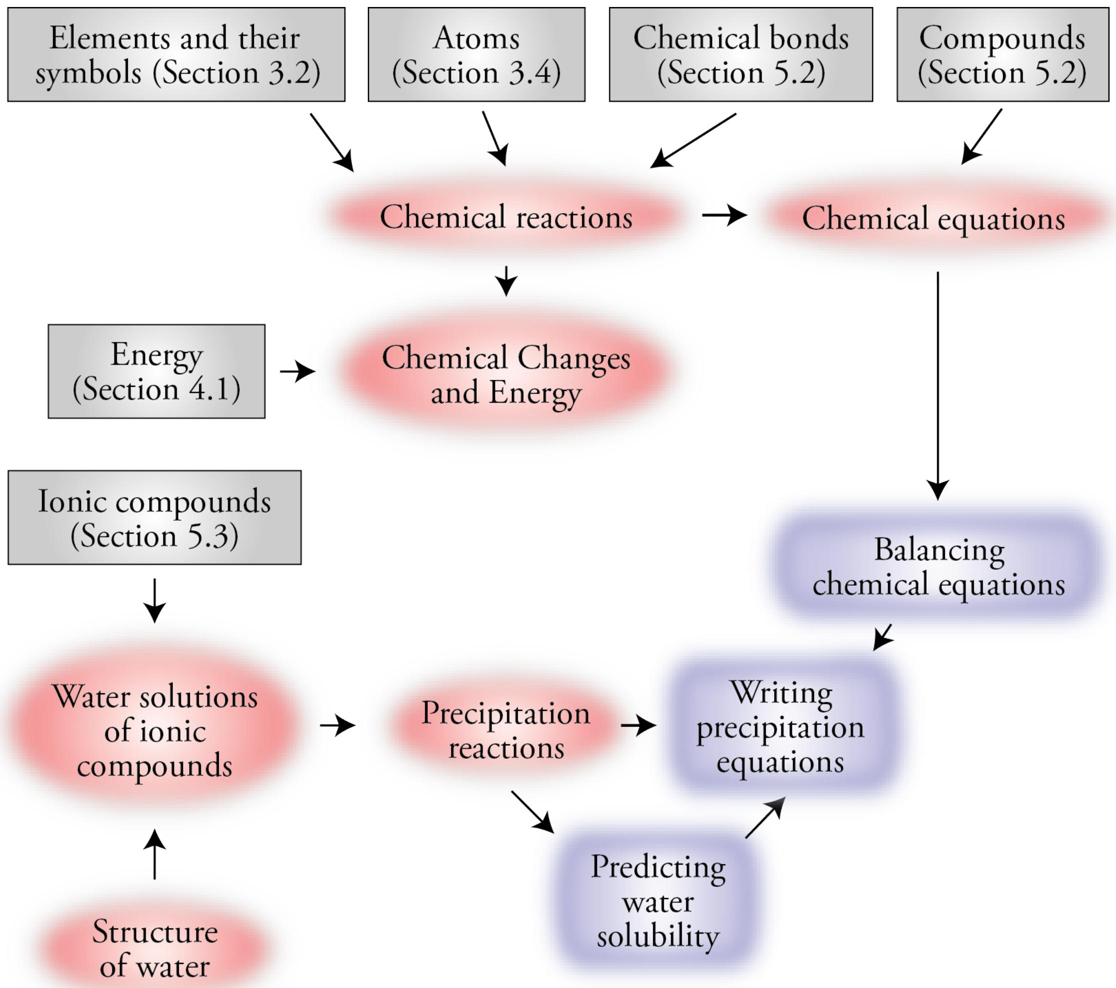
Chapter 7
An Introduction to Chemical Reactions

An Introduction to Chemistry
by Mark Bishop

Chapter Map



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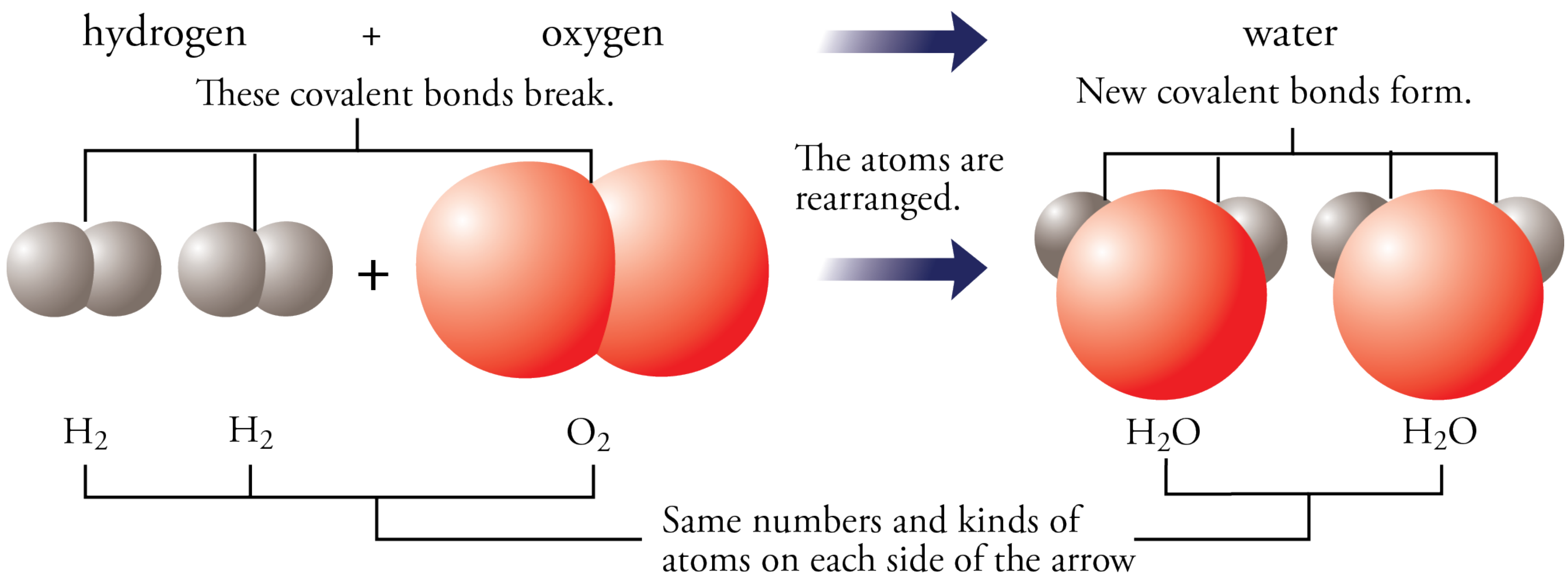
Chemical Reaction

- A ***chemical change*** or ***chemical reaction*** is a process in which one or more pure substances are converted into one or more different pure substances.

Chemical Reactions - Example



Chemical Equations (1)

- Chemical equations show the formulas for the substances that take part in the reaction.
  - The formulas on the left side of the arrow represent the ***reactants***, the substances that change in the reaction. The formulas on the right side of the arrow represent the ***products***, the substances that are formed in the reaction. If there are more than one reactant or more than one product, they are separated by plus signs. The arrow separating the reactants from the products can be read as *"goes to"* or *"yields" or "produces."*

Chemical Equations (2)

- The physical states of the reactants and products are provided in the equation.
  - A *(g)* following a formula tells us the substance is a gas. Solids are described with *(s)*. Liquids are described with *(l)*. When a substance is dissolved in water, it is described with *(aq)* for "aqueous," which means "mixed with water."

Chemical Equations (3)

- The relative numbers of particles of each reactant and product are indicated by numbers placed in front of the formulas.
  - These numbers are called ***coefficients***. An equation containing correct coefficients is called a balanced equation.
  - If a formula in a balanced equation has no stated coefficient, its coefficient is understood to be 1.

Chemical Equations (4)

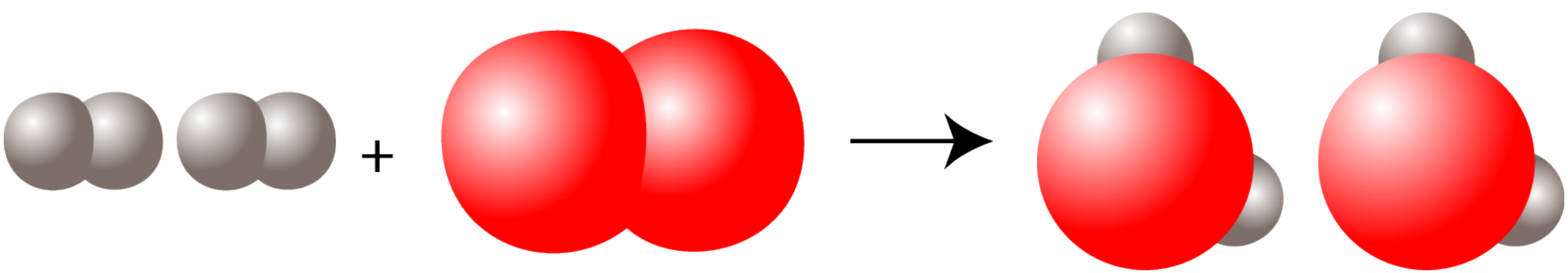
- If special conditions are necessary for a reaction to take place, they are often specified above the arrow.
  - Some examples of special conditions are electric current, high temperature, high pressure, or light.

Chemical Equation Example

Coefficient   Coefficient

$$2H_2(g) + O_2(g) \xrightarrow{\text{"goes to"}} 2H_2O(l)$$

Physical states   Physical state



Special Conditions

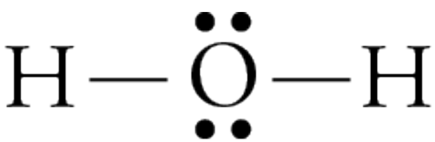
A special condition

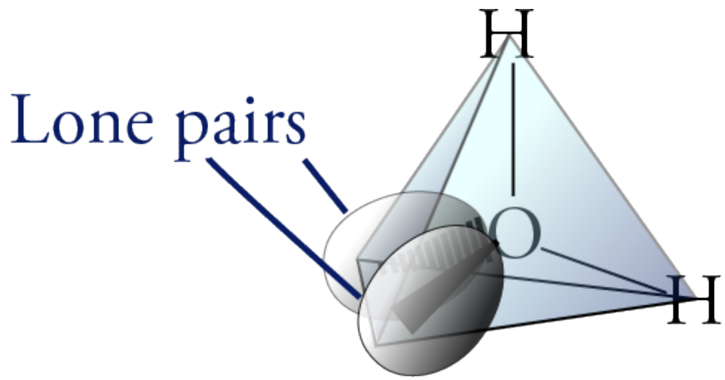
$$2H_2O(l) \xrightarrow{\text{Electric current}} 2H_2(g) + O_2(g)$$

This indicates the continuous addition of heat.

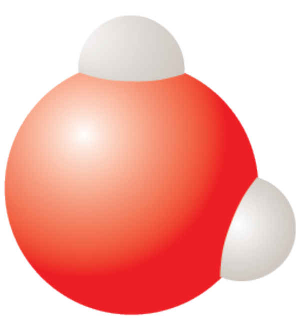
$$2KClO_3(s) \xrightarrow{\Delta} 2KCl(s) + 3O_2(g)$$

Water, H_2O

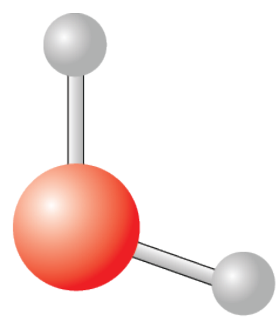




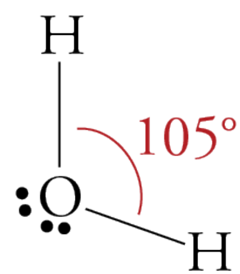
Electron group geometry
(tetrahedral)



Space-filling model

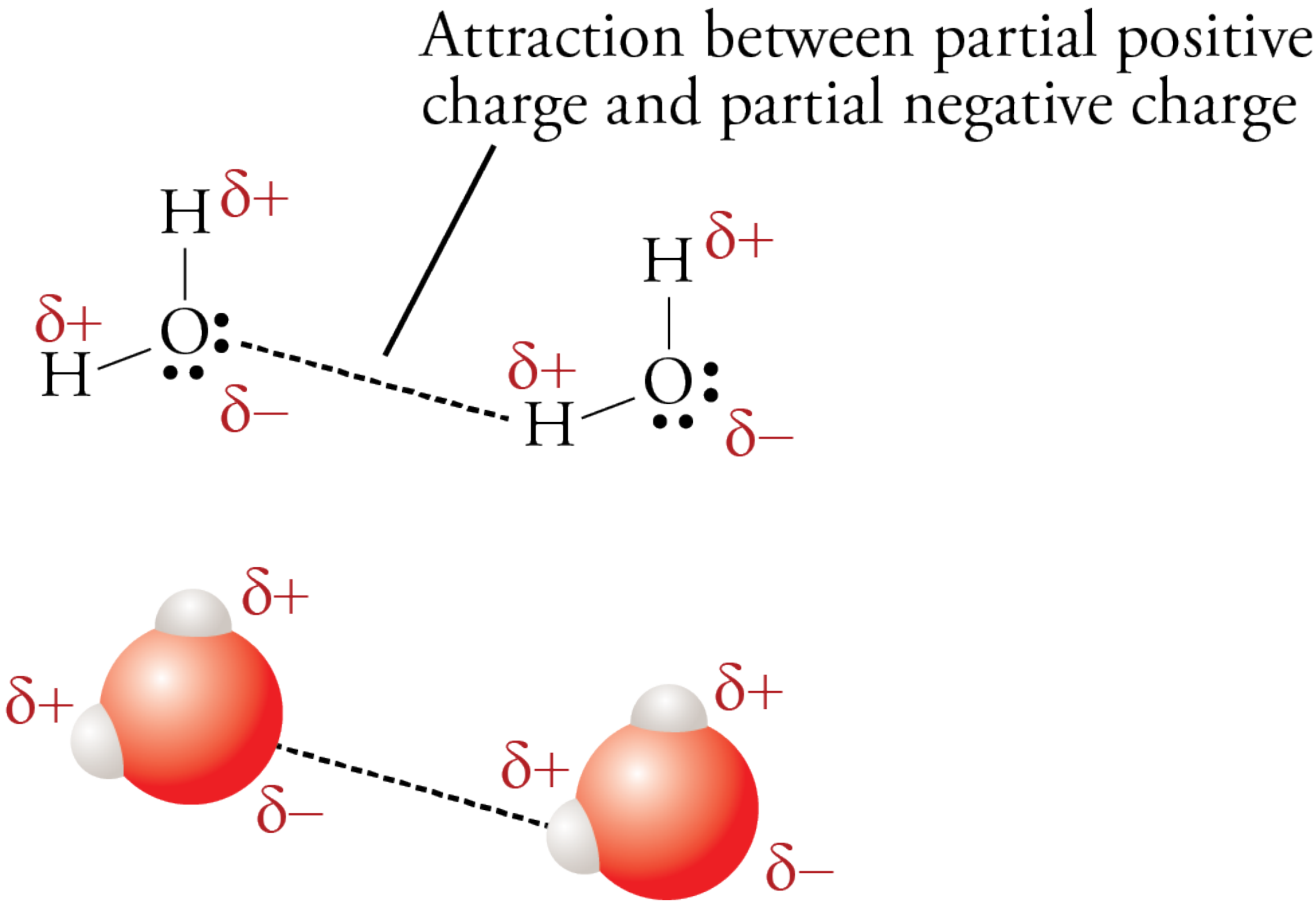


Ball-and-stick model

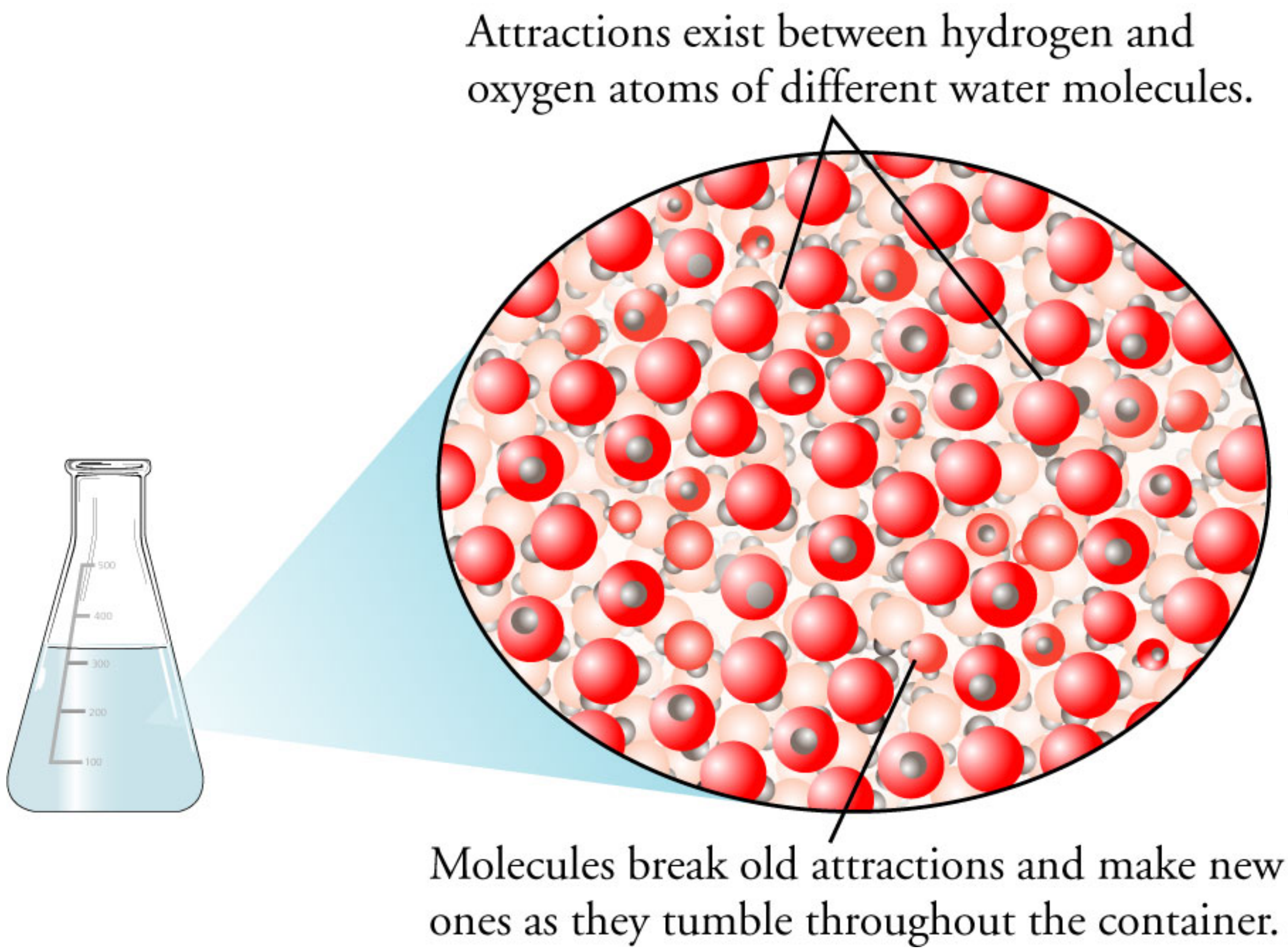


Geometric Sketch

Water Attractions



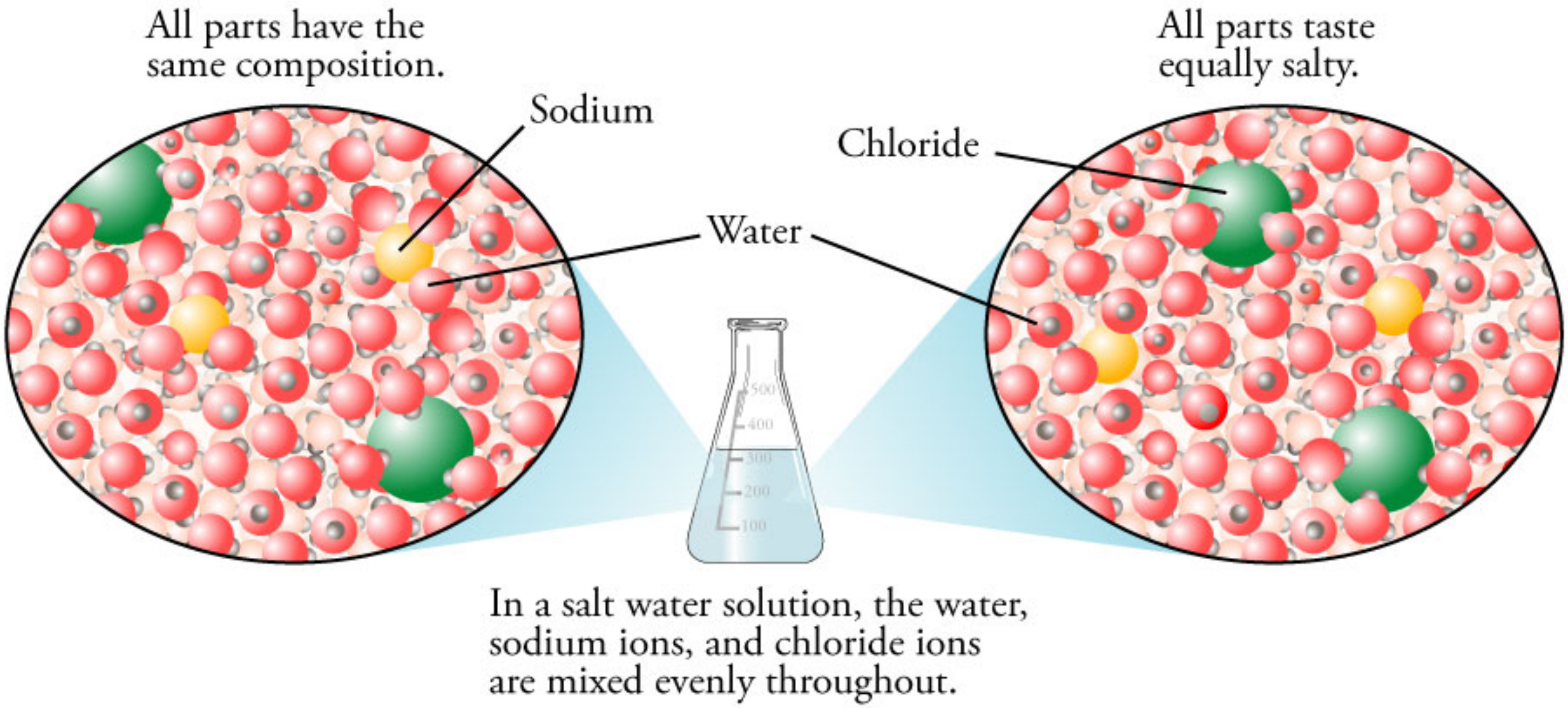
Liquid Water



Solutions

- A ***solution***, also called a homogeneous mixture, is a mixture whose particles are so evenly distributed that the relative concentrations of the components are the same throughout.
- Water solutions are called ***aqueous solutions***.

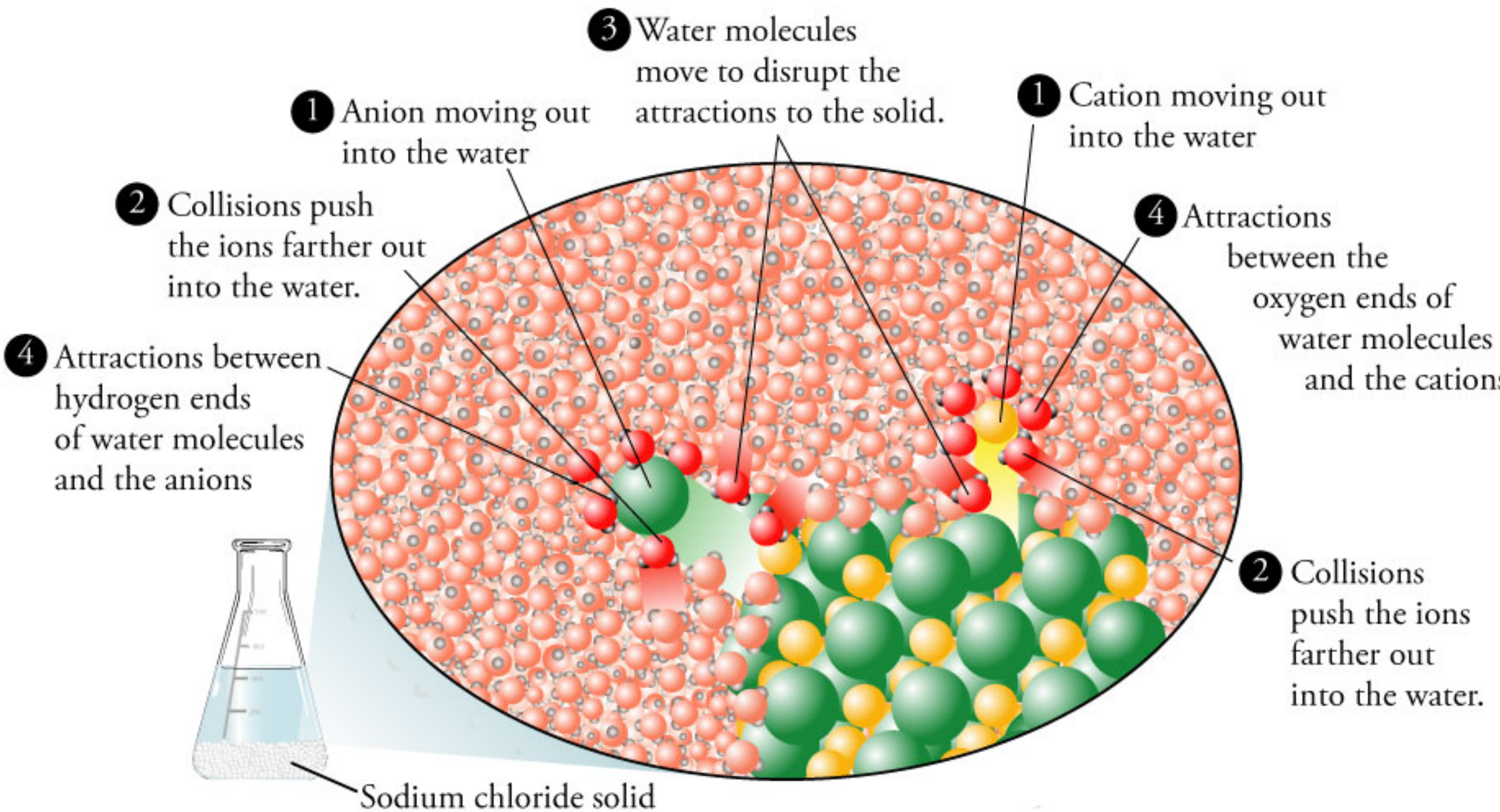
Solution (Homogeneous Mixture)



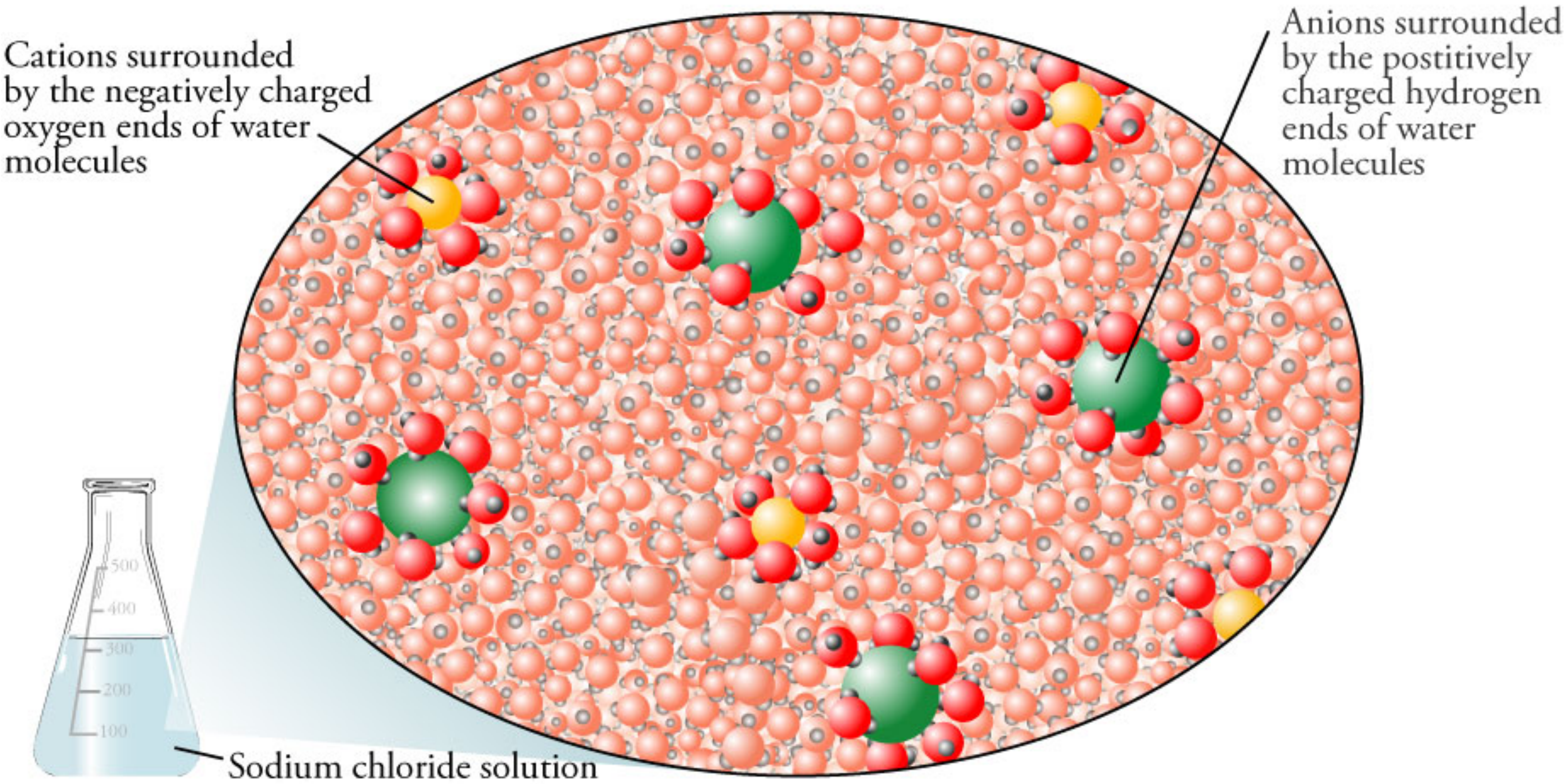
Solute and Solvent

- In solutions of solids dissolved in liquids, we call the solid the ***solute*** and the liquid the ***solvent***.
- In solutions of gases in liquids, we call the gas the ***solute*** and the liquid the ***solvent***.
- In other solutions, we call the minor component the ***solute*** and the major component the ***solvent***.

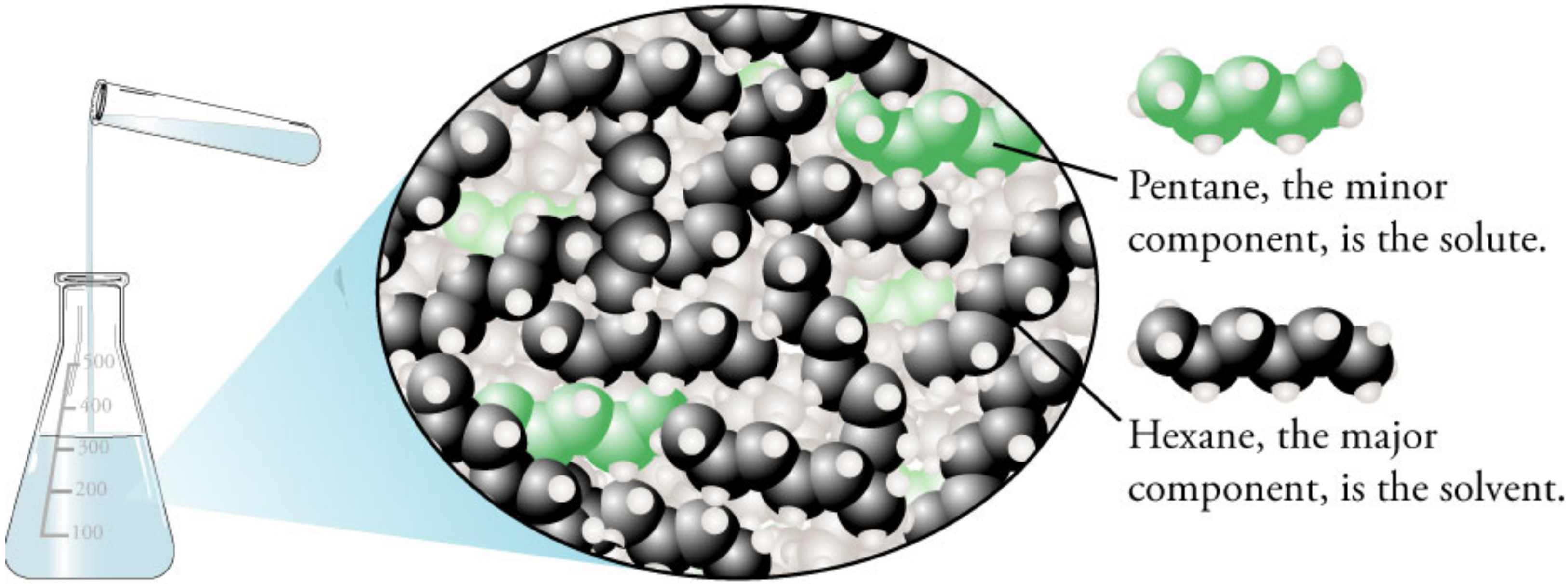
Solution of an Ionic Compound



Solution of an Ionic Compound (cont.)



Liquid-Liquid Solution



Precipitation Reactions

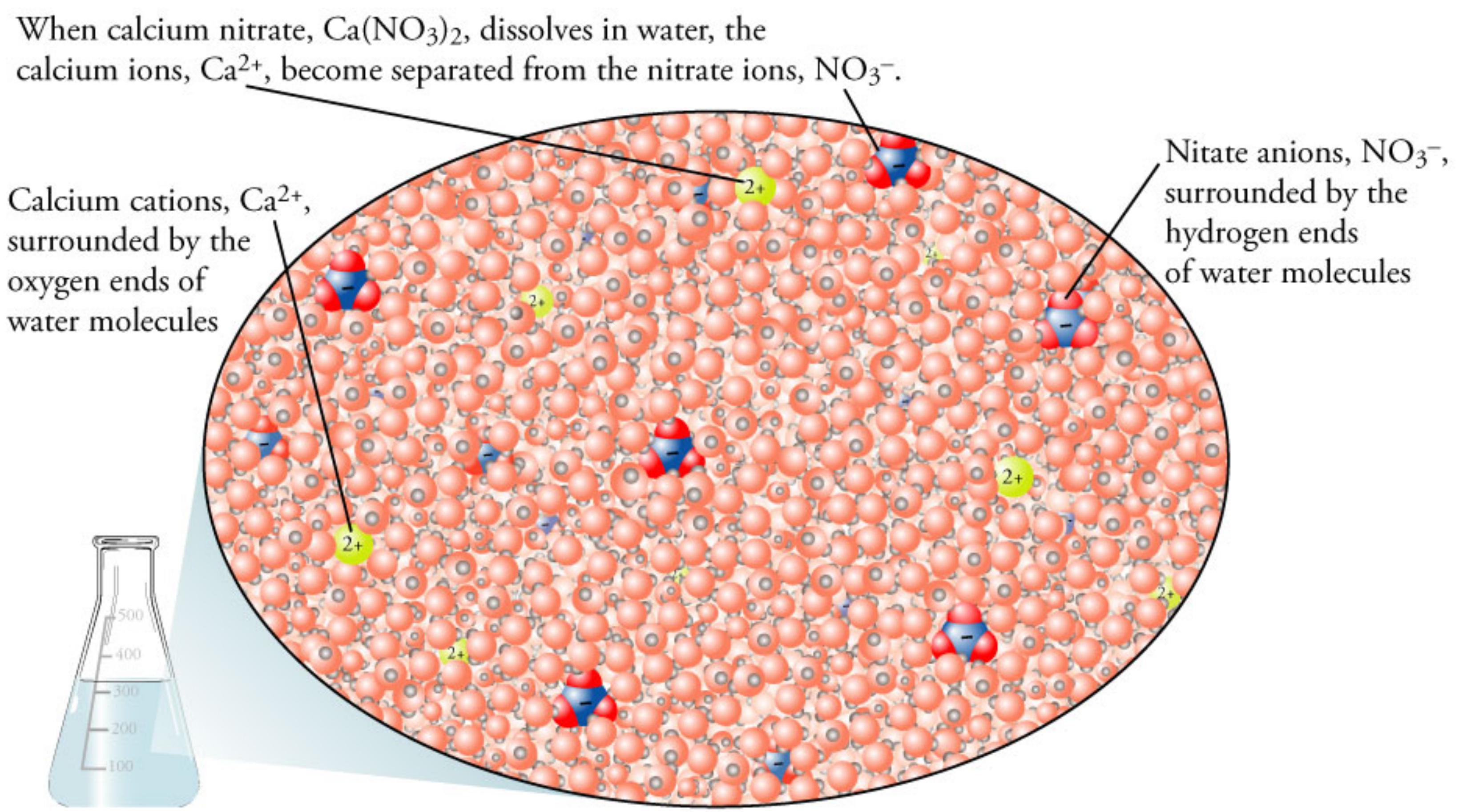
- In a ***precipitation reaction***, one product is insoluble in water.
- As that product forms, it emerges, or ***precipitates***, from the solution as a solid.
- The solid is called a ***precipitate***.
- For example,

$$Ca(NO_3)_2(aq) + Na_2CO_3(aq) \rightarrow CaCO_3(s) + 2NaNO_3(aq)$$

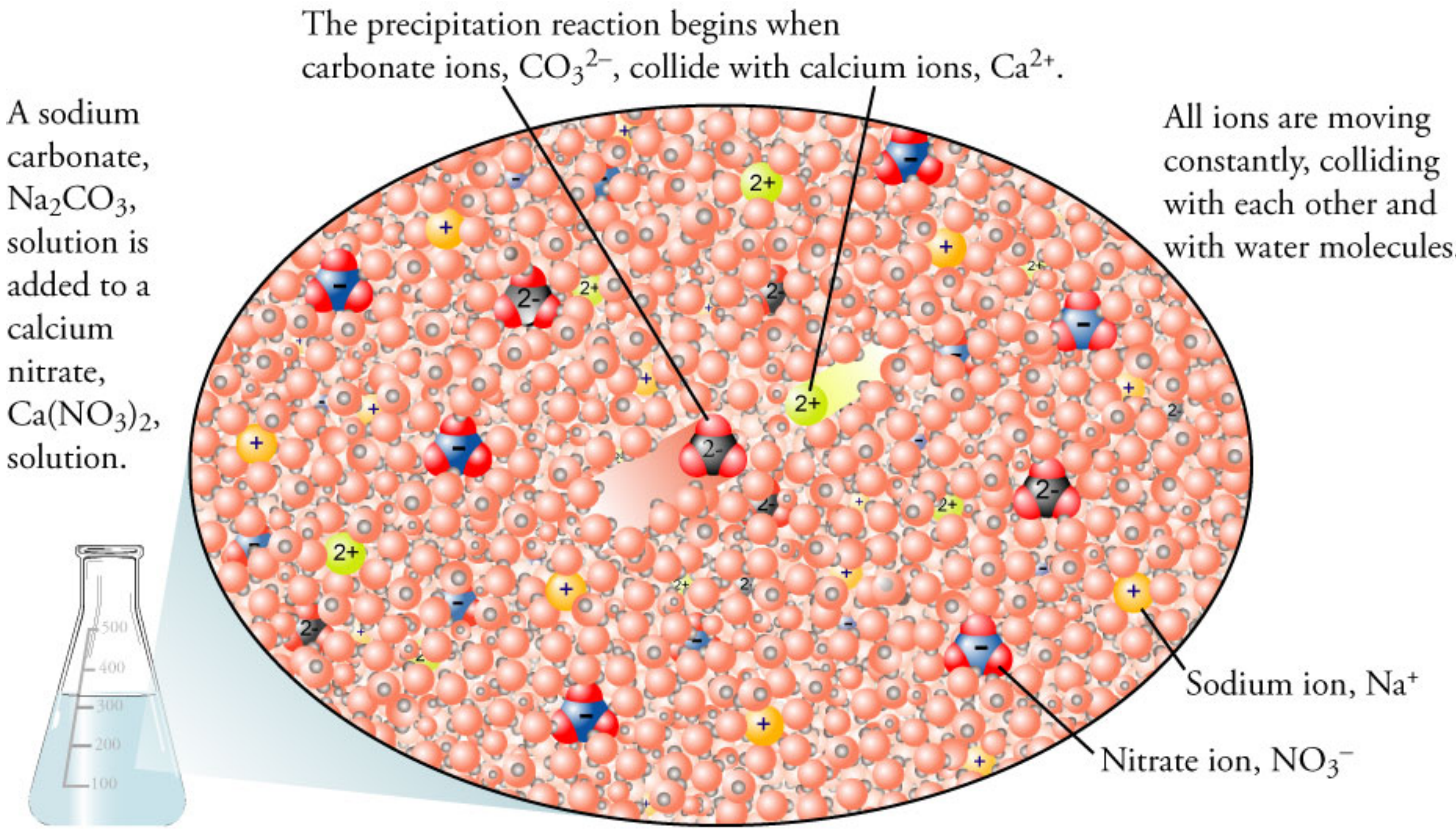
Precipitation Questions

- Describe the solution formed at the instant water solutions of two ionic compounds are mixed (before the reaction takes place).
- Describe the reaction that takes place in this mixture.
- Describe the final mixture.
- Write the complete equation for the reaction.

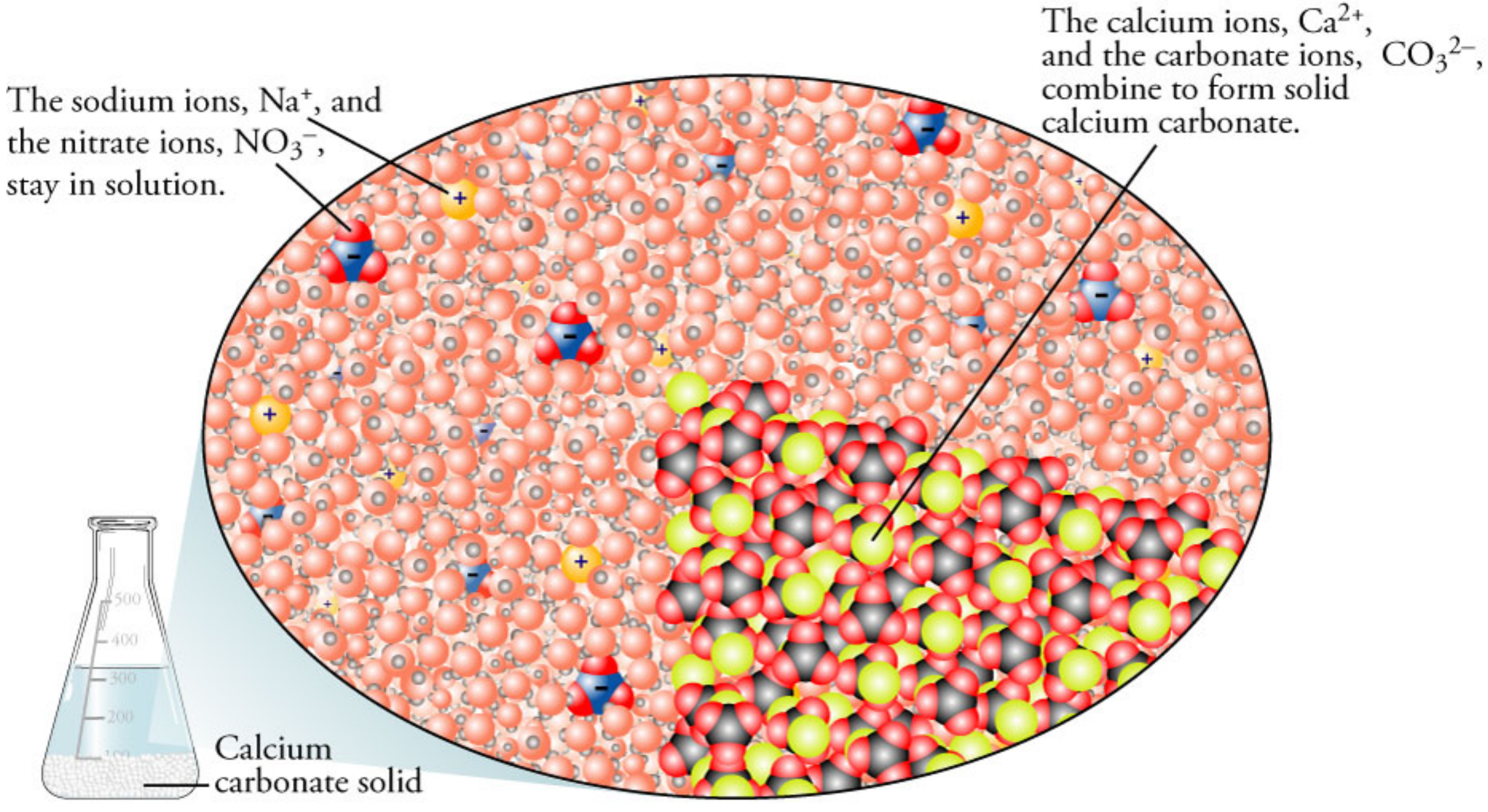
Solution of $Ca(NO_3)_2$



Solution of $Ca(NO_3)_2$ and Na_2CO_3 at the time of mixing, before the reaction



Product Mixture for the reaction of $Ca(NO_3)_2$ and Na_2CO_3



Complete Ionic Equation

This solid precipitates from the solution. It is a precipitate.

$$Ca(NO_3)_2(aq) + Na_2CO_3(aq) \longrightarrow CaCO_3(s) + 2NaNO_3(aq)$$

Described as separate ions.

$$Ca^{2+}(aq) + 2NO_3^-(aq) + 2Na^+(aq) + CO_3^{2-}(aq)$$

$$\longrightarrow CaCO_3(s) + 2Na^+(aq) + 2NO_3^-(aq)$$

Solid precipitate

Described as separate ions.

Spectator Ions

- Ions that are important for delivering other ions into solution but that are not actively involved in the reaction are called ***spectator ions***.
- Spectator ions can be recognized because they are separate and surrounded by water molecules both before and after the reaction.

Net Ionic Equations

- An equation written without spectator ions is called a *net ionic equation*.

$$Ca^{2+}(aq) + CO_3^{2-}(aq) \rightarrow CaCO_3(s)$$

Endergonic Change

more stable + energy $\rightarrow$ less stable system

lesser capacity to do work + energy $\rightarrow$ greater capacity to do work

lower PE + energy $\rightarrow$ higher PE

Exergonic Change

less stable system $\rightarrow$ more stable + energy

greater capacity to do work $\rightarrow$ lesser capacity to do work + energy

higher PE $\rightarrow$ lower PE + energy

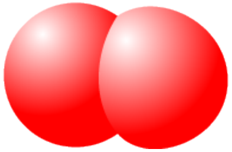
Bond Breaking and Potential Energy

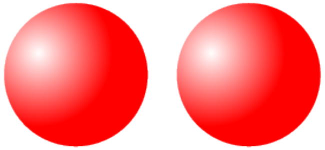
atoms in bond + Energy → separate atoms

more stable + Energy → less stable

lower PE + Energy → higher PE

$$O_2(g) + \text{energy} \longrightarrow 2O(g)$$





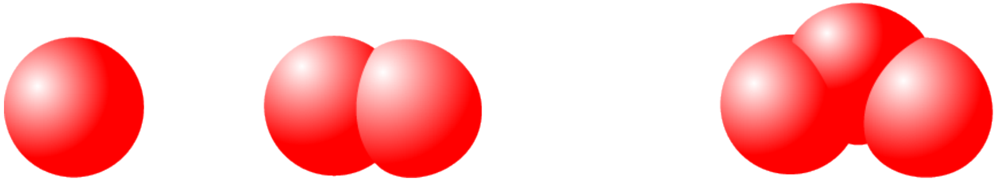
Bond Making and Potential Energy

separate atoms → atoms in bond + Energy

less stable → more stable + Energy

higher PE → lower PE + Energy

$$O(g) + O_2(g) \longrightarrow O_3(g) + \text{energy}$$



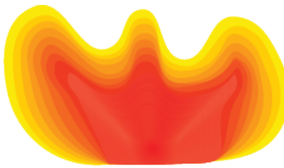
Exergonic (Exothermic) Reaction

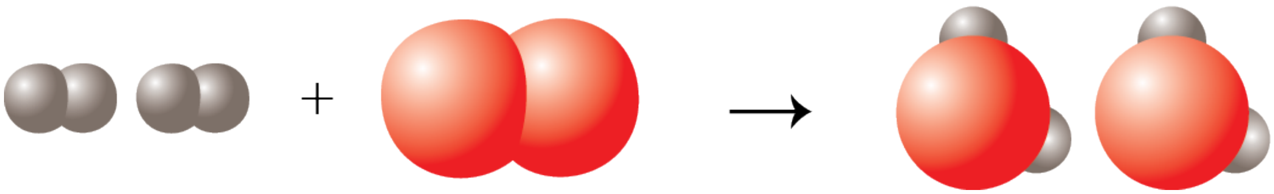
weaker bonds $\rightarrow$ stronger bonds + energy

less stable $\rightarrow$ more stable + energy

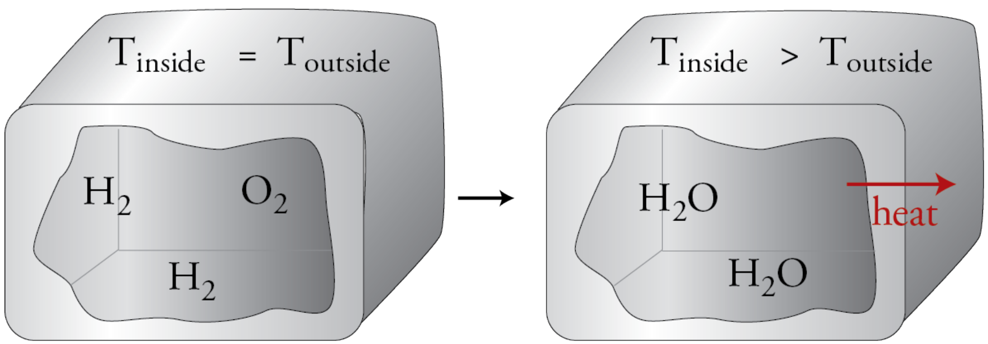
higher PE $\rightarrow$ lower PE + energy

$$2H_2(g) + O_2(g) \longrightarrow 2H_2O(l) +$$





Exothermic Reaction



Stronger bonds → More stable

↓

Energy released ← Lower PE

↓

Increases KE_{ave} of product particles

↓

Increased T → $T_{inside} > T_{outside}$

↓

Heat transferred to surroundings

↓

Exothermic

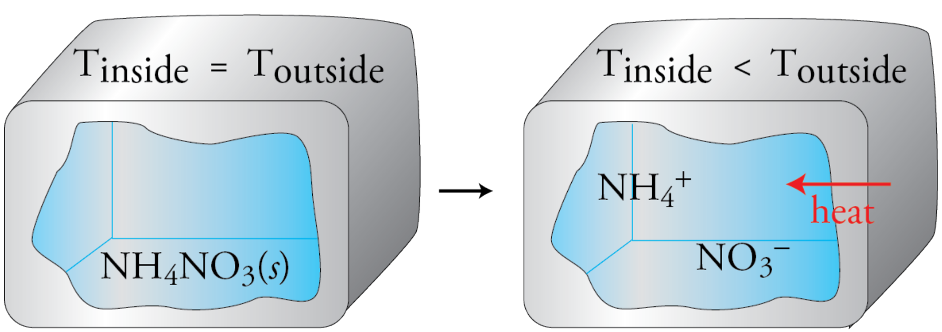
Endothermic Reaction

stronger bonds + energy → weaker bonds

more stable + energy → less stable

lower PE + energy → higher PE

$$NH_4NO_3(s) + \text{energy} \rightarrow NH_4^+(aq) + NO_3^-(aq)$$



Weaker bonds → Less stable
↓
Energy absorbed ← Higher PE
↓
Decreases KE_{ave} of product particles
↓
Decreased T → $T_{inside} < T_{outside}$
↓
Heat transferred to system → Endothermic

Energy and Chemical Reactions

Each chemical bond has a unique stability and therefore a unique potential energy.

Chemical reactions lead to changes in chemical bonds.

Chemical reactions lead to changes in potential energy.

If the bonds in the products are more stable and have lower potential energy than the reactants, energy will be released.

If the bonds in the products are less stable and have higher potential energy than the reactants, energy will be absorbed.

The reaction will be exergonic.

The reaction will be endergonic.

If the energy released comes from the conversion of potential energy to kinetic energy, the temperature of the products will be higher than the original reactants.

If the energy absorbed comes from the conversion of kinetic energy to potential energy, the temperature of the products will be lower than the original reactants.

The higher-temperature products are able to transfer heat to the surroundings, and the temperature of the surroundings increases.

The lower-temperature products are able to absorb heat from the surroundings, and the temperature of the surroundings decreases.

The reaction is exothermic.

The reaction is endothermic.