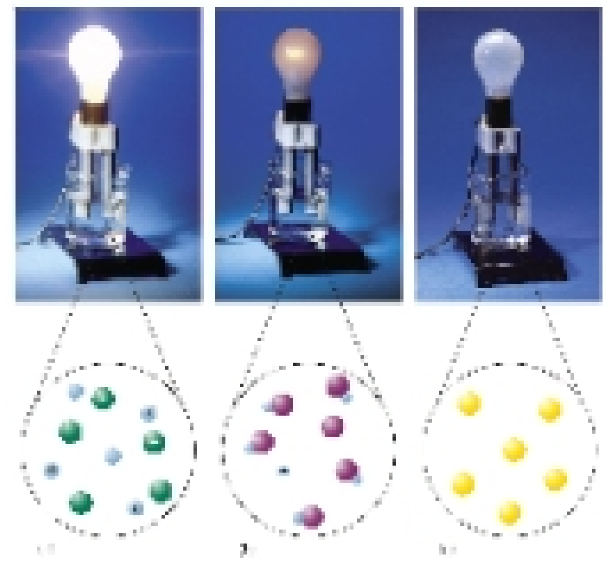
- Ions become solvated/hydrated – they are surrounded by water molecules.
- These ions are labeled "aqueous" – they are free to move throughout the solution and conduct electricity.

Electrolytes and Non-Electrolytes

Electrolytes and electrical conductivity

- If a solution conducts electricity, it contains ions
- A solution that contains many ions is a **strong electrolyte.**
- A solution that contains only a few ions is a **weak electrolyte.**
- A solution that contains no ions is a **nonelectrolyte.**





Strong Electrolytes

strong electrolytes: substances that are good conductors of electricity

- These substances break up to produce many ions in water
  - many ions present to move electrons/conduct electricity → **strong electrolyte**

For example,

$$NaCl\ (s) \xrightarrow{H_2O} Na^+\ (aq) + Cl^-\ (aq)$$

$$KOH\ (s) \xrightarrow{H_2O} K^+\ (aq) + OH^-\ (aq)$$

$$HBr\ (g) \xrightarrow{H_2O} H^+\ (aq) + Br^-\ (aq)$$

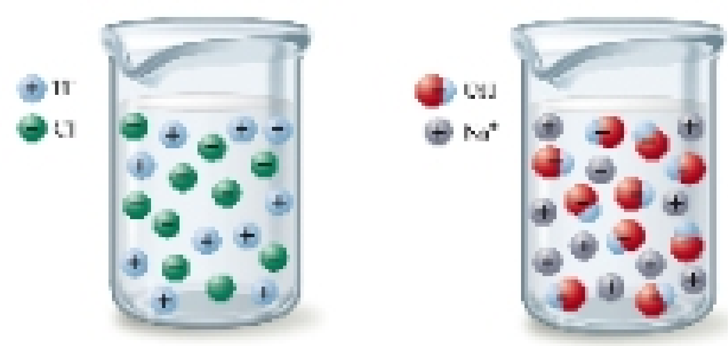
Examples: strong acids, strong bases, all soluble ionic compounds

HCl (aq) is completely ionized.

Strong acids fully dissociate, forming the anion and a hydrated proton.

NaOH (aq) is completely ionized.

Strong bases fully dissociate, forming a cation and the hydroxide anion.



Weak Electrolytes

weak electrolytes: substances that are weak/poor conductors of electricity

- These substances mostly remain intact as compounds, producing very few ions in water
  - only a few ions present to move electrons/conduct electricity → **weak electrolyte**

For example,

acetic acid is a typical weak acid:

$$HC_2H_3O_2(aq) \qquad H^+(aq) + C_2H_3O_2^-(aq)$$

ammonia is a common weak base:

$$NH_3(aq) + H_2O(l) \qquad NH_4^+(aq) + OH^-(aq)$$

Both of these species are ionized only ~1%

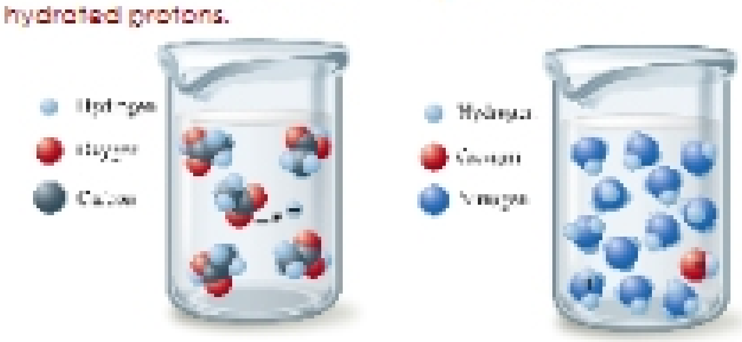
Examples: weak acids, weak bases, insoluble ionic compounds

Acetic acid ($HC_2H_3O_2$) exists in water mostly as undissociated molecules.

Weak acids partially dissociate, forming only a small number of anions and hydrated protons.

The reaction of NH_3 in water.

Weak bases partially dissociate (or react with water to a limited extent), forming only a small number of cations and hydroxide anions.



Non-electrolytes

nonelectrolytes: substances that cannot conduct electricity

- These molecules never break down into ions.
  - They always remain intact as neutral molecules that have no charge → no ions to move electrons/conduct electricity

For example,

$$C_{12}H_{22}O_{11}(s) \xrightarrow{H_2O} C_{12}H_{22}O_{11}(aq)$$

Examples: sugar (e.g. sucrose), ethanol (C_2H_5OH), and all other molecules that are not acids

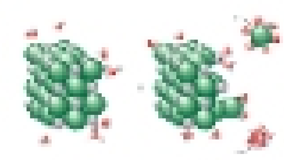
Dissolving compounds in water

- When an ionic compound is dissolved in water:
  - Ions are "hydrated"
  - Separated from their solid crystal
  - Become individual ions in solution

$NaCl\ (s) \rightarrow Na^+\ (aq) + Cl^-\ (aq)$ **(2 ions)**

$MgCl_2\ (s) \rightarrow Mg^{2+}\ (aq) + 2\ Cl^-\ (aq)$ **(3 ions)**

$NH_4NO_3\ (s) \rightarrow NH_4^+\ (aq) + NO_3^-\ (aq)$ **(2 ions)**



Determining Moles of Ions in Aqueous Solutions of Ionic Compounds

How many moles of each ion are formed when the following compounds are dissolved in water:

a) 4.0 moles of sodium carbonate
b) 46.5 g of rubidium fluoride
c) 9.32×10^{21} formula units of iron(III) chloride

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a) $Na_2CO_3\ (s) \xrightarrow{H_2O} 2\ Na^+(aq) + CO_3^{2-}(aq)$

moles of Na^+ = 4.0 moles $Na_2CO_3 \times \frac{2 \text{ mol } Na^+}{1 \text{ mol } Na_2CO_3}$

= 8.0 moles Na^+ AND 4.0 moles of CO_3^{2-}

Determining Moles of Ions in Aqueous Solutions of Ionic Compounds

b) $RbF\ (s) \xrightarrow{H_2O} Rb^+\ (aq) + F^-\ (aq)$

moles of RbF = 46.5 g RbF $\times \frac{1 \text{ mol RbF}}{104.47 \text{ g RbF}}$ = 0.445 moles RbF

thus, 0.445 mol Rb^+ and 0.445 mol F^-

Determining Moles of Ions in Aqueous Solutions of Ionic Compounds

c) $FeCl_3\ (s) \xrightarrow{H_2O} Fe^{3+}\ (aq) + 3\ Cl^-(aq)$

moles of $FeCl_3$ =

9.32×10^{21} formula units $\times \frac{1 \text{ mol } FeCl_3}{6.022 \times 10^{23} \text{ formula units } FeCl}$

= 0.0155 mol $FeCl_3$

= 0.0155 mol Fe^{3+}

moles of Cl^- = 0.0155 mol $FeCl_3 \times \frac{3 \text{ mol } Cl^-}{1 \text{ mol } FeCl_3}$ **= 0.0465 mol Cl^-**