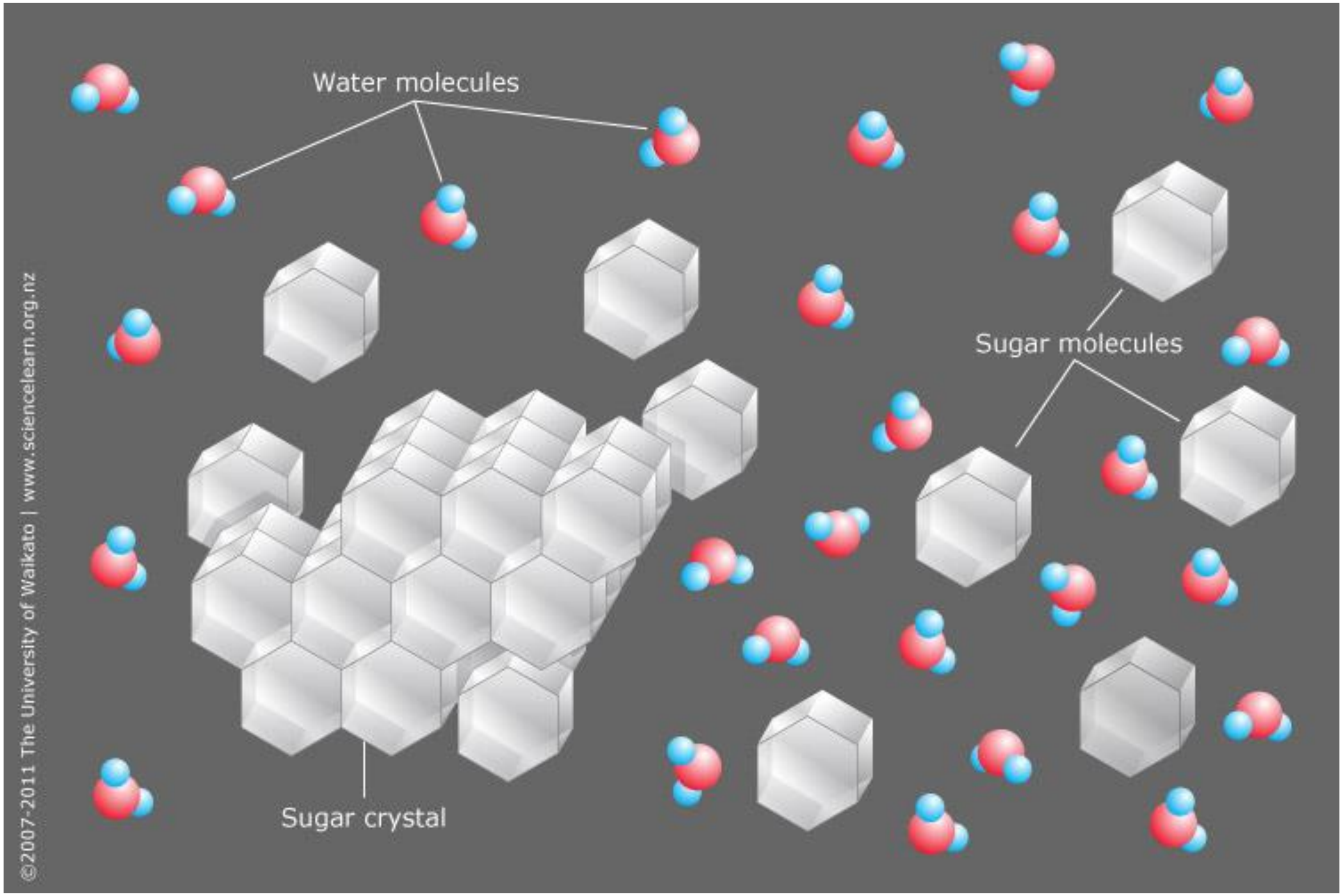
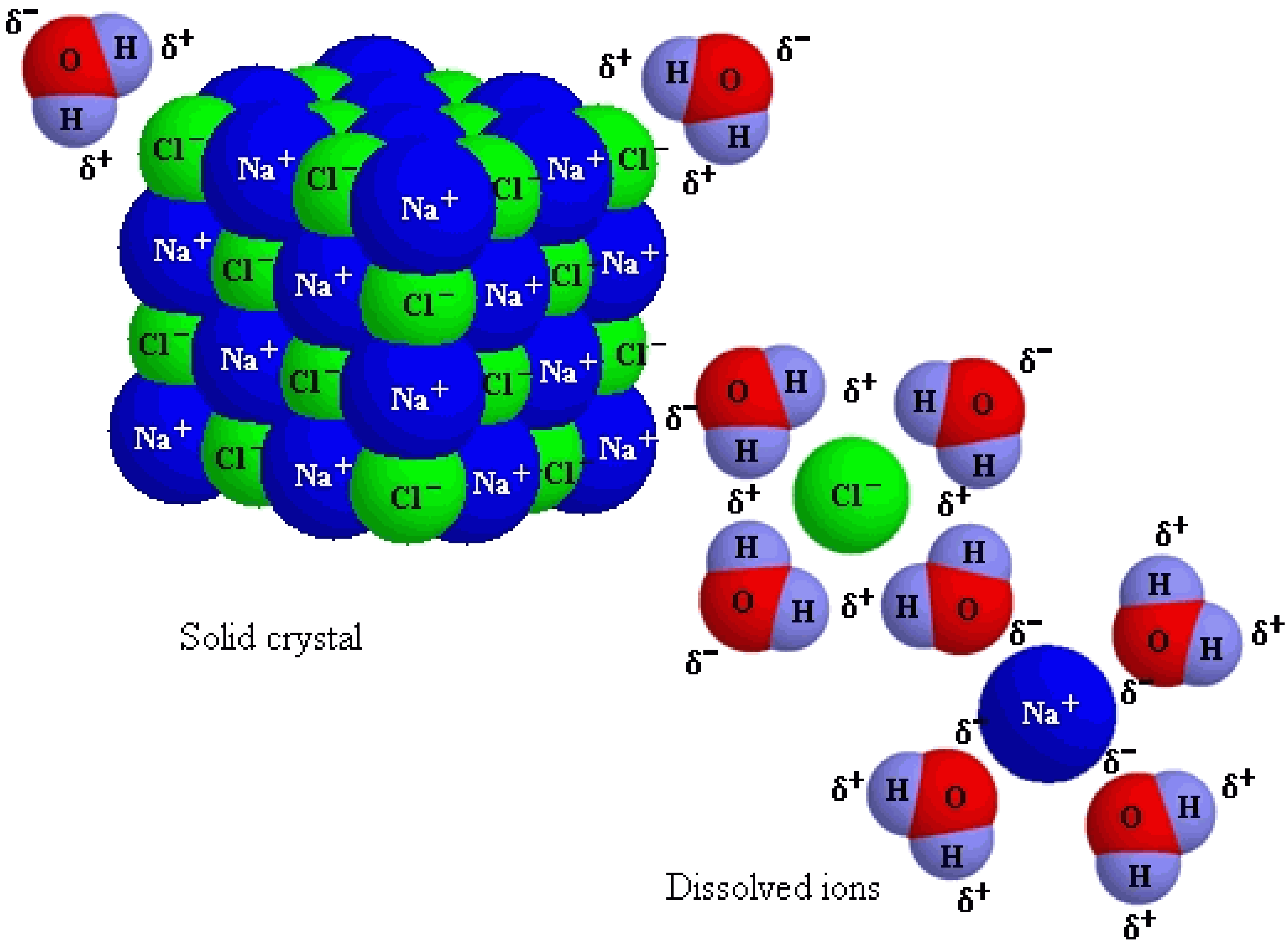
Solution Chemistry

Chapter 4

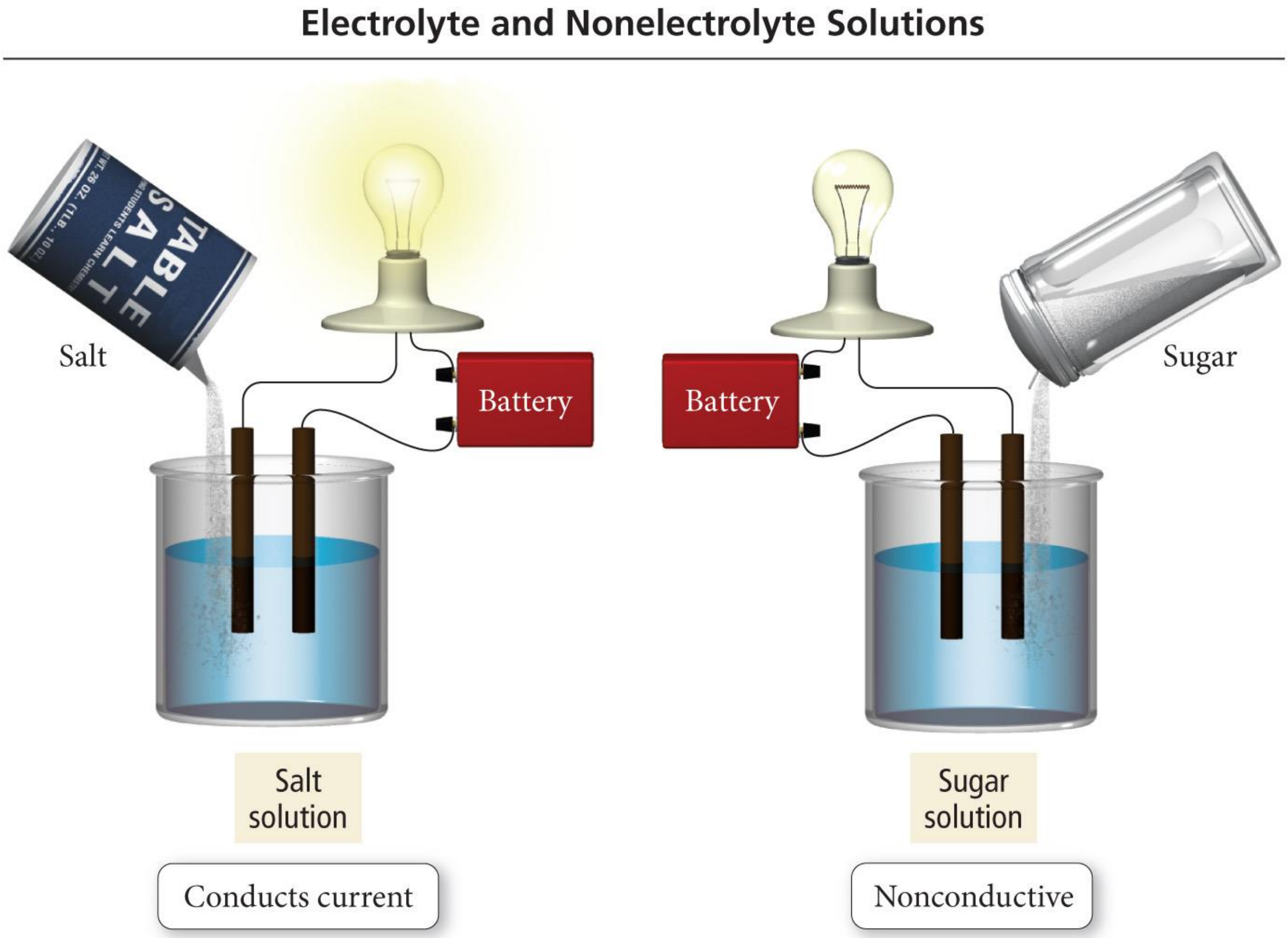
Covalent Molecule Dissolving in Water



Ionic Compound Dissolving in Water



Electrolytes and Nonelectrolytes



Electrolytes/Nonelectrolytes

Type	Dissociation	Electrical Conductivity	Examples
Strong Electrolytes	Fully or Mostly (>70%)	Strong	Soluble ionic compounds Strong Acids Strong Bases
Weak Electrolytes	Some (even very little counts here)	Weak	Weak Acids Weak Bases
Nonelectrolytes	None	None	Organic Molecules Sugars, alcohols

Ionic Dissociation

- **When ionic compounds dissolve in water, the anions and cations are separated from each other. This is called dissociation.**

$$Na_2S(aq) \rightarrow 2\ Na^+(aq) + S^{2-}(aq)$$
$$K_2SO_4(aq) \rightarrow 2\ K^+(aq) + SO_4^{2-}(aq)$$
$$H_2SO_4(aq) \rightarrow 2\ H^+(aq) + SO_4^{2-}(aq)$$

- **You should think of ALL AQUEOUS, IONIC compounds as DISSOCIATED.**
- **AQUEOUS ACIDS may also be considered as DISSOCIATED**

Molarity of Ions

- Calculate the Molarity of a solution if 15.25 g of $Mg(NO_3)_2$ is dissolved in water to a final volume of 250 mL.

- Now, calculate the molarity of nitrate ions found in the solution.
- What is the total ion concentration?

Solubility Rules (Table 4.1, provided on the exam)

(Compounds That Are Generally Soluble in Water)

Compounds Containing the Following Ions Are Generally Soluble:	Exceptions (when combined with ions on the left, the compound is insoluble)
Li^+, Na^+, K^+, NH_4^+	none
NO_3^-, $C_2H_3O_2^-$	none
Cl^-, Br^-, I^-	Ag^+, Hg_2^{2+}, Pb^{2+}
SO_4^{2-}	Ag^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Pb^{2+}

Solubility Rules (Table 4.1, cont.)
(Compounds That Are Generally Insoluble in Water)

Compounds Containing the Following Ions Are Generally Insoluble:	**Exceptions** **(when combined with ions on the left, the compound is soluble or slightly soluble)**
OH^-	Li^+, Na^+, K^+, NH_4^+, **Ca^{2+}, Sr^{2+}, Ba^{2+}**
S^{2-}	Li^+, Na^+, K^+, NH_4^+, Ca^{2+}, Sr^{2+}, Ba^{2+}
CO_3^{2-}, PO_4^{3-}	Li^+, Na^+, K^+, NH_4^+

Which of the following salts are soluble in water?

KOH

$AgBr$

$CaCl_2$

$Pb(NO_3)_2$

PbI_2

Net Ionic Equations

$Mg(NO_3)_2(aq) + K_2CrO_4(aq) \rightarrow MgCrO_4(s) + 2\ KNO_3(aq)$

The above chemical reaction is written as a **"molecular equation."**

- Because $Pb(NO_3)_2$ and K_2CrO_4 are strong electrolytes we can write

$$Mg^{2+}(aq) + 2\ NO_3^-(aq) + 2\ K^+(aq) + CrO_4^{2-}(aq)$$
$$\rightarrow MgCrO_4(s) + 2\ K^+(aq) + 2\ NO_3^-(aq)$$

This is written now as a **"complete ionic equation."**

Question: What about K^+ and NO_3^- ions?

Answer: They are "spectator ions." These ions DO NOT participate in the reaction.

Net Ionic Equations

Complete ionic equation:

$$Mg^{2+}(aq) + 2\ NO_3^{-}(aq) + 2\ K^{+}(aq) + CrO_4^{2-}(aq) \rightarrow MgCrO_4(s) + 2\ K^{+}(aq) + 2\ NO_3^{-}(aq)$$

- **Spectator ions are left out when writing net ionic equations.**

$$Mg^{2+}(aq) + CrO_4^{2-}(aq) \rightarrow MgCrO_4(s)$$

is the NET IONIC EQUATION for this reaction.

$$K_2SO_4(aq) + 2\ AgNO_3(aq) \rightarrow Ag_2SO_4(s) + 2\ KNO_3(aq)$$

$$AlCl_3\ (aq) + NH_4NO_3\ (aq) \rightarrow Al(NO_3)_3\ (aq) + NH_4Cl\ (aq)$$

Evidence of a Reaction

1. Produces Light
2. Absorbs/Gives off Heat
3. Forms Bubbles
4. Forms a Precipitate (solid)
5. Color Change





Reactions in Solution

- Double Displacement Reactions (Exchange of Ions)
  - Precipitation Reactions

$$AB(aq) + CD(aq) \longrightarrow AD(s) + CB$$

  - Acid/Base Neutralization Reactions

$$HA(aq) + MOH(aq) \longrightarrow H_2O(l) + MA(aq)$$

  - Gas Evolution Reaction

$$AB(aq) + CD(aq) \longrightarrow AD(g) + CB$$

Reactions in Solution

- Redox Reactions (Exchange of Electrons)
  - Combustion Reactions

$$fuel + O_2 \longrightarrow CO_2 + H_2O$$

  - Single Displacement Reactions (can sometimes be gas evolution reactions when A=H)

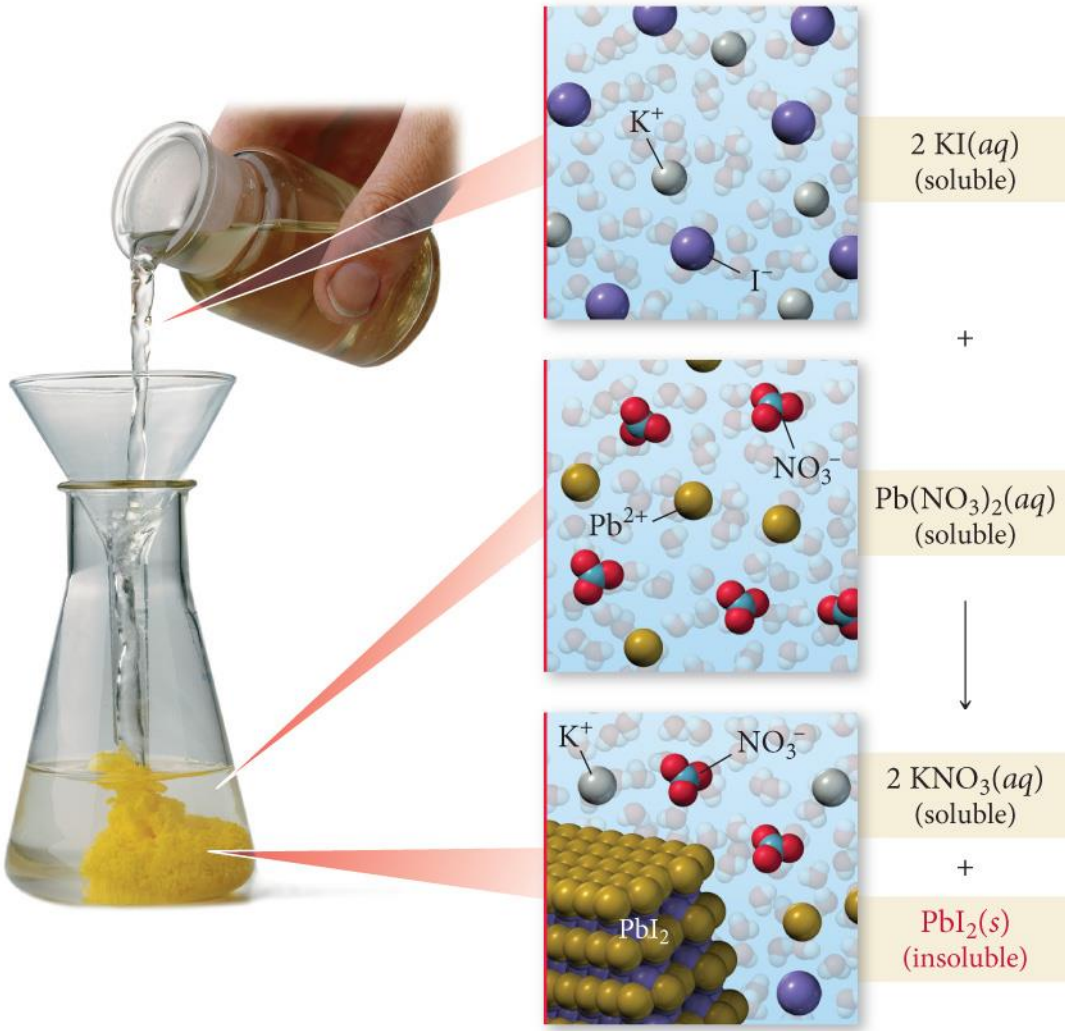
$$M + AB \longrightarrow MB + A$$

Precipitation Reaction

$$2\,KI(aq) + Pb(NO_3)_2(aq) \longrightarrow 2\,KNO_3(aq) + PbI_2(s)$$

(soluble) (soluble) (soluble) (insoluble)

When a potassium iodide solution is mixed with a lead(II) nitrate solution, a yellow lead(II) iodide precipitate forms.



Problem: Write the equation for the precipitation reaction between an aqueous solution of potassium carbonate and an aqueous solution of nickel(II) chloride.

Strategy for writing an equation for a double displacement reaction:

1. **Write the formulas of the reactants.**
2. **Determine the possible products.**
    - **a) Determine the ions present.**
    - **b) Exchange the ions.**
    - **c) Write the formulas of the products.**
3. **Determine the solubility of each product.**
4. **If both products soluble, write no reaction.**
5. **Write (*aq*) next to soluble products and (*s*) next to insoluble products.**
6. **Balance the equation.**

Review Problem

- What is the mass and identity of the precipitate formed when you mix 25 mL of 0.150M $Fe(NO_3)_3$ and 15mL of 0.204M NaOH?

Acid-Base Reactions

- The "driving force" for many strong acid- strong base reactions is the formation of water.

  NaOH(aq) + HCl(aq) → NaCl(aq) + H_2O(l)

  – Net ionic equation:

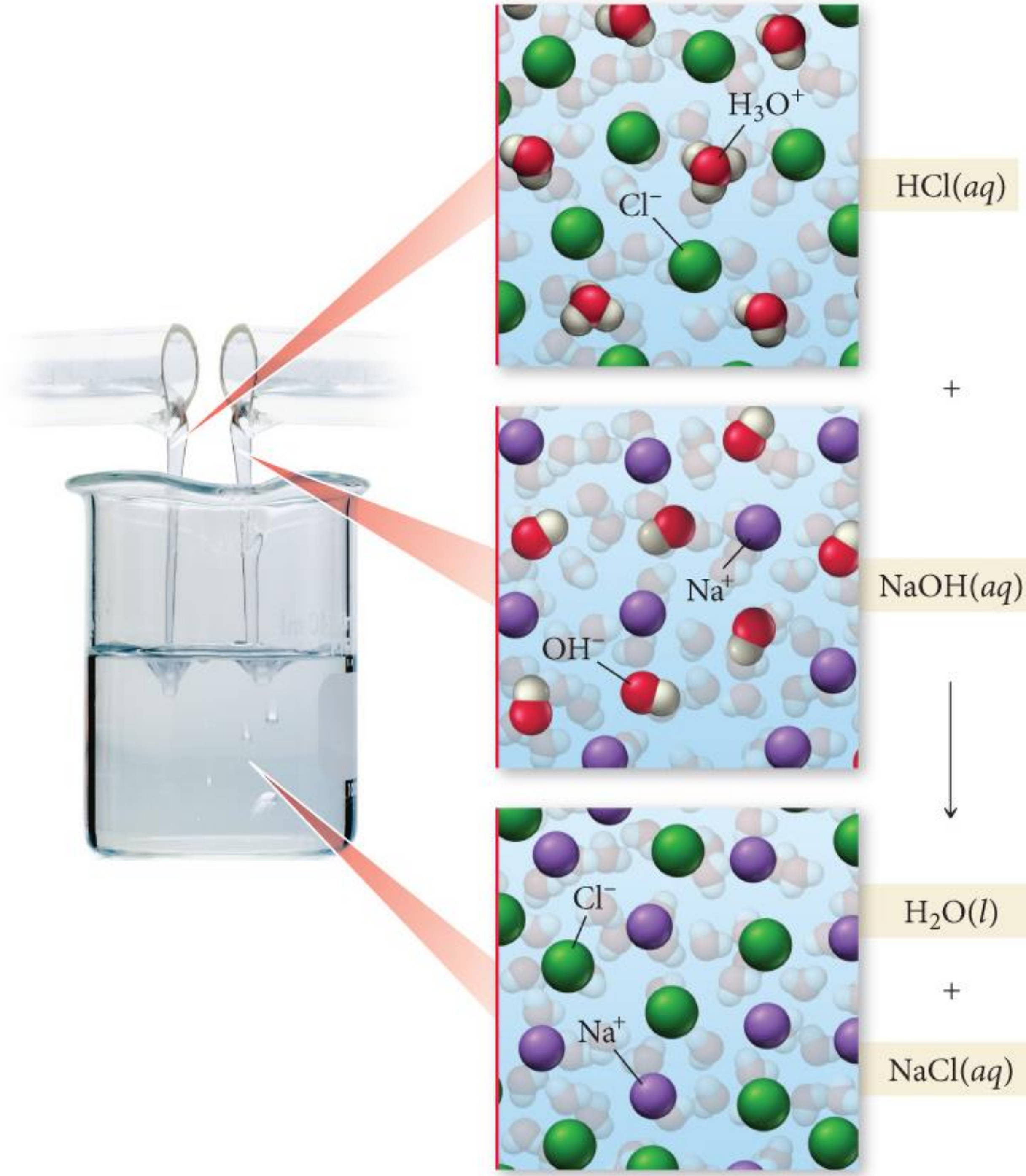
  OH^- (*aq*) + H^+ (*aq*) → H_2O(*l*)

- A common product of many acid-base reactions is water and a SALT, MX.

  HX + MOH → MX + H_2O

  M^{n+} comes from base and X^{n-} comes from acid.

- Acid-base reactions are referred to as NEUTRALIZATION reactions.


H_3O^+
Cl^-
HCl(*aq*)
+
Na^+
OH^-
NaOH(*aq*)
Cl^-
Na^+
$H_2O(l)$
+
NaCl(*aq*)

Gas Evolution Reactions

- Direct Formation
  - Acid + metal sulfide → H_2S (g)

- Indirect Formation
  - When H_2SO_3, H_2CO_3, or NH_4OH are formed by a Double Displacement Rxn, they decompose forming a gas.

Other Patterns in Reactions: Transfer of electrons rather than ions

- **The precipitation, acid/base, and gas-evolving reactions are all involved in exchanging the ions in the solution.**

- **Other kinds of reactions involve transferring electrons from one atom to another; these are called oxidation–reduction reactions.**

  - **Known as redox reactions**
  - **Many involve the reaction of a substance with $O_2(g)$**

$$4\ Fe(s) + 3\ O_2(g) \rightarrow 2\ Fe_2O_3(s)$$

Rules for Assigning Oxidation Numbers

1. Oxidation number of a free atom or an atom in its elemental state is 0.
2. The oxidation number of a monatomic ion is the same as its charge.
3. The sum of oxidation numbers in a polyatomic ion or compound usually has the same oxidation number it would have if it were a monatomic ion.
    a) Hydrogen is +1 with nonmetals, -1 if bound to a metal.
    b) Oxygen is always -2 unless in a peroxide
    c) Halogens are usually -1, unless bound to oxygen
4. The sum of the oxidation numbers of all elements is equal to the compound/ion’s charge.

Problem:

Assign an oxidation state to each element in the following:

- Br_2
- K^+
- LiF
- H_2O_2
- CO_2
- SO_4^{2-}
- $Na_2Cr_2O_7$

Oxidation and Reduction Reactions

Oxidation:

- **The process that occurs when**
  - **the oxidation number of an element increases**
  - **an element loses electrons**
- **OXIDIZING AGENT is an electron acceptor; it causes another species to be OXIDIZED but it (agent) is being reduced.**

Reduction:

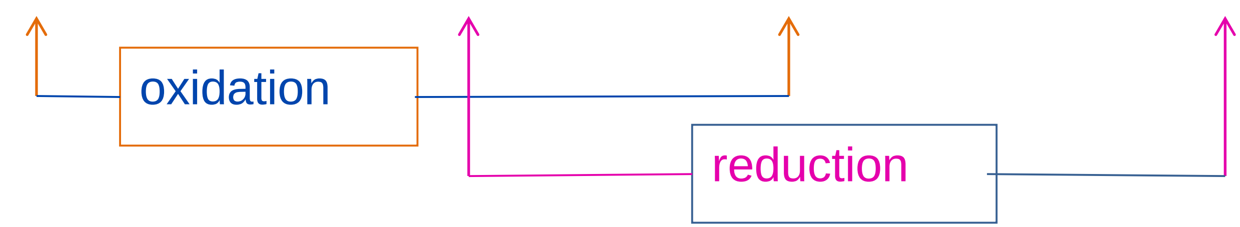
- **The process that occurs when**
  - **the oxidation number of an element decreases**
  - **an element gains electrons**
- **REDUCING AGENT is an electron donor; it causes another species to be REDUCED but it (agent) is being oxidized.**

Oxidation and Reduction

- **Oxidation and reduction MUST occur simultaneously.**
- **Oxidation occurs when an atom's oxidation state increases during a reaction.**
- **Reduction occurs when an atom's oxidation state decreases during a reaction.**

$$CH_4 + 2\,O_2 \rightarrow CO_2 + 2\,H_2O$$

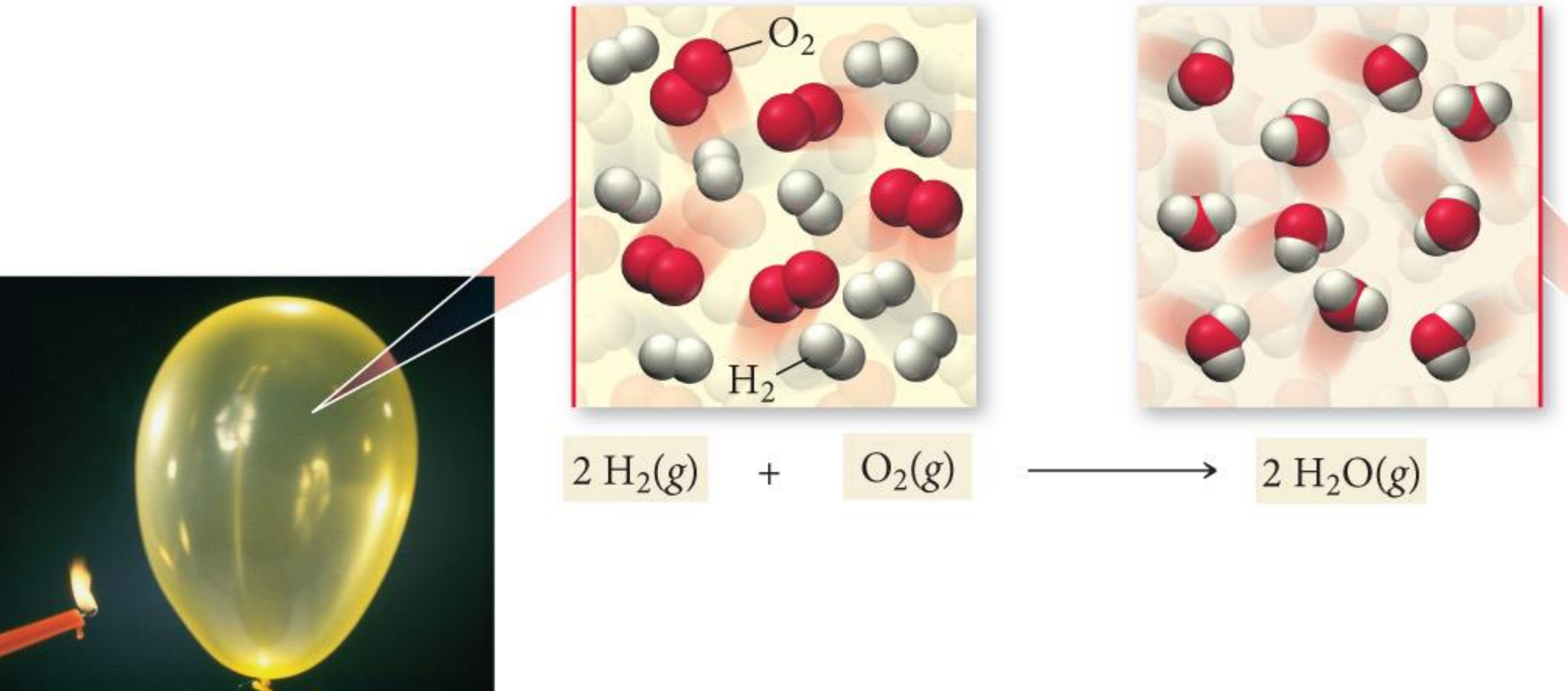
CH₄		O₂	CO₂		H₂O	
–4	+1	0	+4	–2	+1	–2



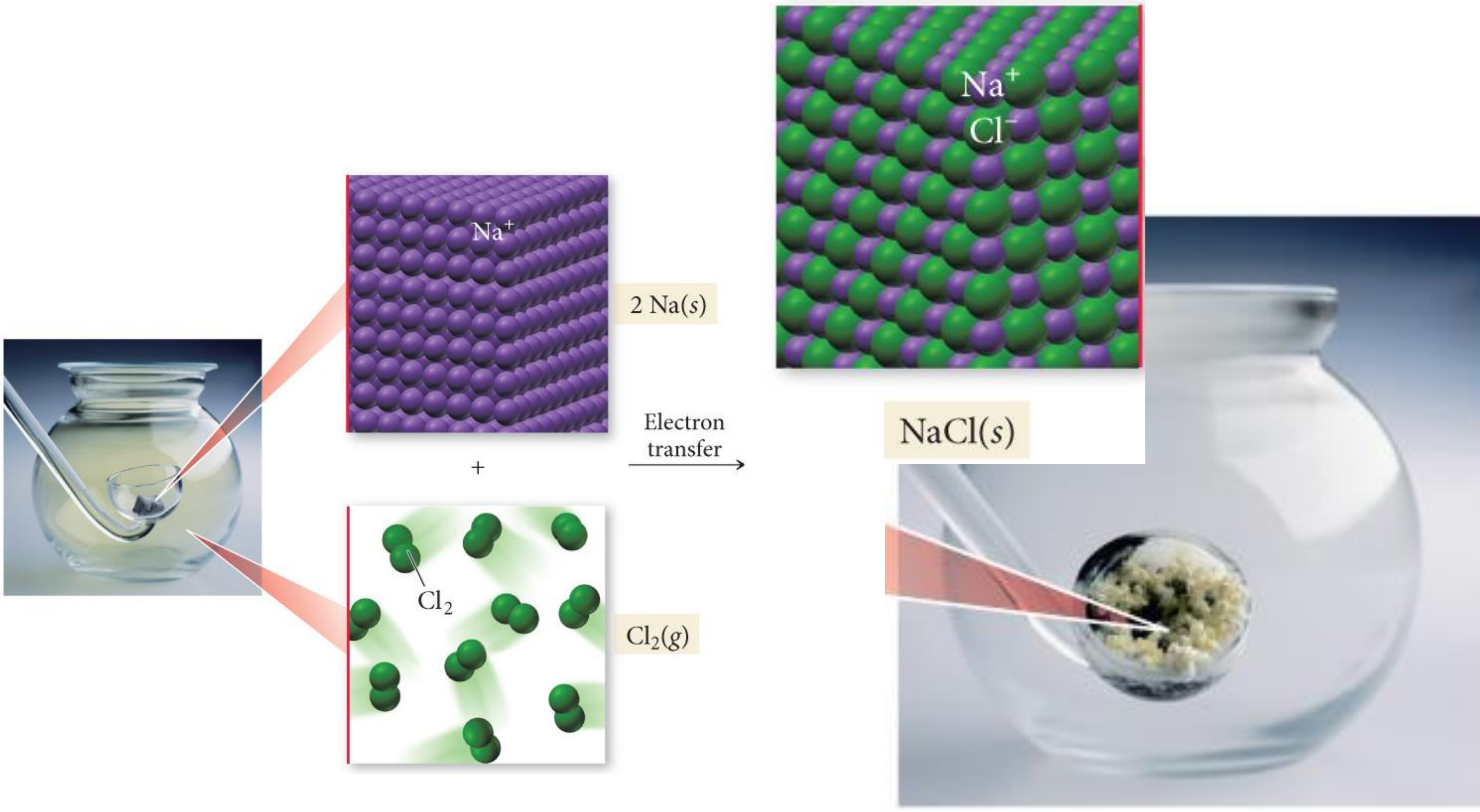
Oxidation–Reduction Reaction

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

Hydrogen and oxygen in the balloon react to form gaseous water.



Redox without Oxygen



Combustion Reactions

$$2\ C_8H_{18}(g) + 25\ O_2(g) \rightarrow 16\ CO_2(g) + 18\ H_2O(g)$$

- **Reactions in which $O_2(g)$ is a reactant are called combustion reactions.**
- **Combustion reactions release lots of energy.**
- **Combustion reactions are a subclass of oxidation–reduction reactions.**

Problem: Complete and balance the following reactions.

1. **Combustion of acetic acid, $HC_2H_3O_2(l)$**
2. **Combustion of isopropyl alcohol, $C_3H_7OH(l)$**