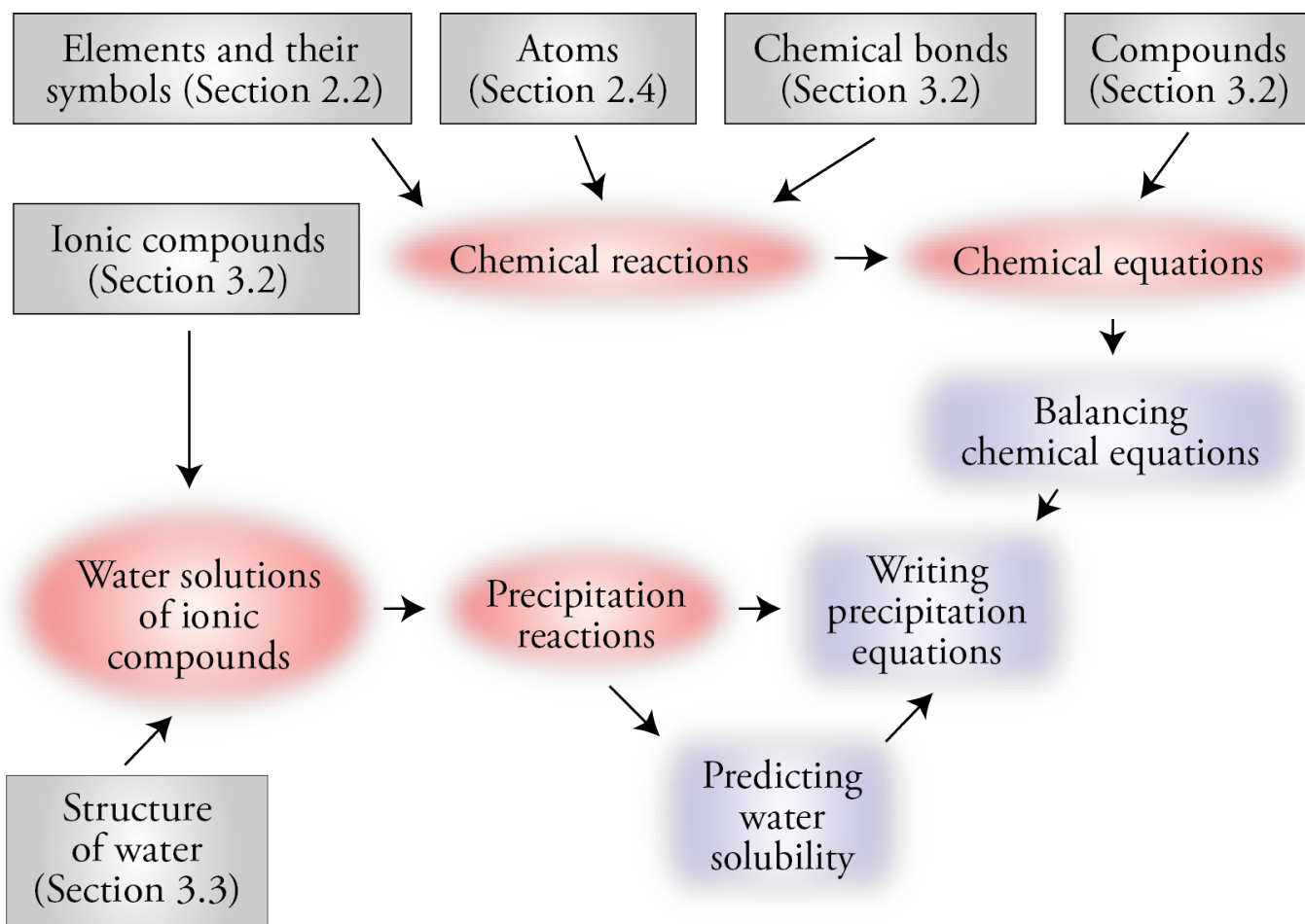


# Chapter 4

## An Introduction to Chemical Reactions

***An Introduction to Chemistry***  
by Mark Bishop

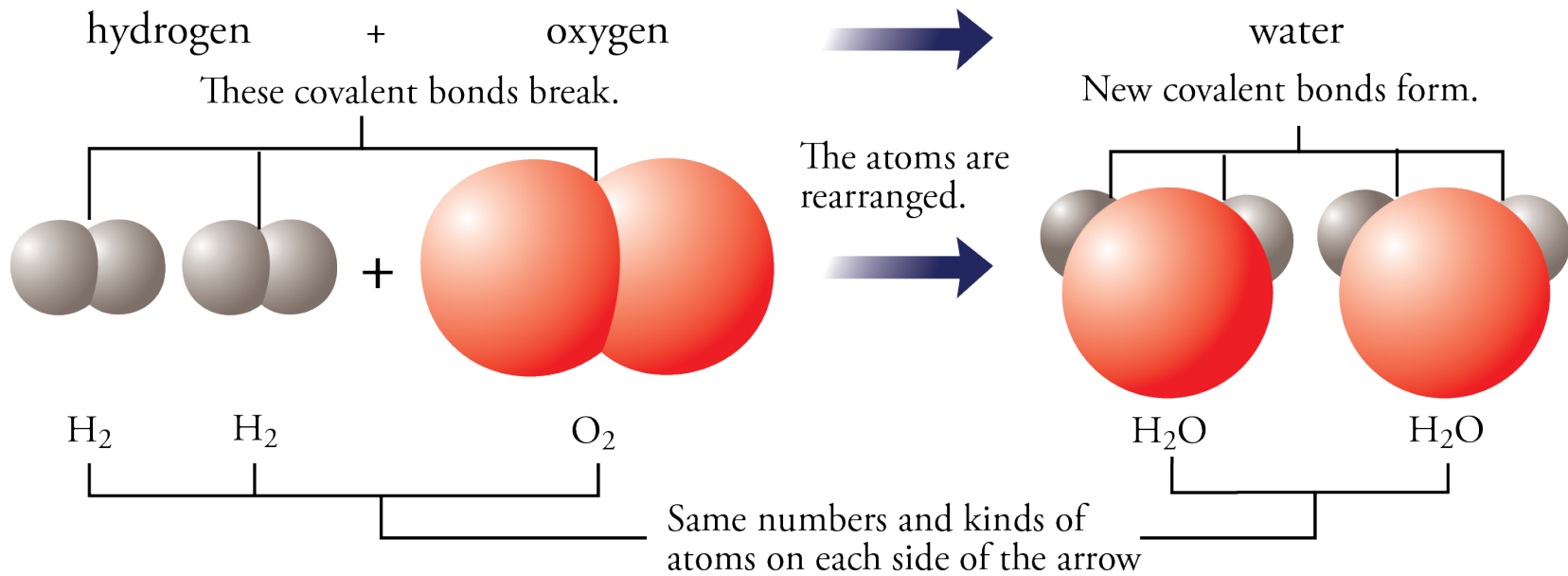
# Chapter Map



# 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)

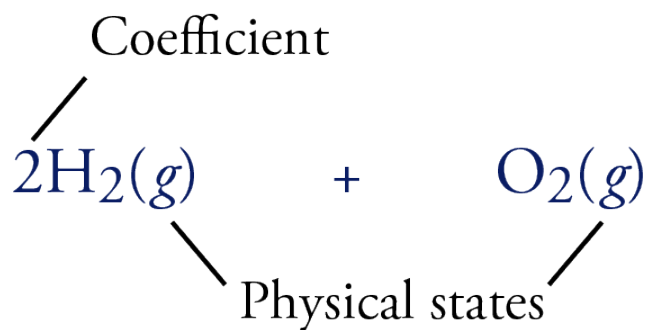
- The relative numbers of particles of each reactant and product are indicated by numbers placed in front of the formulas.
  - These numbers are called **coefficients**. An equation containing correct coefficients is called a balanced equation.
  - If a formula in a balanced equation has no stated coefficient,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

# Chemical Equations (4)

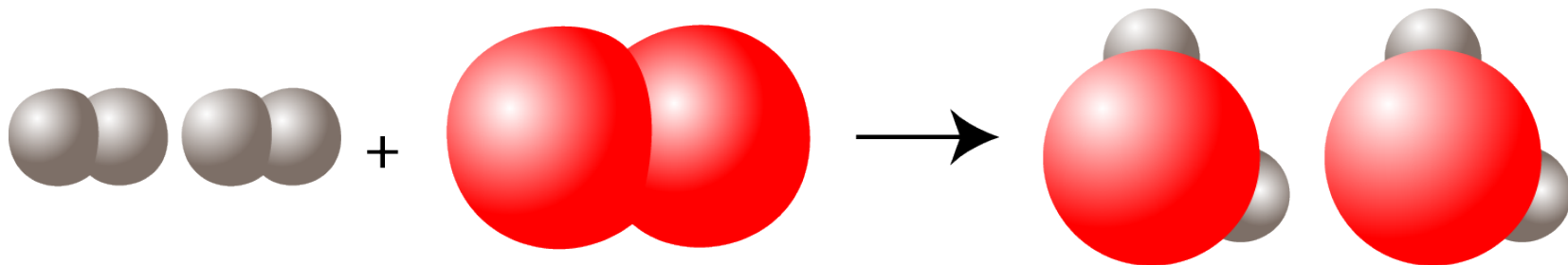
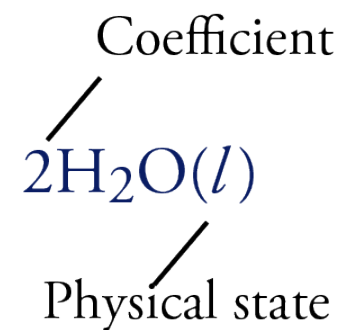
- If special conditions are necessary for a reaction to take place, they are often specified above the arrow.
  - Some examples of special conditions are electric current, high temperature, high pressure, or light.



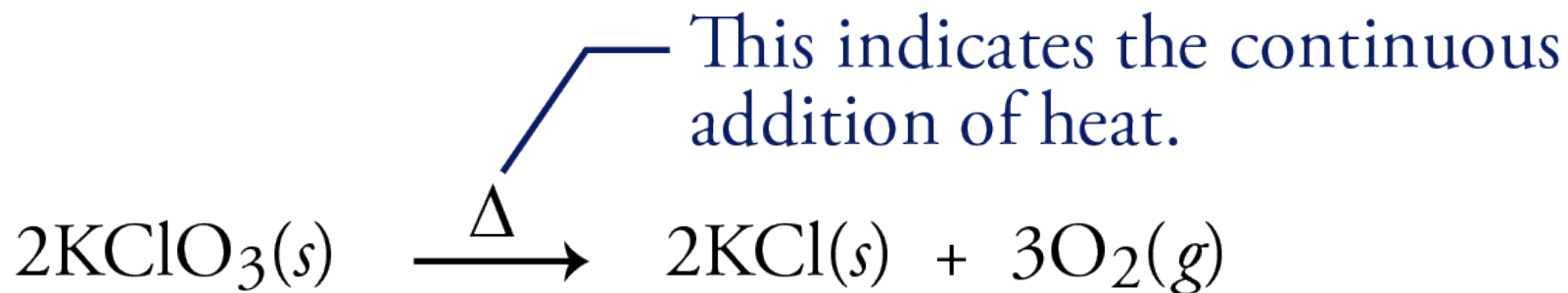
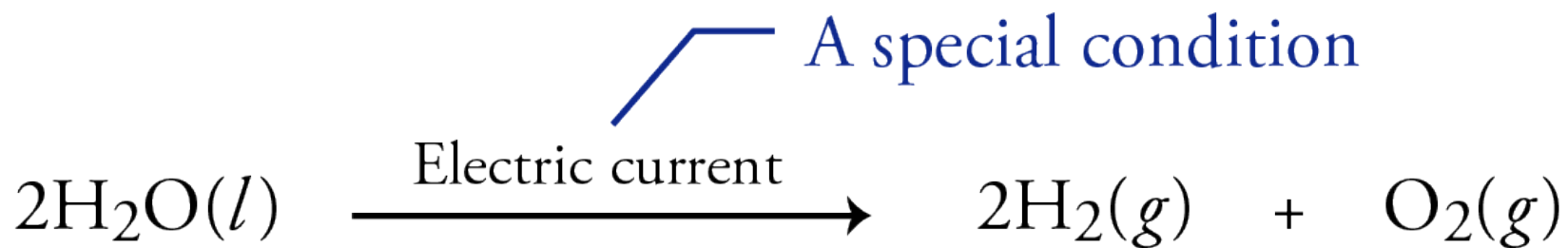
# Chemical Equation Example



"goes to"  
→



# Special Conditions



# Balancing Chemical Equations



- Consider the first element listed in the first formula in the equation.
  - If this element is mentioned in two or more formulas on the same side of the arrow, skip it until after the other elements are balanced.
  - If this element is mentioned in one formula on each side of the arrow, balance it by placing coefficients in front of one or both of these formulas.
- Moving from left to right, repeat the process for each element.
- When you place a number in front of a formula that contains an element you tried to balance previously, recheck that element and put its atoms back in balance.

# Balancing Equations – Strategies (1)

- **Strategy 1:** Often, an element can be balanced by using the subscript for this element on the left side of the arrow as the coefficient in front of the formula containing this element on the right side of the arrow and vice versa (using the subscript of this element on the right side of the arrow as the coefficient in front of the formula containing this element on the left side).

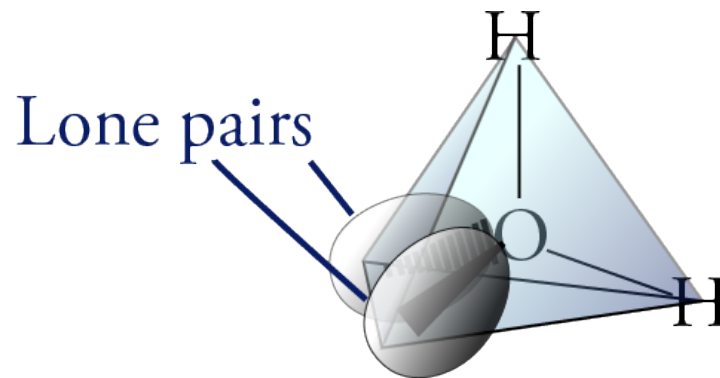
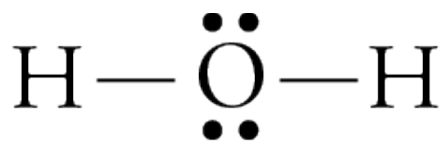
# Balancing Equations – Strategies (2)

- **Strategy 2:** The pure nonmetallic elements ( $\text{H}_2$ ,  $\text{O}_2$ ,  $\text{N}_2$ ,  $\text{F}_2$ ,  $\text{Cl}_2$ ,  $\text{Br}_2$ ,  $\text{I}_2$ ,  $\text{S}_8$ ,  $\text{Se}_8$ , and  $\text{P}_4$ ) can be temporarily balanced with a fractional coefficient ( $1/2$ ,  $3/2$ ,  $5/2$ , etc.). If you do use a fraction during the balancing process, you can eliminate it later by multiplying each coefficient in the equation by the fraction's denominator.

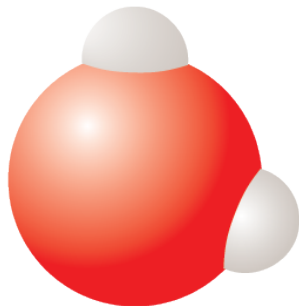
# Balancing Equations – Strategies (3)

- **Strategy 3:** If polyatomic ions do not change in the reaction, and therefore appear in the same form on both sides of the chemical equation, they can be balanced as if they were single atoms.
- **Strategy 4:** If you find an element difficult to balance, leave it for later.

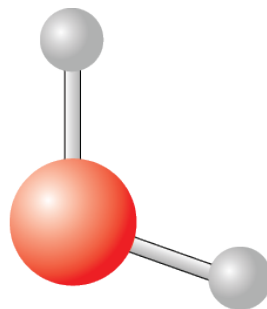
# Water, H<sub>2</sub>O



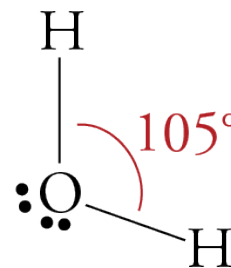
Electron group geometry  
(tetrahedral)



Space-filling model



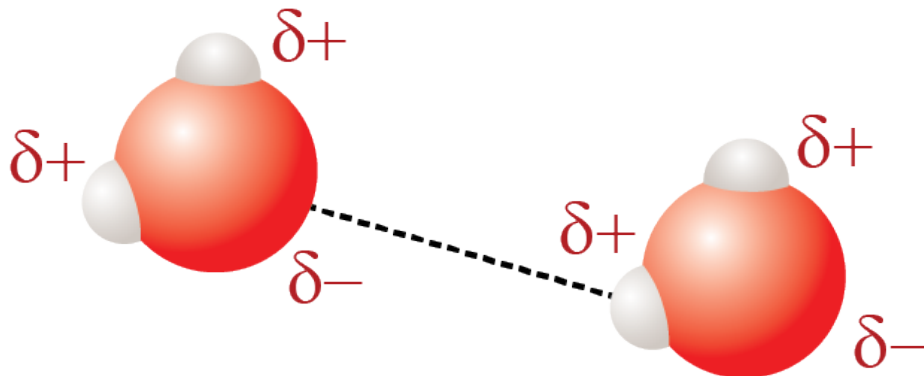
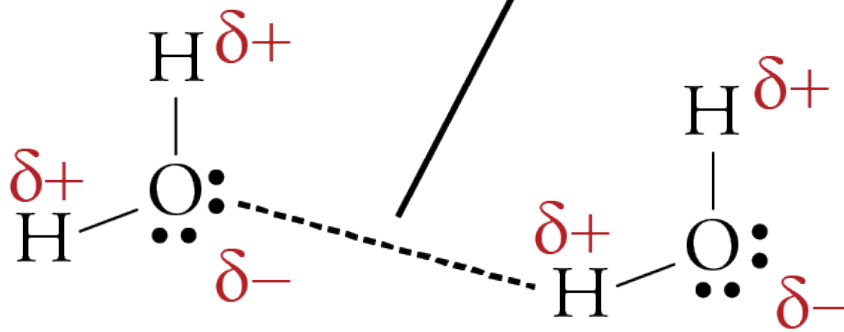
Ball-and-stick model



Geometric Sketch

# Water Attractions

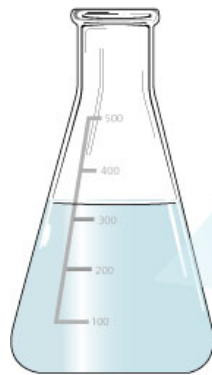
Attraction between partial positive charge and partial negative charge





# Liquid Water

Attractions exist between hydrogen and oxygen atoms of different water molecules.



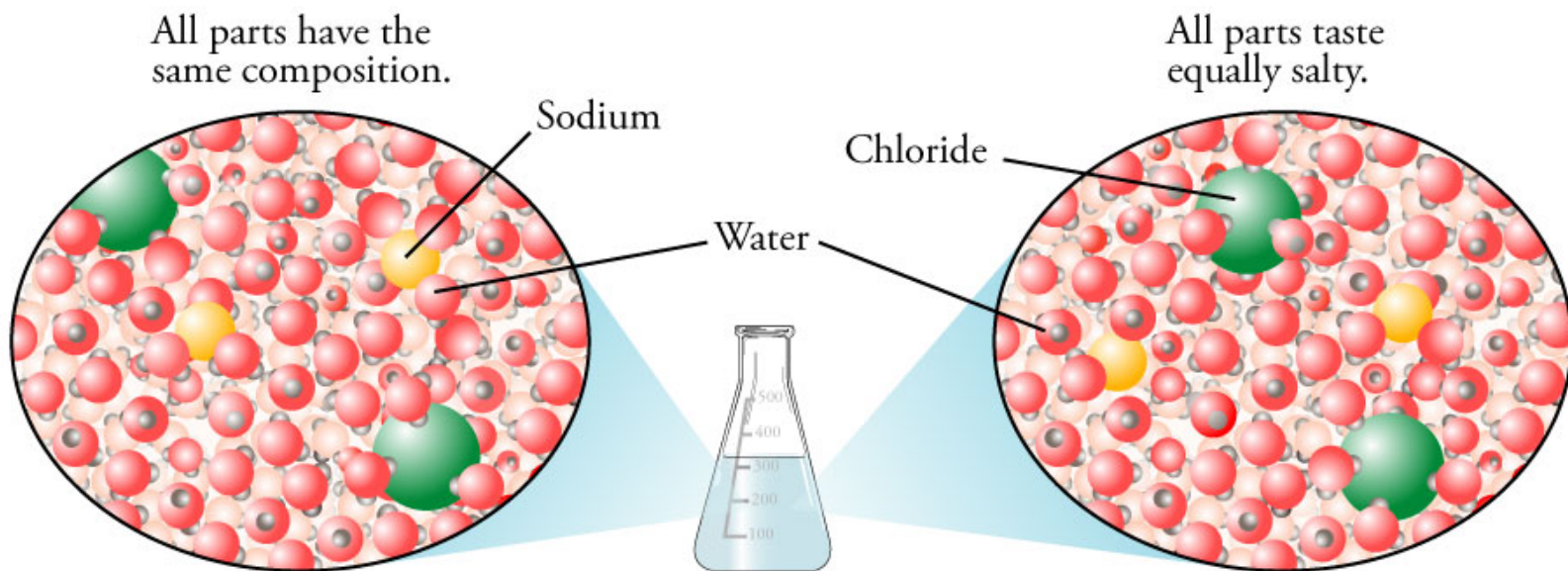
Molecules break old attractions and make new ones as they tumble throughout the container.

# 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)



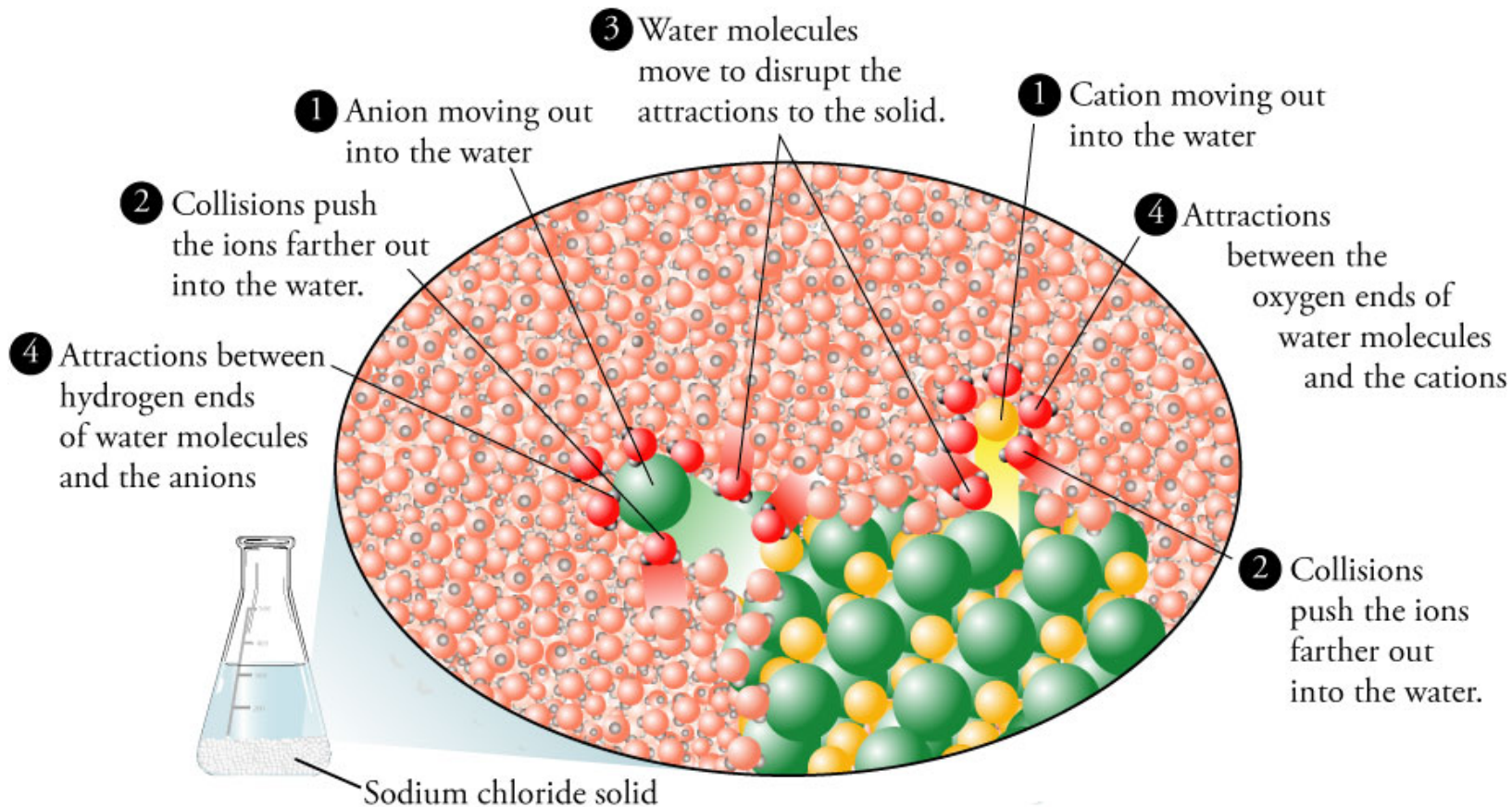
In a salt water solution, the water, sodium ions, and chloride ions are mixed evenly throughout.

# 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***.

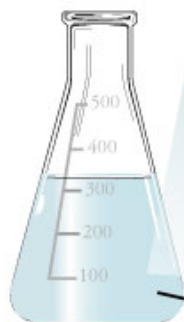
# Solution of an Ionic Compound



# Solution of an Ionic Compound (cont.)

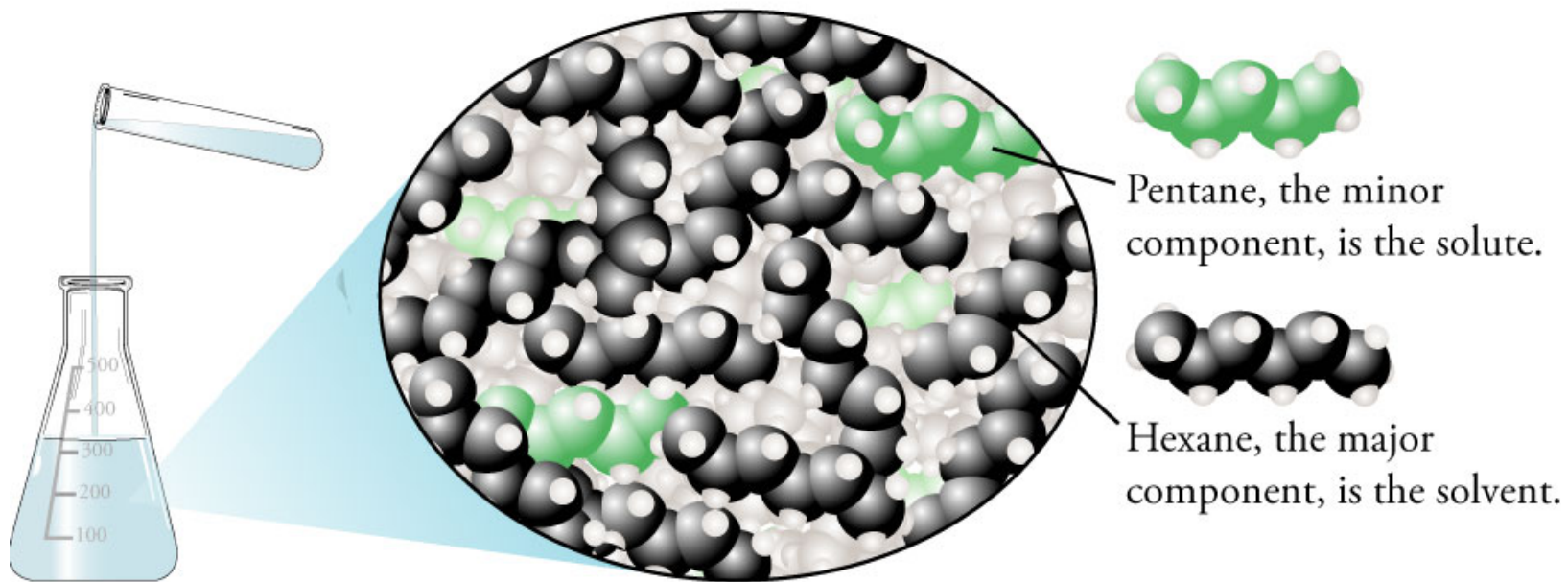
Cations surrounded by the negatively charged oxygen ends of water molecules

Anions surrounded by the positively charged hydrogen ends of water molecules



Sodium chloride solution

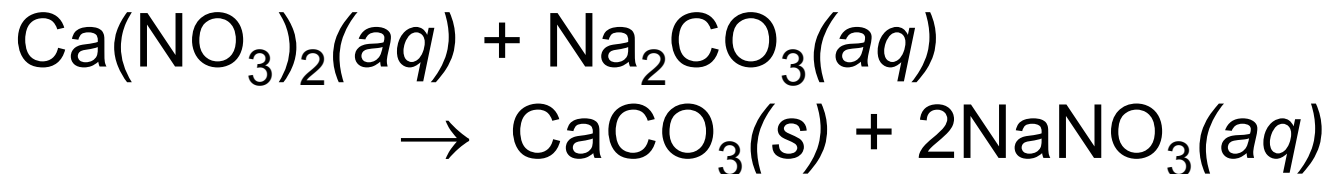
# Liquid-Liquid Solution



# 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,





# Precipitation Questions



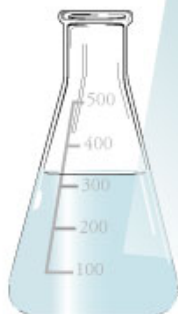
- Describe the solution formed at the instant water solutions of two ionic compounds are mixed (before the reaction takes place).
- Describe the reaction that takes place in this mixture.
- Describe the final mixture.
- Write the complete equation for the reaction.

# Solution of $\text{Ca}(\text{NO}_3)_2$

When calcium nitrate,  $\text{Ca}(\text{NO}_3)_2$ , dissolves in water, the calcium ions,  $\text{Ca}^{2+}$ , become separated from the nitrate ions,  $\text{NO}_3^-$ .

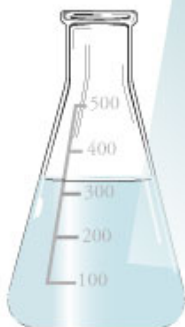
Calcium cations,  $\text{Ca}^{2+}$ , surrounded by the oxygen ends of water molecules

Nitrate anions,  $\text{NO}_3^-$ , surrounded by the hydrogen ends of water molecules

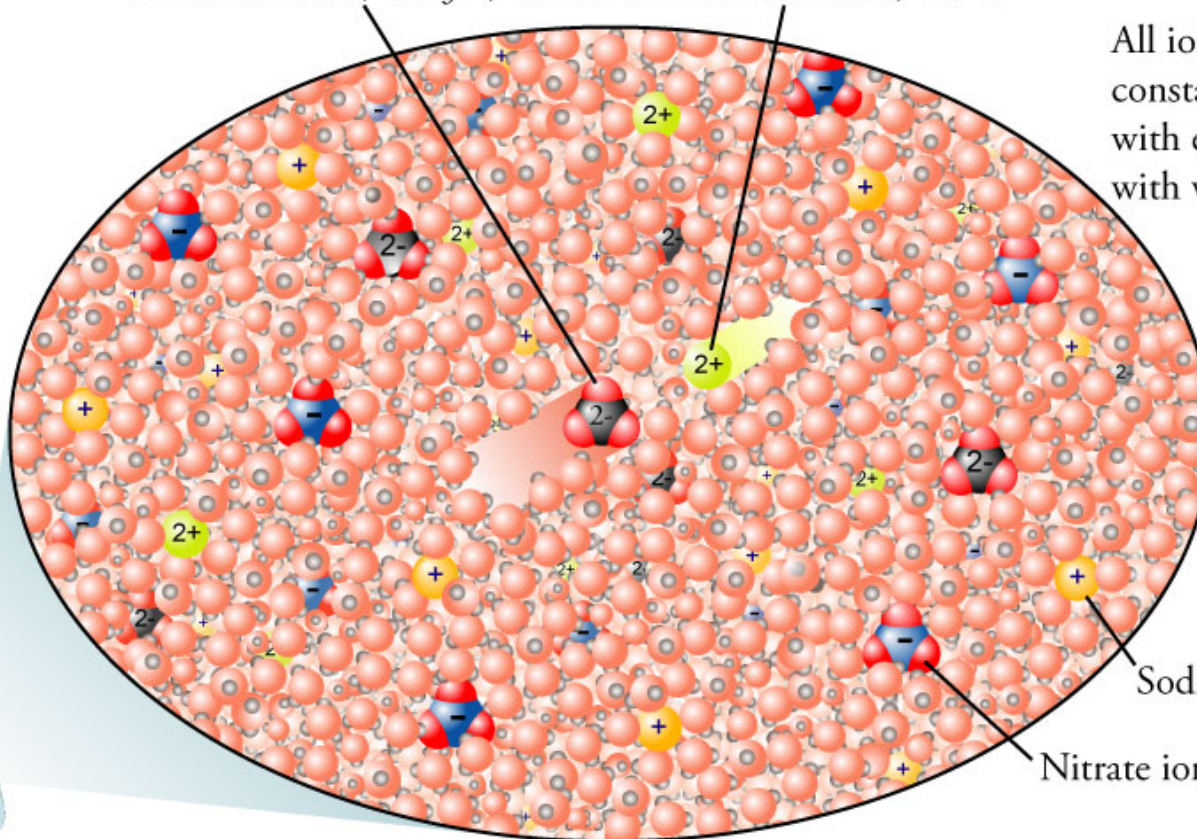


# Solution of $\text{Ca}(\text{NO}_3)_2$ and $\text{Na}_2\text{CO}_3$ at the time of mixing, before the reaction.

A sodium carbonate,  $\text{Na}_2\text{CO}_3$ , solution is added to a calcium nitrate,  $\text{Ca}(\text{NO}_3)_2$ , solution.



The precipitation reaction begins when carbonate ions,  $\text{CO}_3^{2-}$ , collide with calcium ions,  $\text{Ca}^{2+}$ .



All ions are moving constantly, colliding with each other and with water molecules.

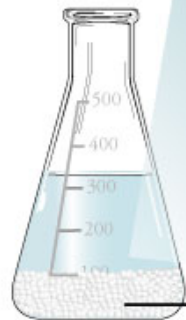
Sodium ion,  $\text{Na}^+$

Nitrate ion,  $\text{NO}_3^-$

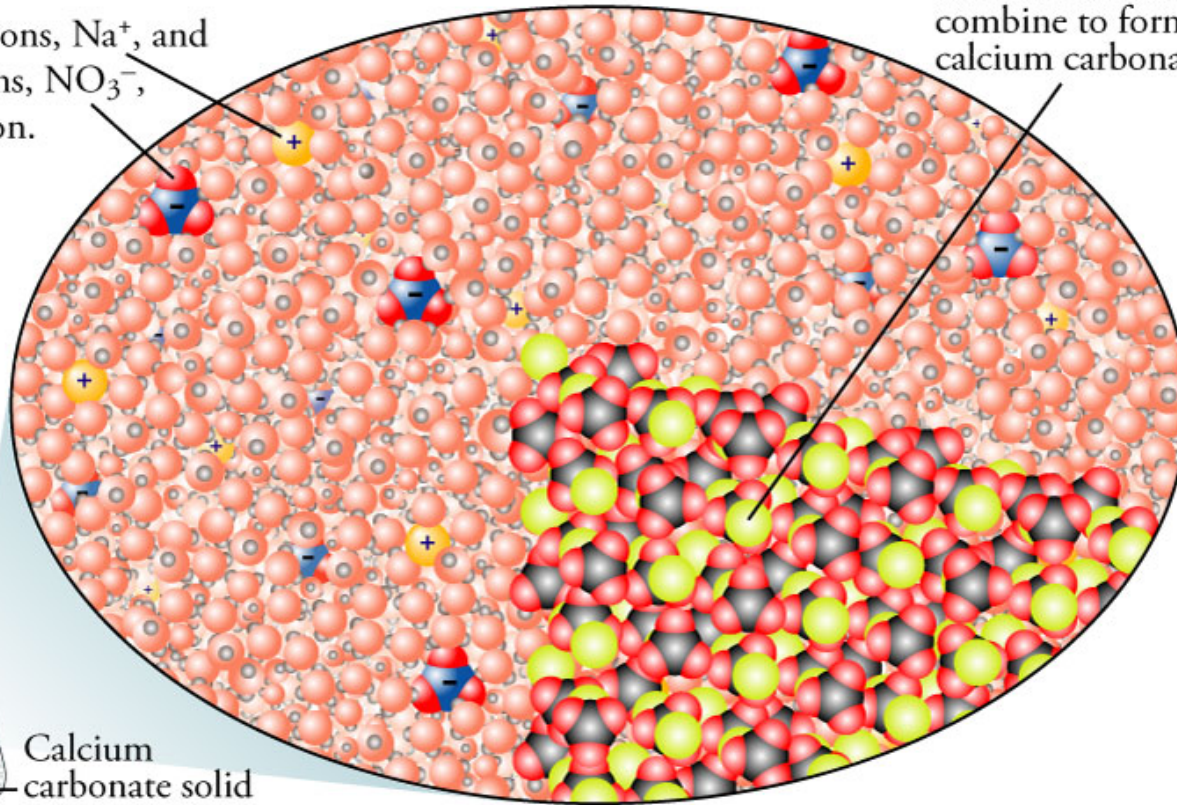
# Product Mixture for the reaction of $\text{Ca}(\text{NO}_3)_2$ and $\text{Na}_2\text{CO}_3$

The sodium ions,  $\text{Na}^+$ , and the nitrate ions,  $\text{NO}_3^-$ , stay in solution.

The calcium ions,  $\text{Ca}^{2+}$ , and the carbonate ions,  $\text{CO}_3^{2-}$ , combine to form solid calcium carbonate.

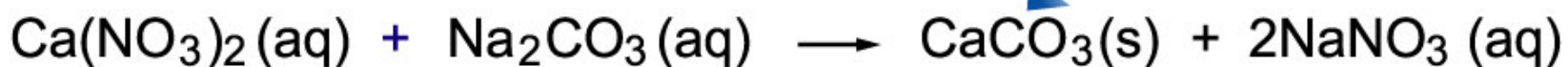


Calcium carbonate solid

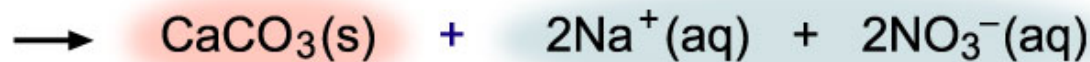


# Complete Ionic Equation

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



*Described as separate ions.*



Solid precipitate

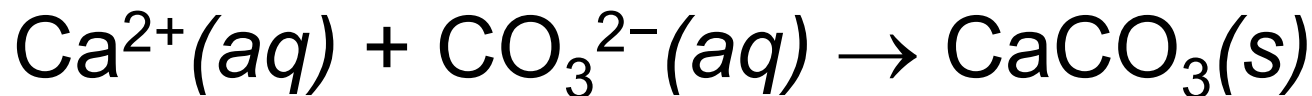
*Described as separate ions.*

# 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*.



# Writing Precipitation Equations

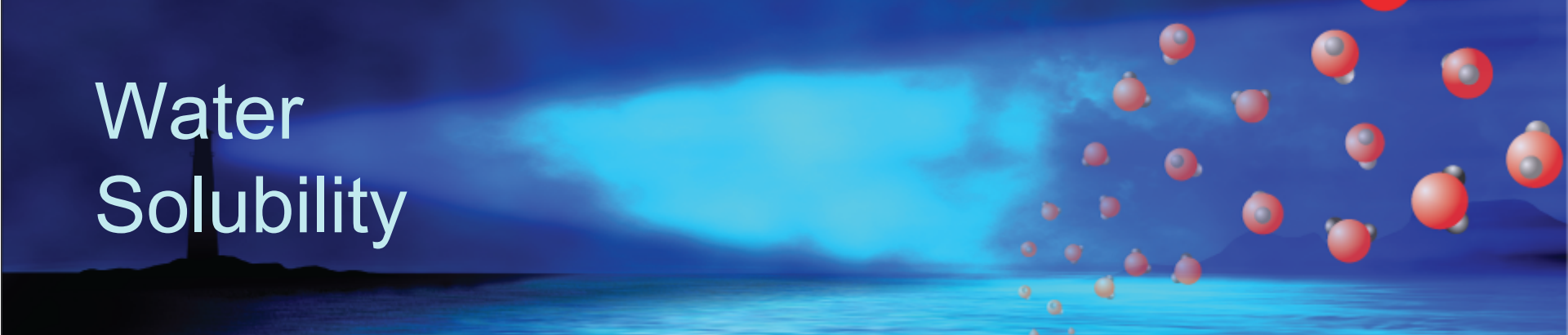
- **Step 1:** Determine the formulas for the possible products using the general double-displacement equation.



- **Step 2:** Predict whether either of the possible products is water insoluble. If either possible product is insoluble, a precipitation reaction takes place, and you may continue with step 3. If neither is insoluble, write “No reaction”.



# Water Solubility



- Ionic compounds with the following ions are soluble.
  - $\text{NH}_4^+$ , group 1 metal ions,  $\text{NO}_3^-$ , and  $\text{C}_2\text{H}_3\text{O}_2^-$
- Ionic compounds with the following ions are usually soluble.
  - $\text{Cl}^-$ ,  $\text{Br}^-$ ,  $\text{I}^-$  except with  $\text{Ag}^+$  and  $\text{Pb}^{2+}$
  - $\text{SO}_4^{2-}$  except with  $\text{Ba}^{2+}$  and  $\text{Pb}^{2+}$
- Ionic compounds with the following ions are insoluble.
  - $\text{CO}_3^{2-}$ ,  $\text{PO}_4^{3-}$ , and  $\text{OH}^-$  except with  $\text{NH}_4^+$  and group 1 metal cations
  - $\text{S}^{2-}$  except with  $\text{NH}_4^+$  and group 1 and 2 metal cations

# Writing Precipitation Equations (cont)



- Step 3: Follow these steps to write the complete equation.
  - Write the formulas for the reactants separated by a “+”.
  - Separate the formulas for the reactants and products with a single arrow.
  - Write the formulas for the products separated by a “+”.
  - Write the physical state for each formula.
    - The insoluble product will be followed by *(s)*.
    - Water-soluble ionic compounds will be followed by *(aq)*.
  - Balance the equation.

# Skills to Master (1)



- Convert between names and symbols for the common elements.
- Identify whether an element is a metal or a nonmetal.
- Determine the charges on many of the monatomic ions.
- Convert between the name and formula for polyatomic ions.

# Skills to Master (2)



- Convert between the name and formula for ionic compounds.
- Balance chemical equations.
- Predict the products of double displacement reactions.
- Predict ionic solubility.