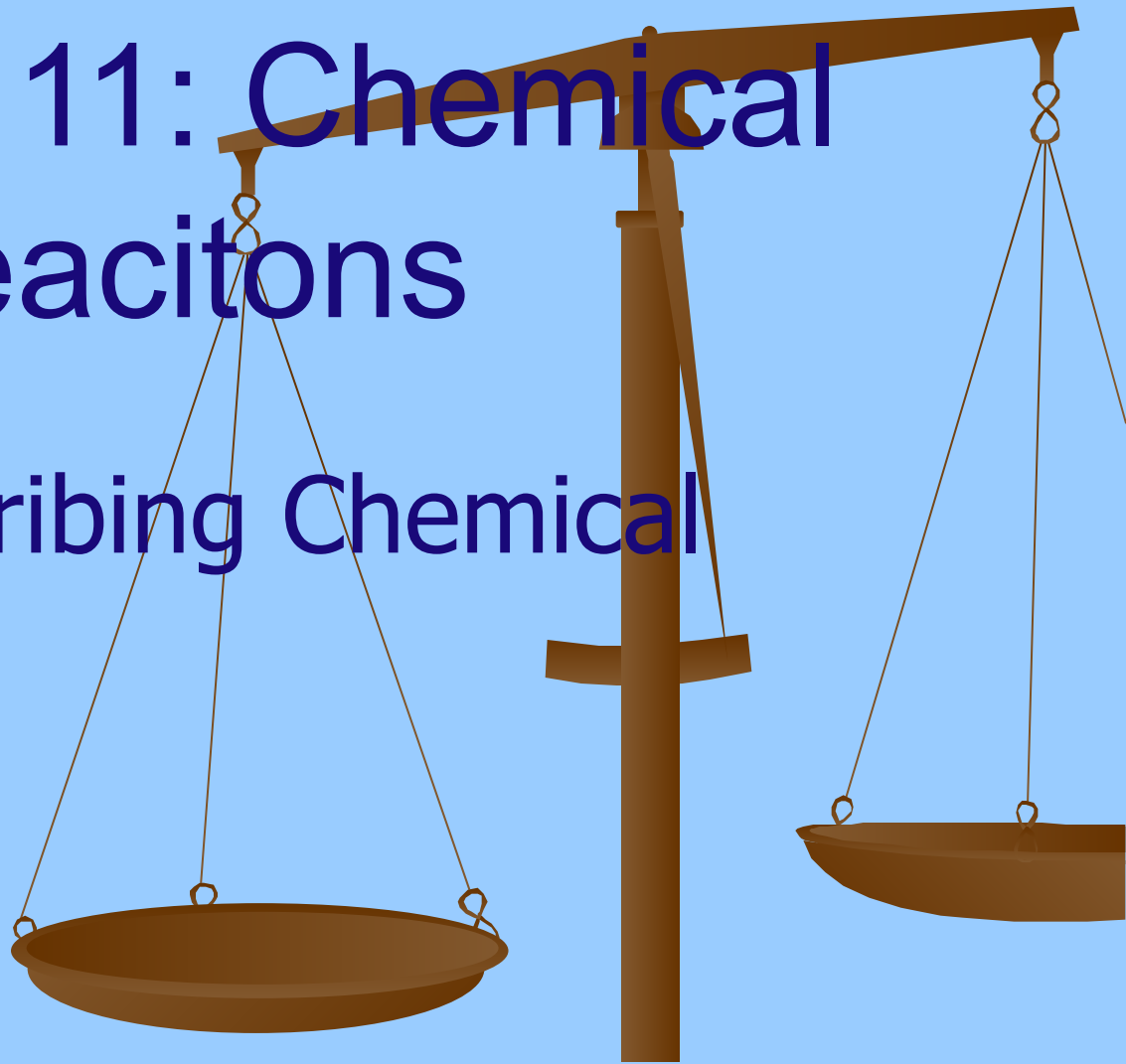


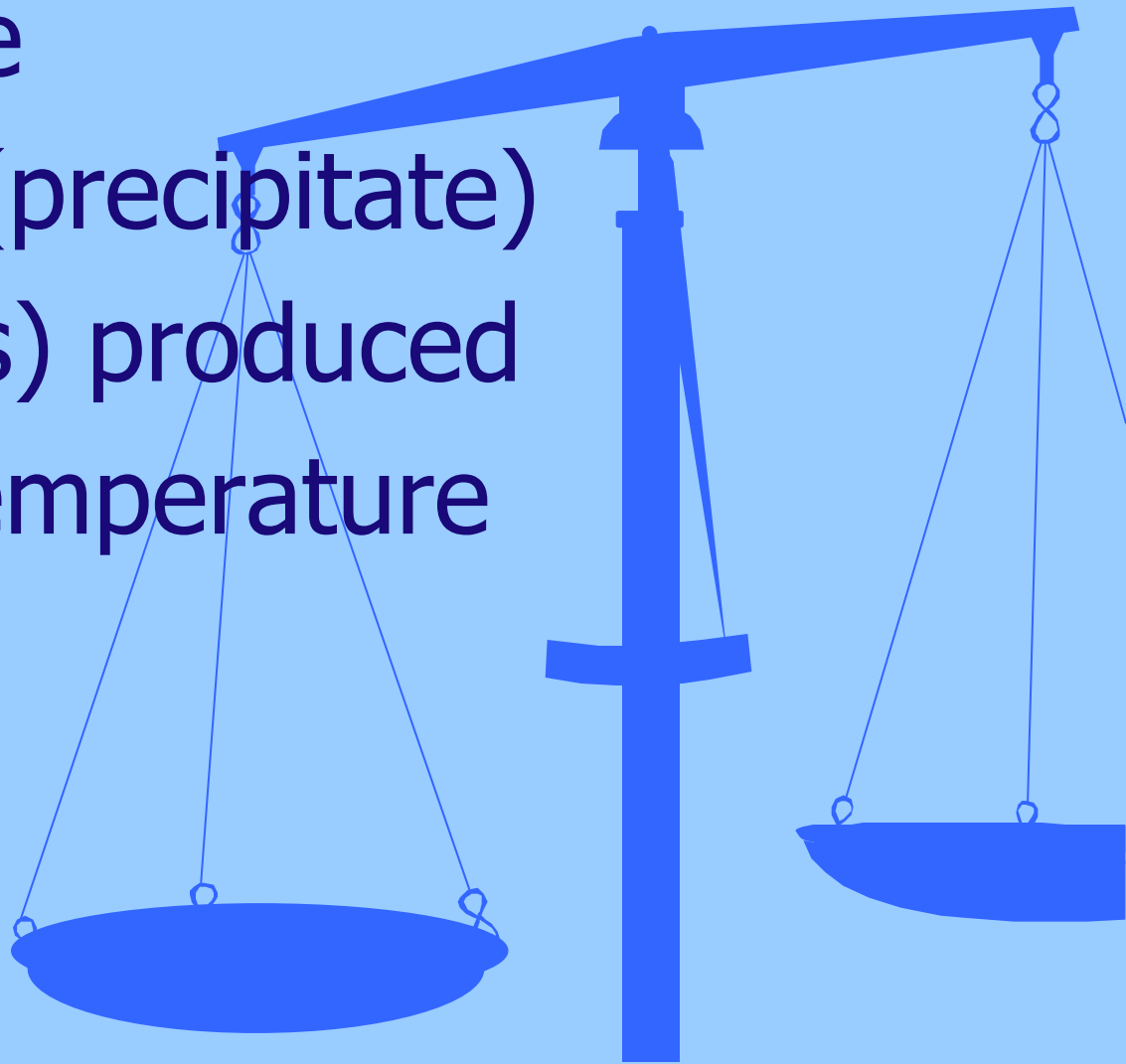
Chapter 11: Chemical Reactions

11.1 Describing Chemical Reactions



Signs of a Chemical Reaction

- Color change
- Solid forms (precipitate)
- Bubbles (gas) produced
- Change in temperature



11.1

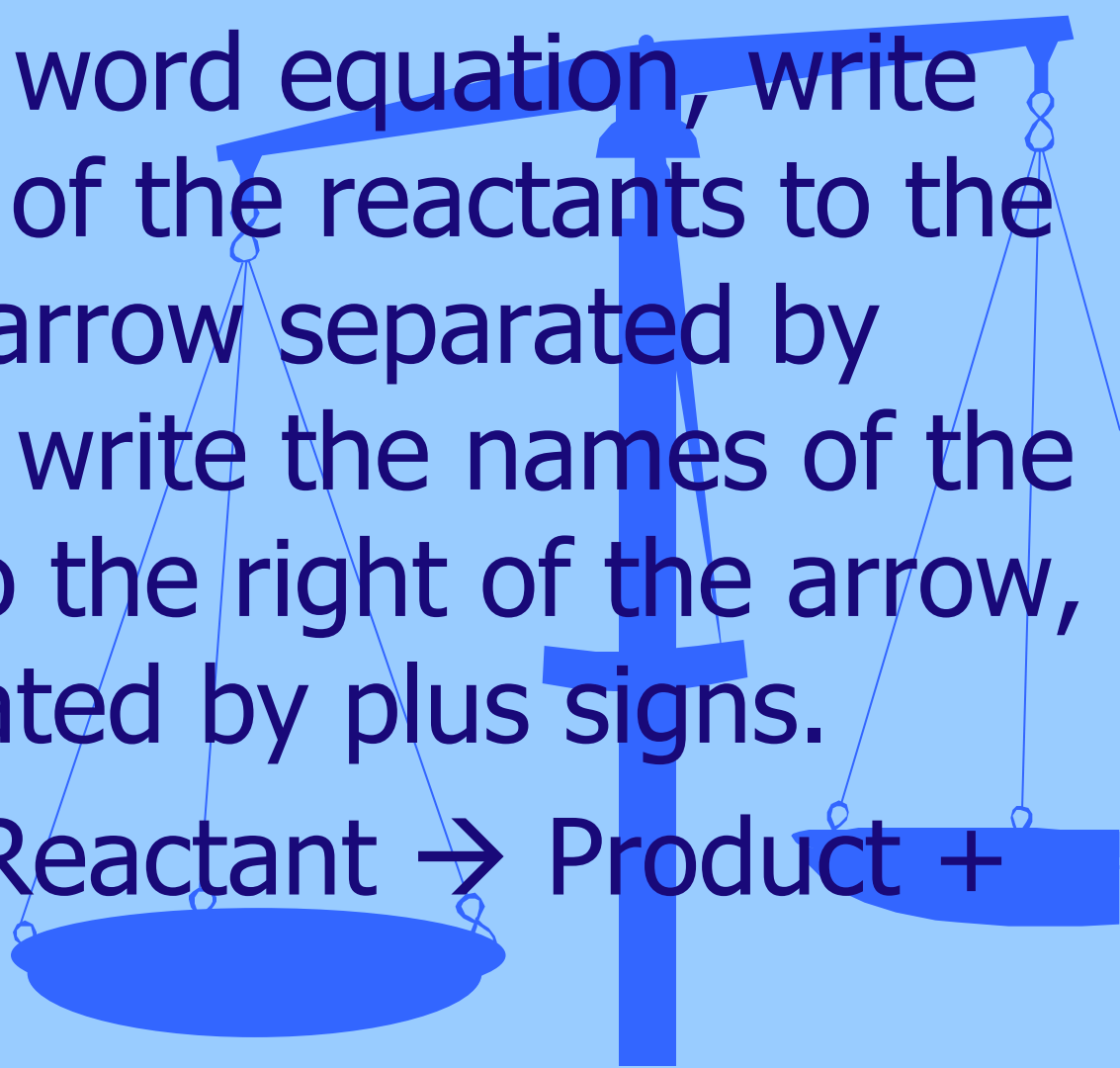
Writing Chemical Equations

■ Word Equations



■ To write a word equation, write the names of the reactants to the left of the arrow separated by plus signs; write the names of the products to the right of the arrow, also separated by plus signs.

■ Reactant + Reactant → Product +
Product

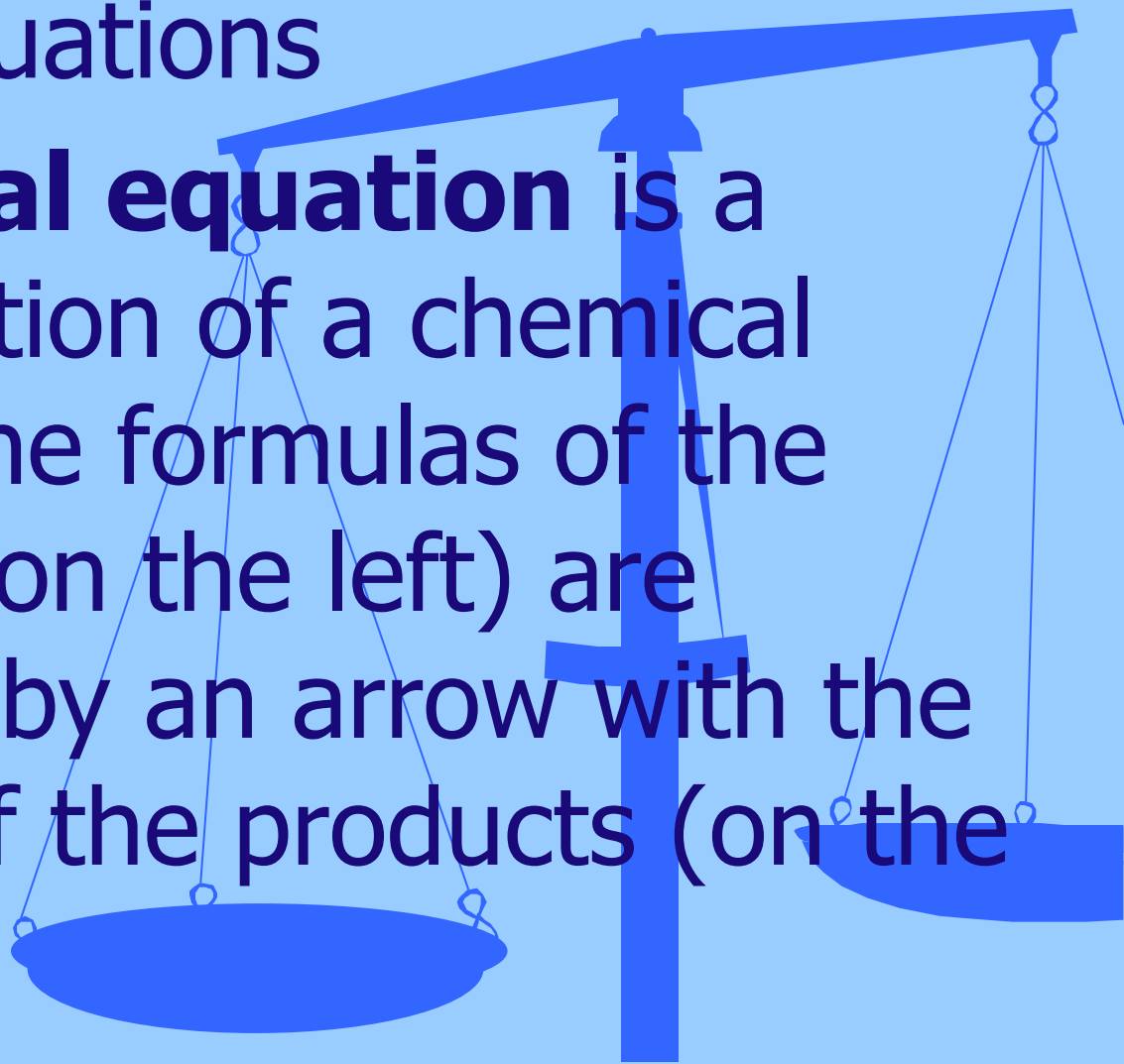


11.1

Writing Chemical Equations

■ Chemical Equations

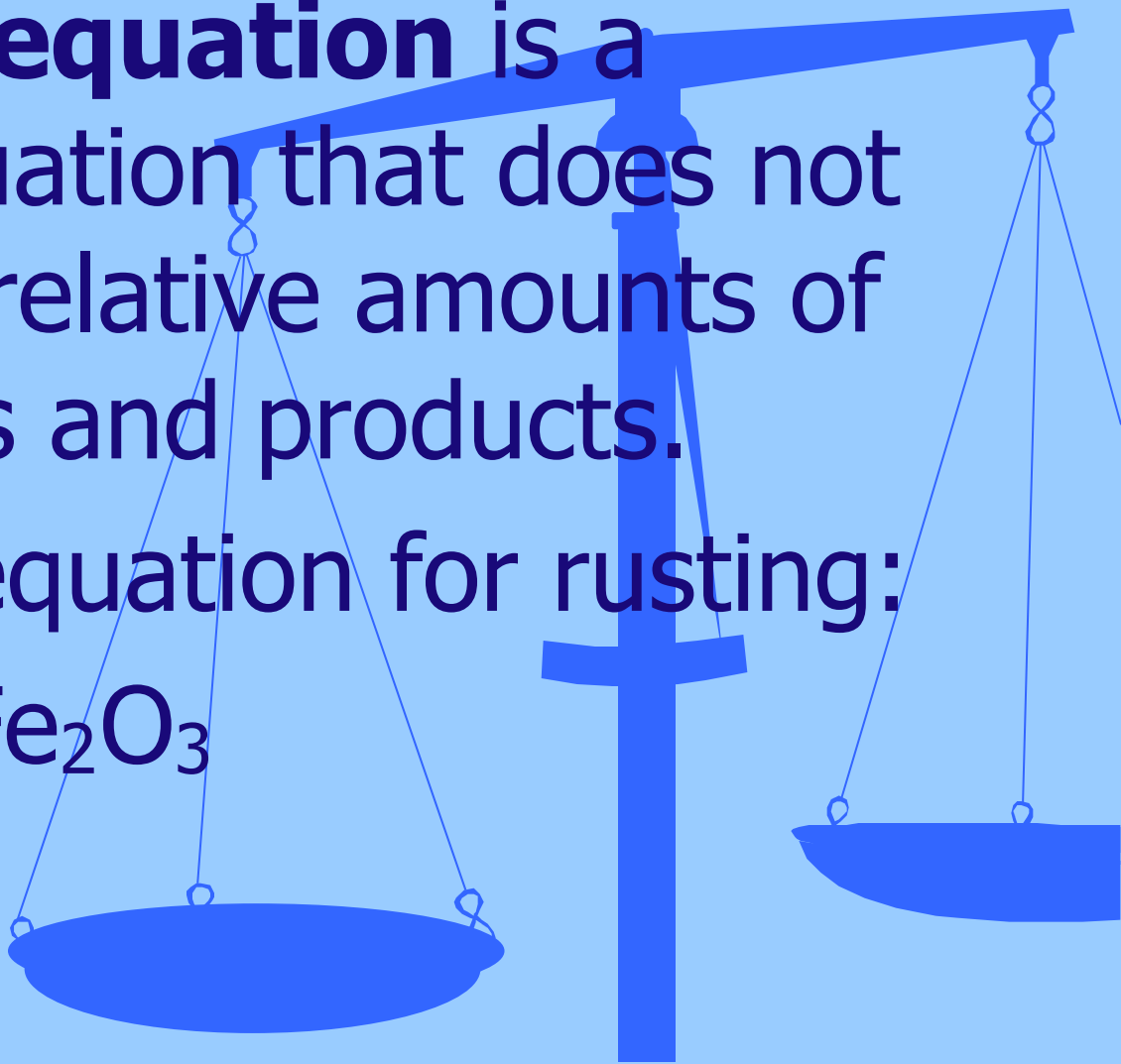
- A **chemical equation** is a representation of a chemical reaction; the formulas of the reactants (on the left) are connected by an arrow with the formulas of the products (on the right).



11.1

Writing Chemical Equations

- A **skeleton equation** is a chemical equation that does not indicate the relative amounts of the reactants and products.
- Here is the equation for rusting:
- $\text{Fe} + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3$

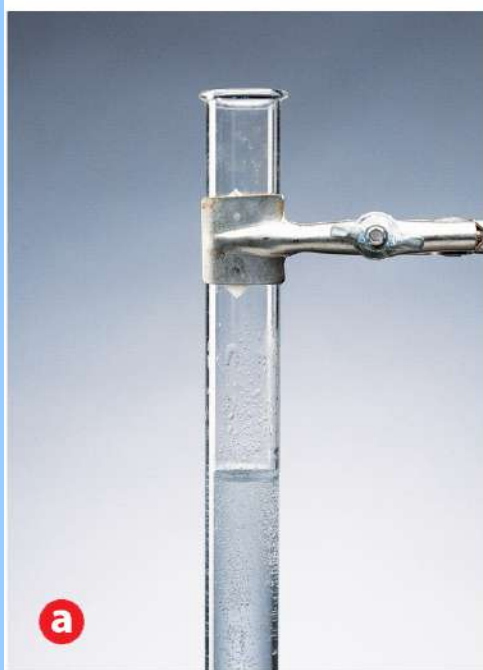


11.1

Writing Chemical Equations

- A **catalyst** is a substance that speeds up the reaction but is not used up in the reaction.

■ Without Catalyst



■ With Catalyst



11.1
Table 11.1

Symbols Used in Chemical Equations

| Symbol | Explanation |
|--|--|
| + | Used to separate two reactants or two products |
| \longrightarrow | "Yields," separates reactants from products |
| \rightleftharpoons | Used in place of \longrightarrow for reversible reactions |
| (s) | Designates a reactant or product in the solid state; placed after the formula |
| (l) | Designates a reactant or product in the liquid state; placed after the formula |
| (g) | Designates a reactant or product in the gaseous state; placed after the formula |
| (aq) | Designates an aqueous solution; the substance is dissolved in water; placed after the formula |
| $\xrightarrow{\Delta}$ $\xrightarrow{\text{heat}}$ | Indicates that heat is supplied to the reaction |
| $\xrightarrow{\text{Pt}}$ | A formula written above or below the yield sign indicates its use as a catalyst (in this example, platinum). |

Writing a Skeleton Equation

Hydrochloric acid and solid sodium hydrogen carbonate are shown before being placed in the beaker to react. The products formed are aqueous sodium chloride, water, and carbon dioxide gas. Write a skeleton equation for this chemical reaction.



for Conceptual Problem 11.1

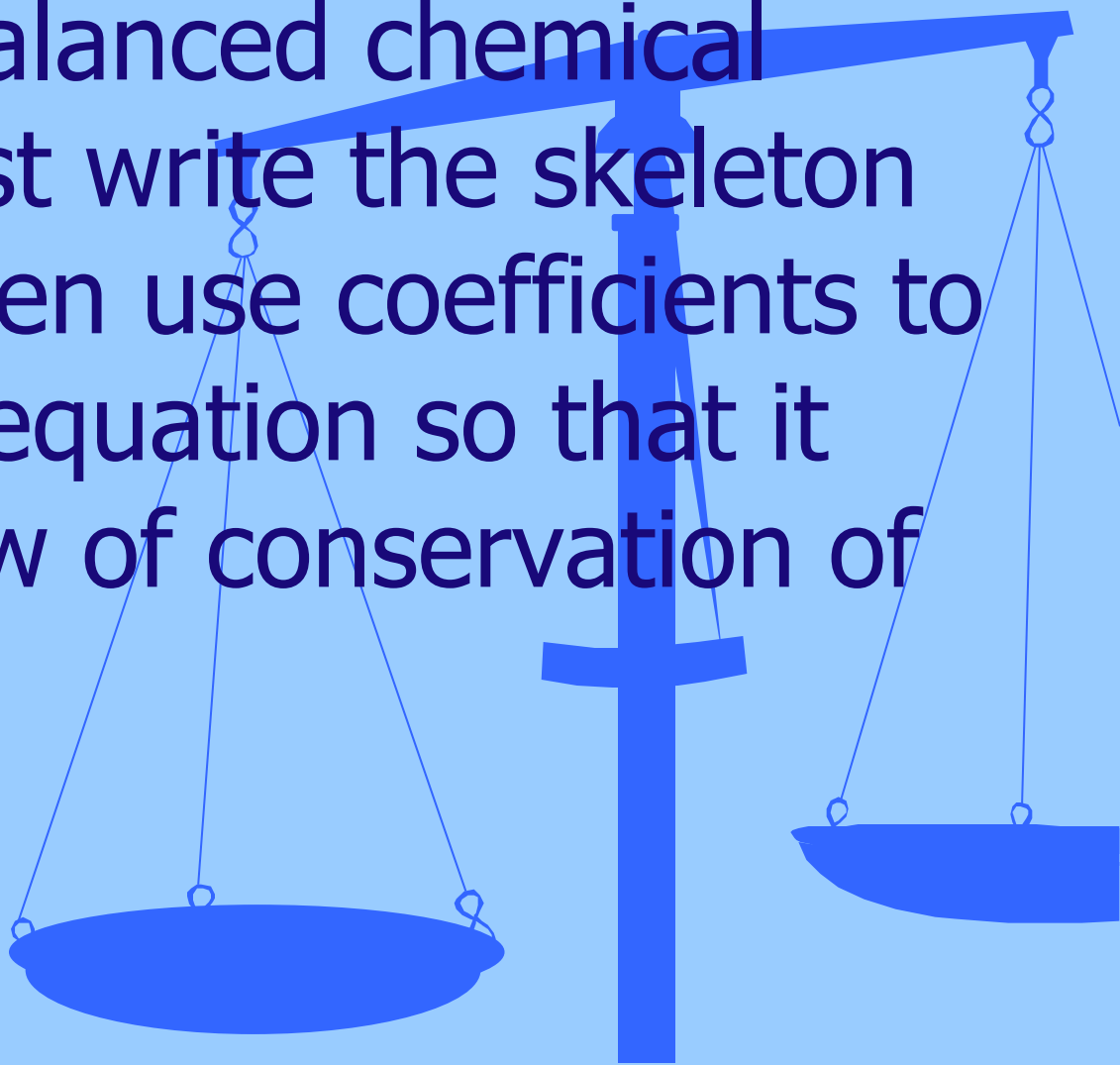
2. Sulfur burns in oxygen to form sulfur dioxide. Write a skeleton equation for this chemical reaction. Include appropriate symbols from Table 11.1.



11.1

Balancing Chemical Equations

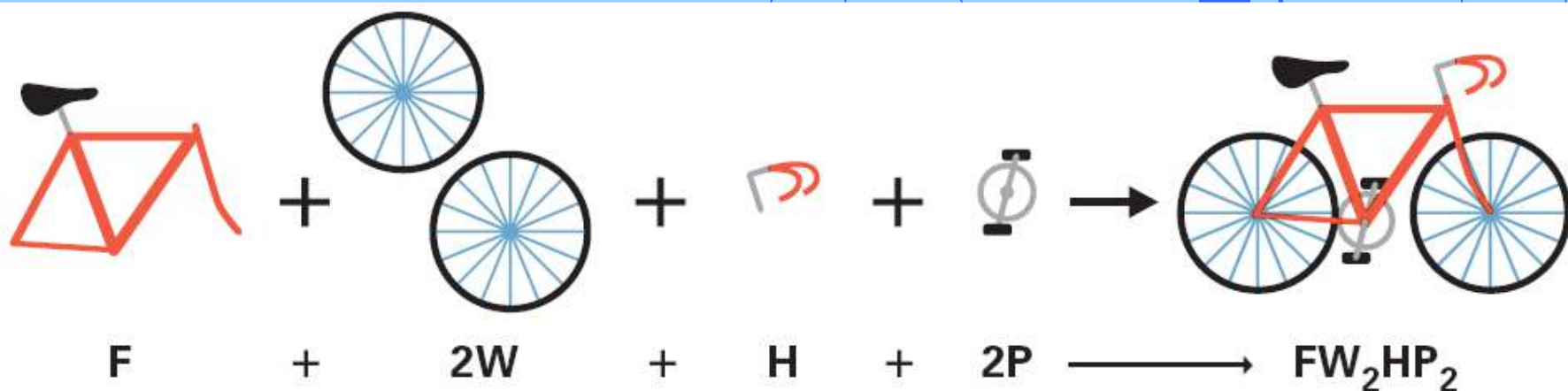
- To write a balanced chemical equation, first write the skeleton equation. Then use coefficients to balance the equation so that it obeys the law of conservation of mass.



11.1

Balancing Chemical Equations

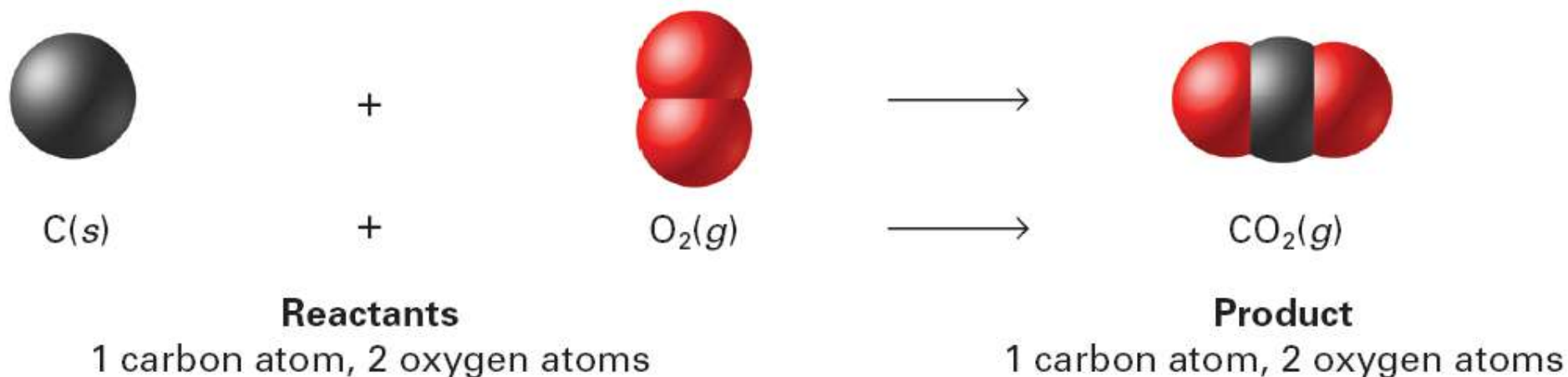
- This is a balanced equation for making a bicycle. The numbers are called **coefficients**—small whole numbers that are placed in front of the formulas in an equation in order to balance it.



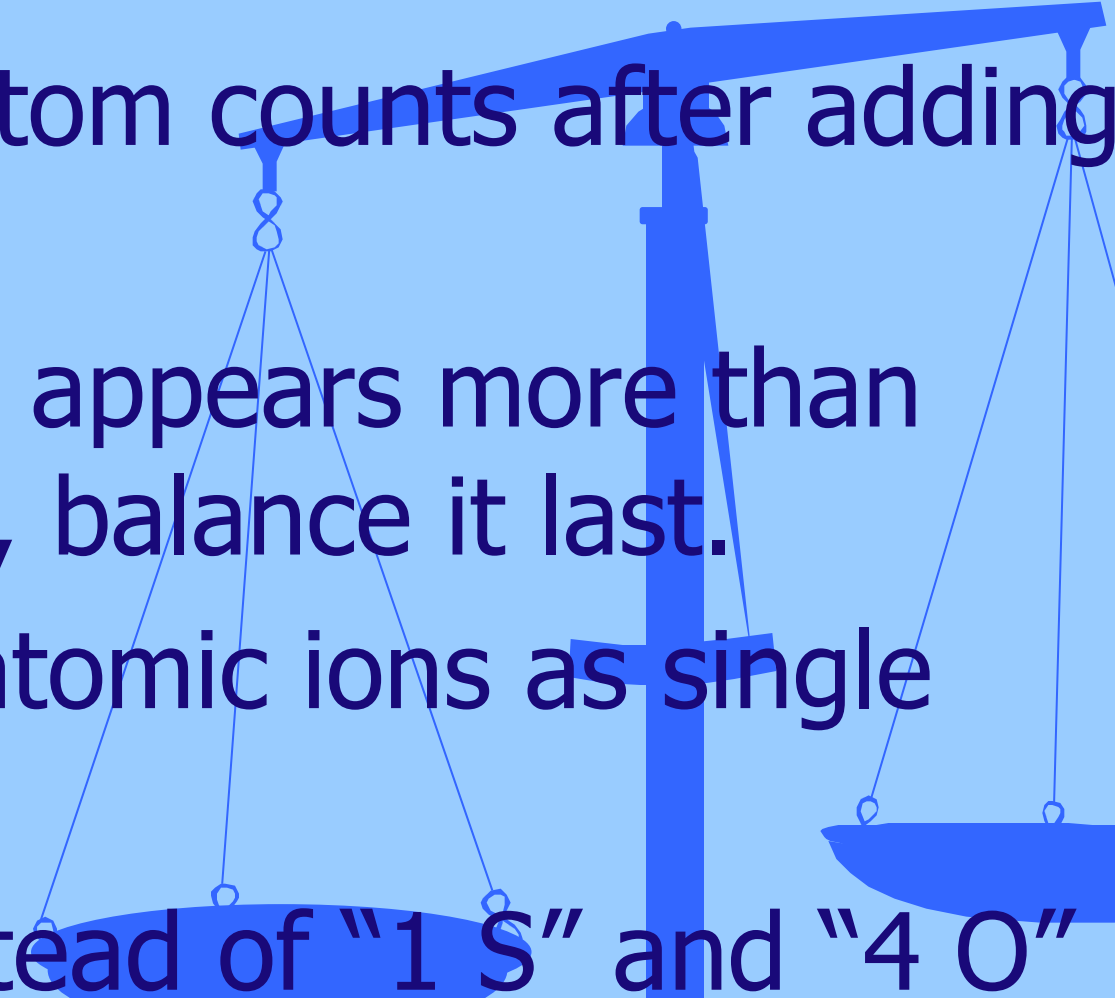
11.1

Balancing Chemical Equations

- A chemical reaction is also described by a **balanced equation** in which each side of the equation has the same number of atoms of each element and mass is conserved.



Helpful Tips

- Balance one element at a time.
 - Update ALL atom counts after adding a coefficient.
 - If an element appears more than once per side, balance it last.
 - Balance polyatomic ions as single units.
 - "1 SO₄" instead of "1 S" and "4 O"
- 

Writing a Balanced Chemical Equation

Hydrogen and oxygen react to form water. The reaction releases enough energy to launch a rocket. Write a balanced equation for the reaction.

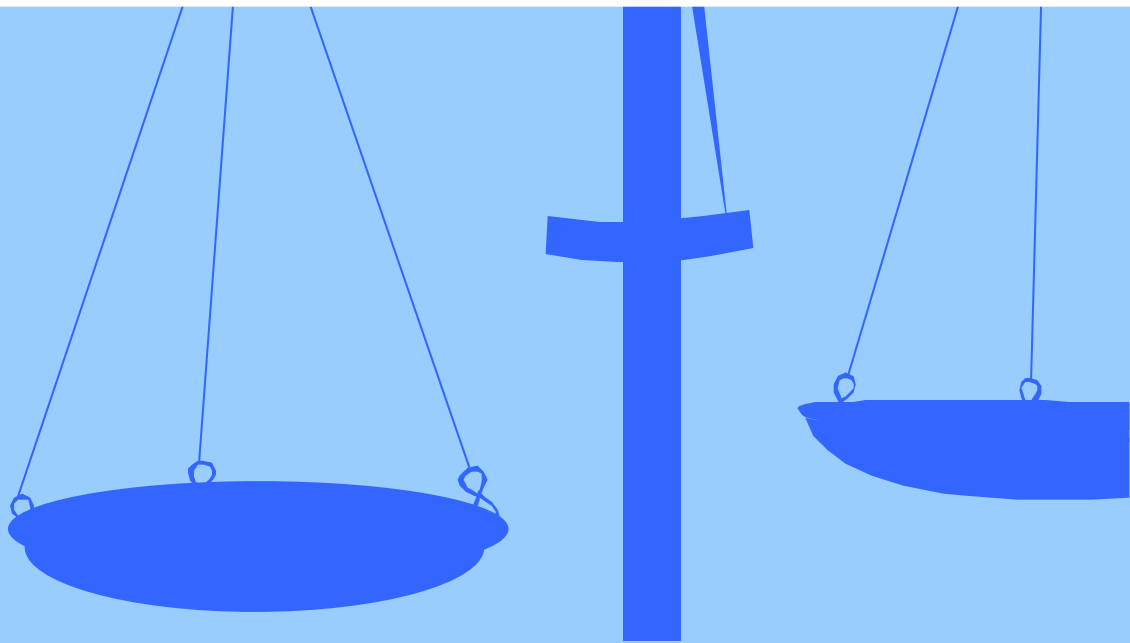


for Conceptual Problem 11.2

4. Rewrite these word equations as balanced chemical equations.

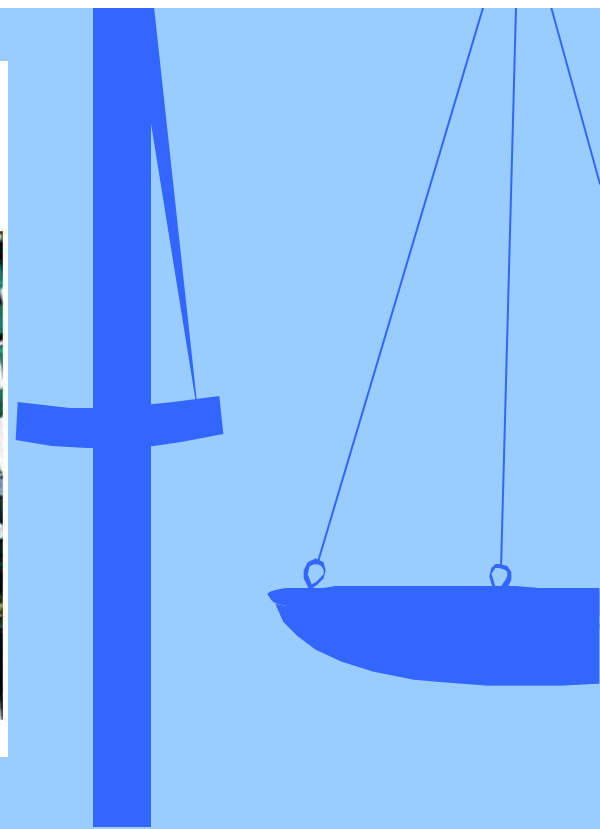
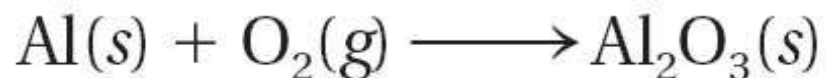
a. hydrogen + sulfur \longrightarrow hydrogen sulfide

b. iron(III) chloride + calcium hydroxide \longrightarrow
iron(III) hydroxide + calcium chloride



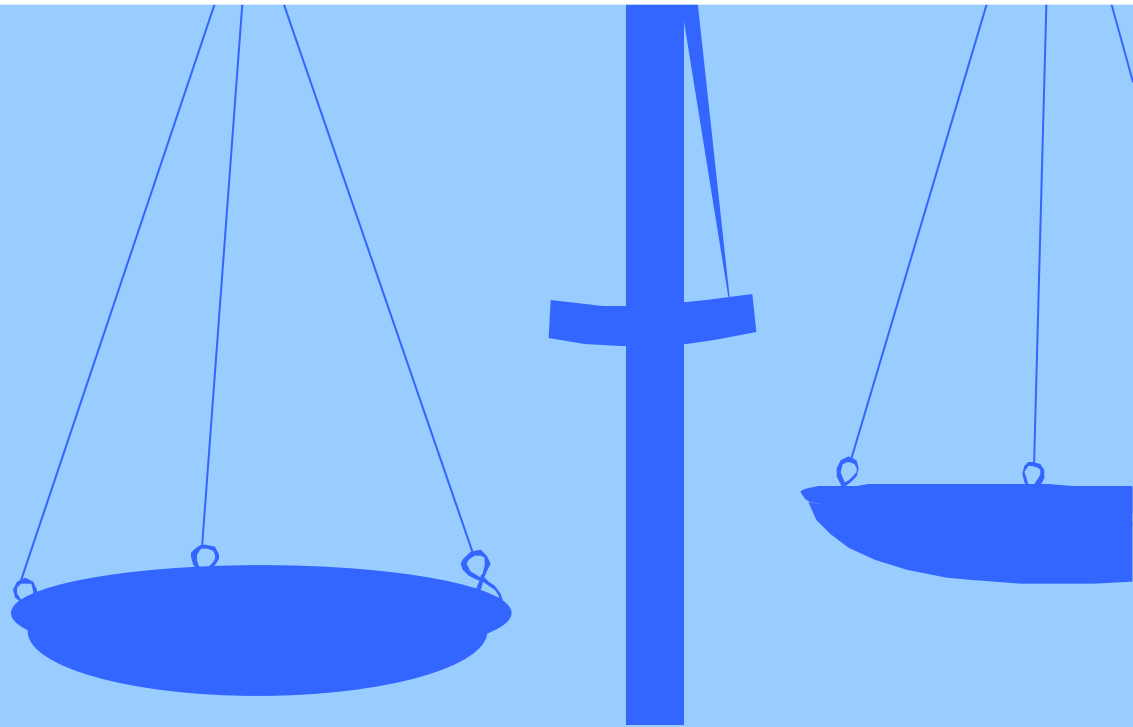
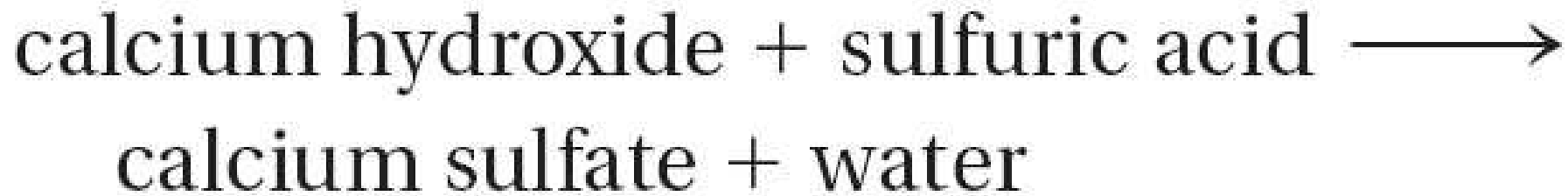
Balancing a Chemical Equation

Aluminum is a good choice for outdoor furniture because it reacts with oxygen in the air to form a thin protective coat of aluminum oxide. Balance the equation for this reaction.



for Conceptual Problem 11.2

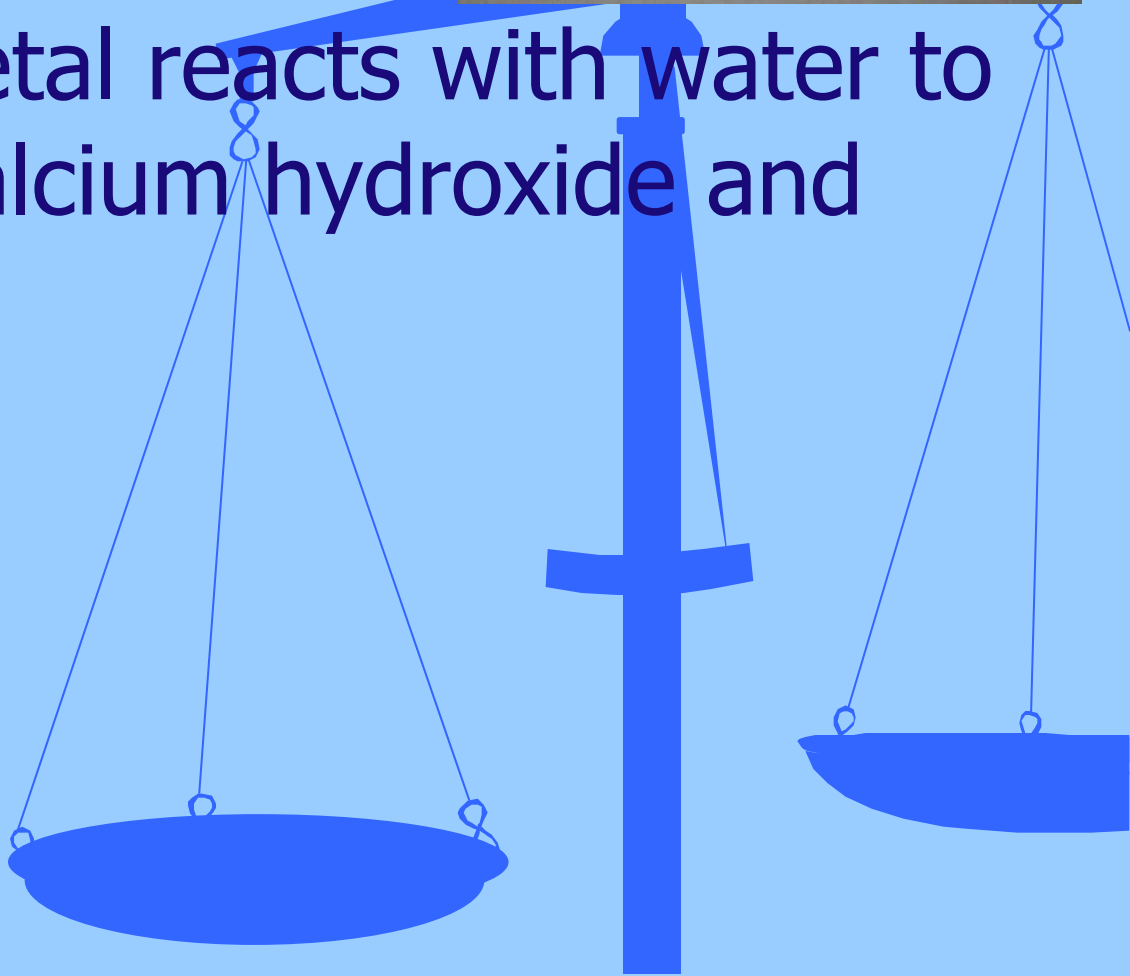
6. Write and balance this equation.



Example

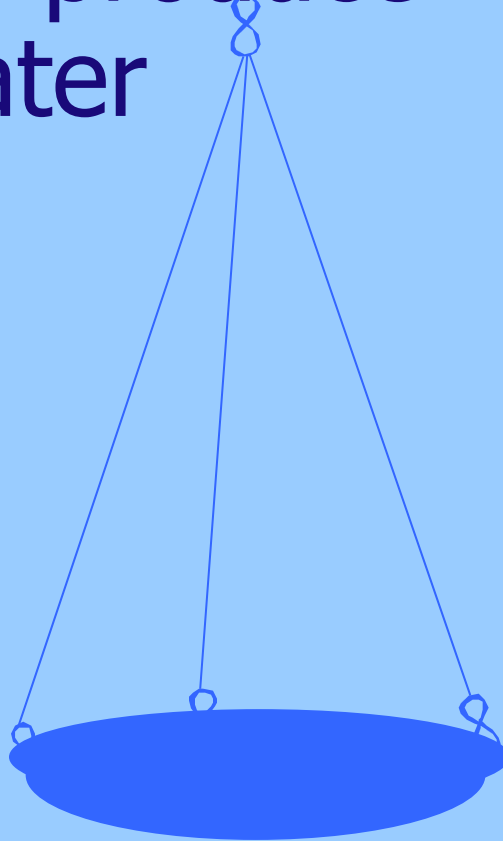


- Solid calcium metal reacts with water to form aqueous calcium hydroxide and hydrogen gas.

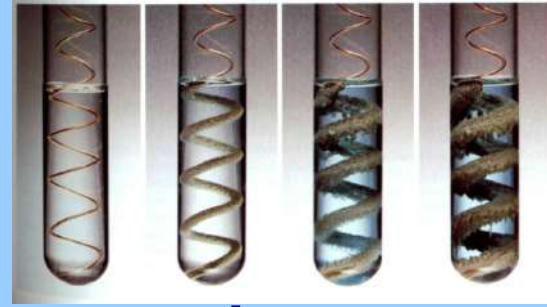


Example

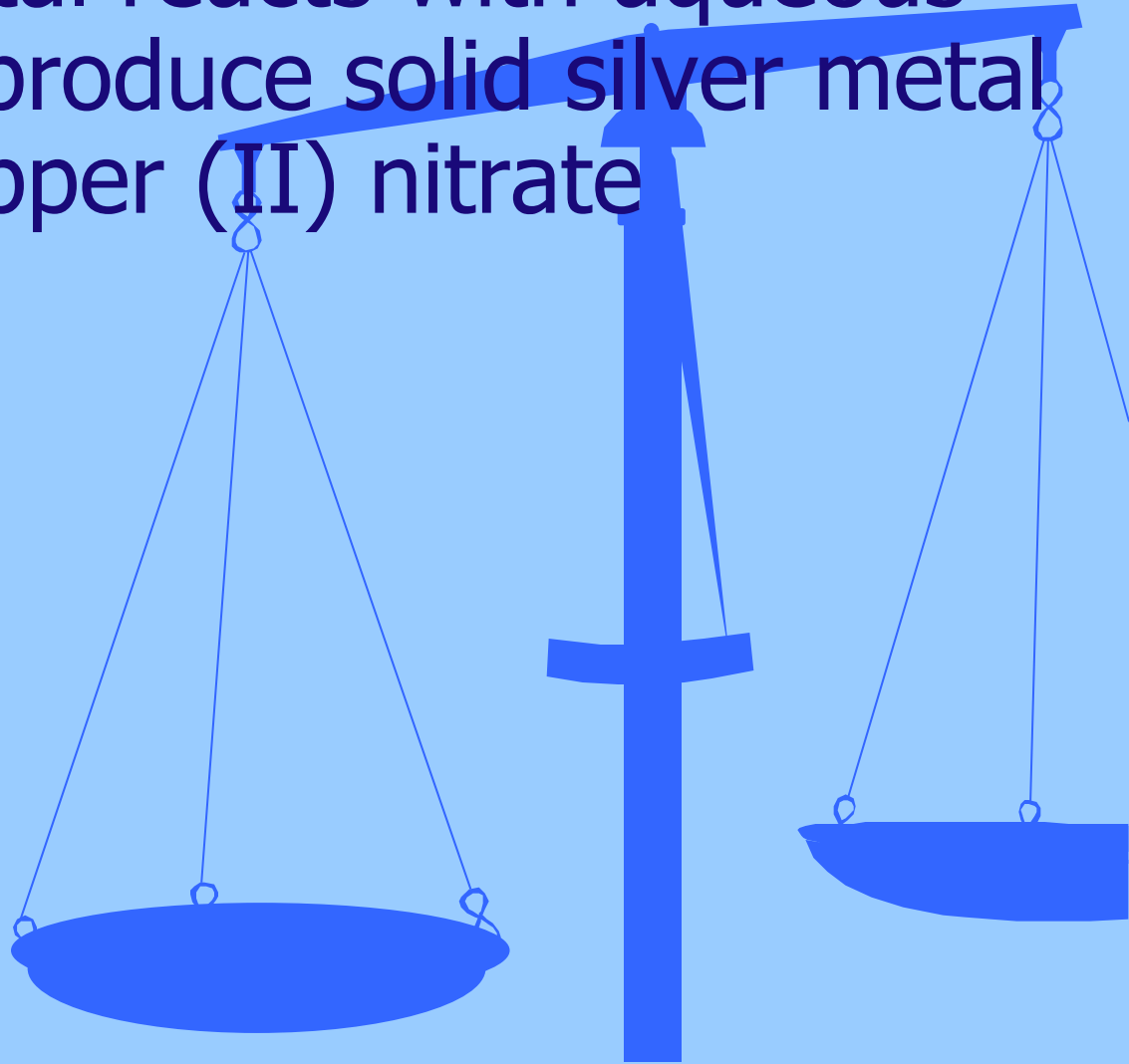
■ Hydrogen peroxide in an aqueous solution decomposes to produce oxygen and water



Example

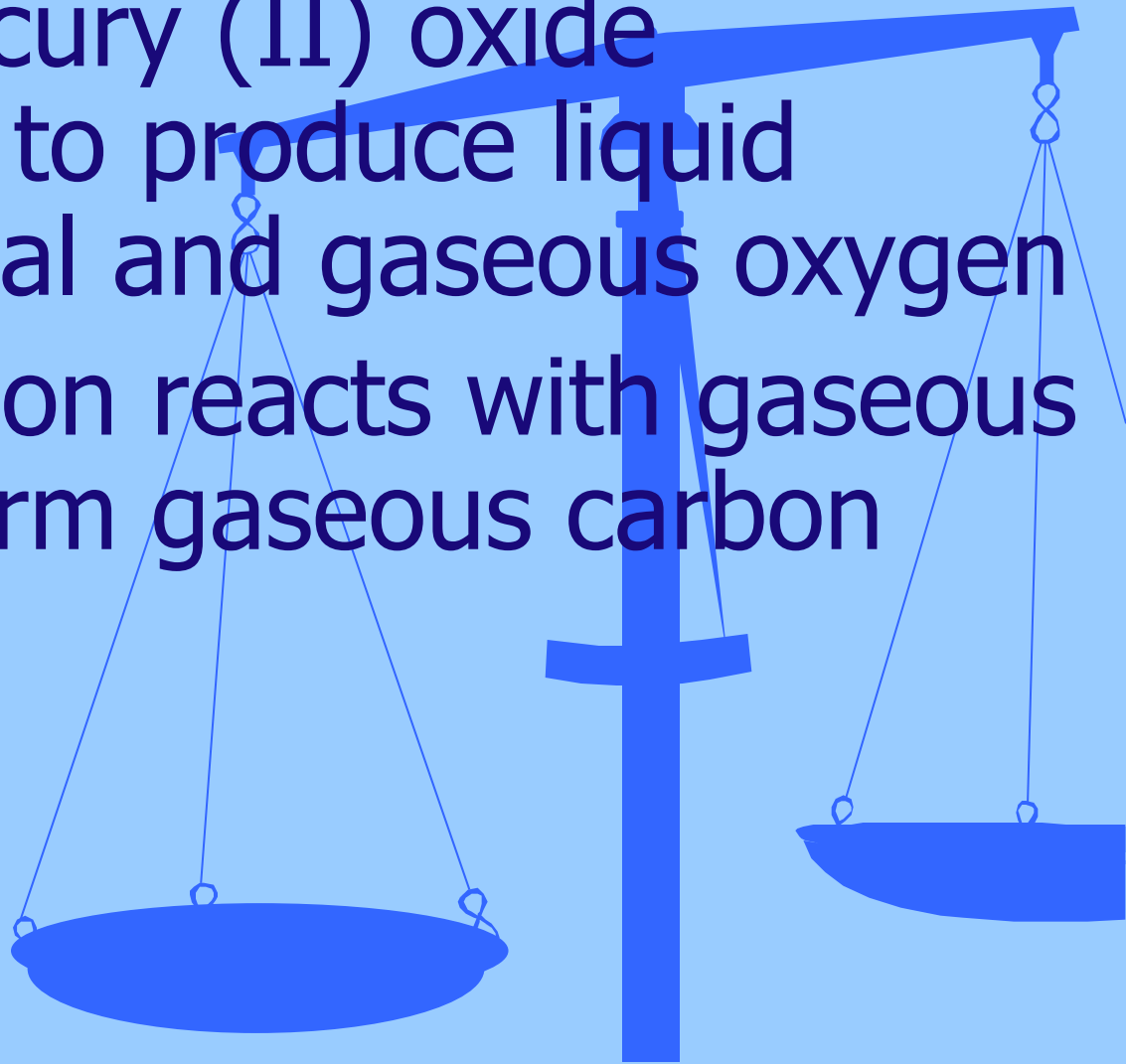


- Solid copper metal reacts with aqueous silver nitrate to produce solid silver metal and aqueous copper (II) nitrate



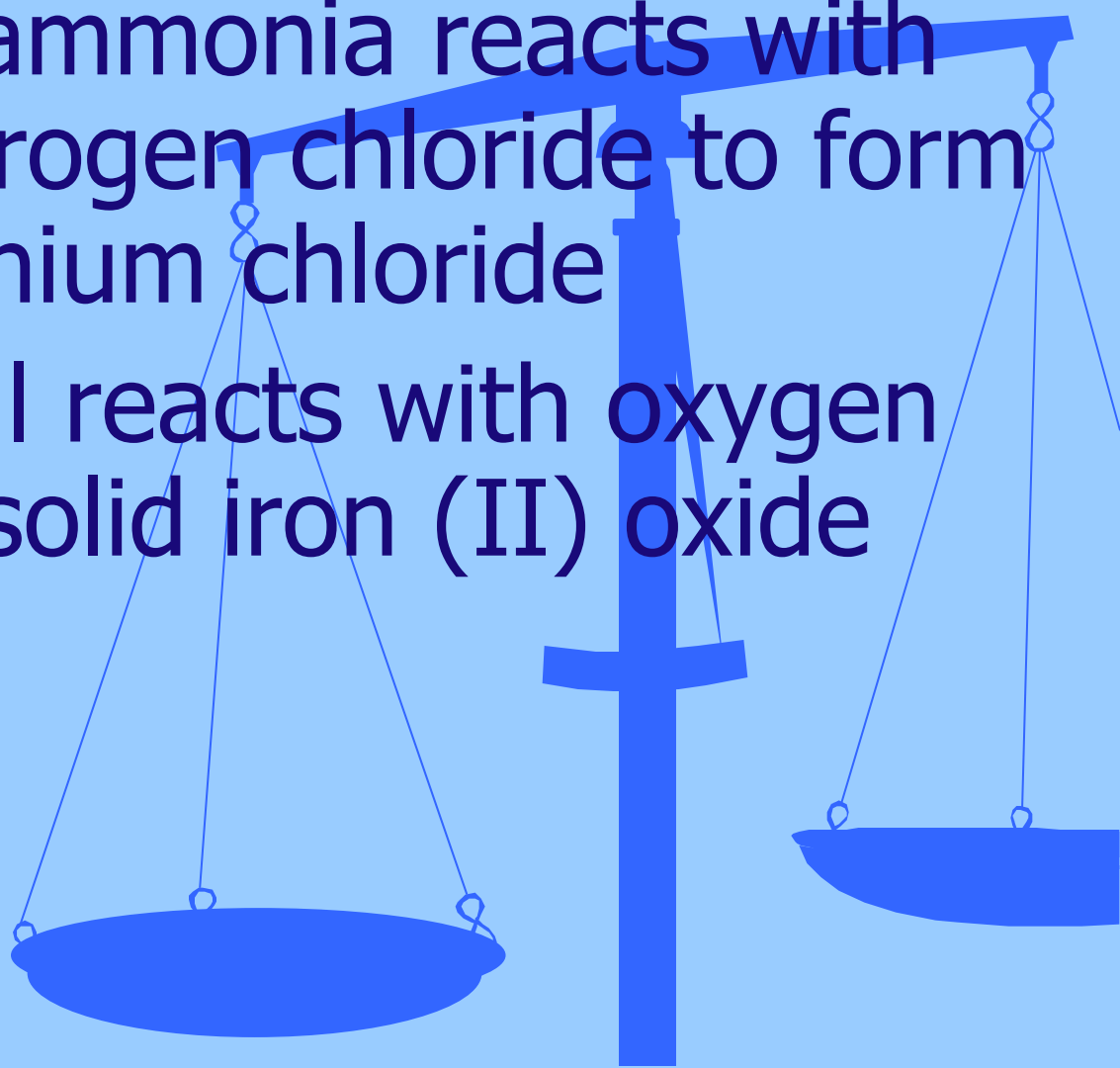
Practice

- 1) Solid mercury (II) oxide decomposes to produce liquid mercury metal and gaseous oxygen
- 2) Solid carbon reacts with gaseous oxygen to form gaseous carbon dioxide



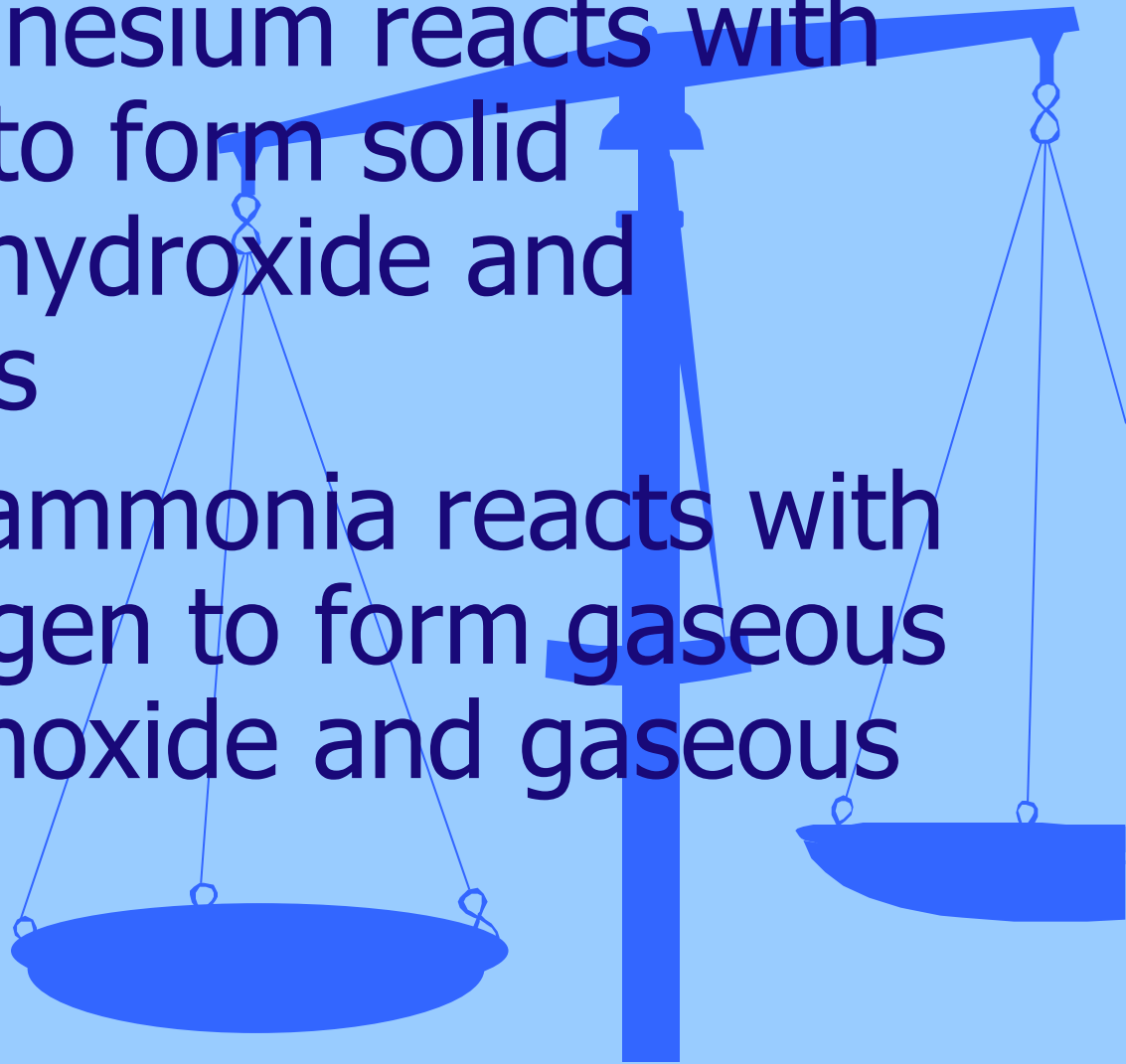
Practice

- 3) Gaseous ammonia reacts with gaseous hydrogen chloride to form solid ammonium chloride
- 4) Iron metal reacts with oxygen gas to form solid iron (II) oxide



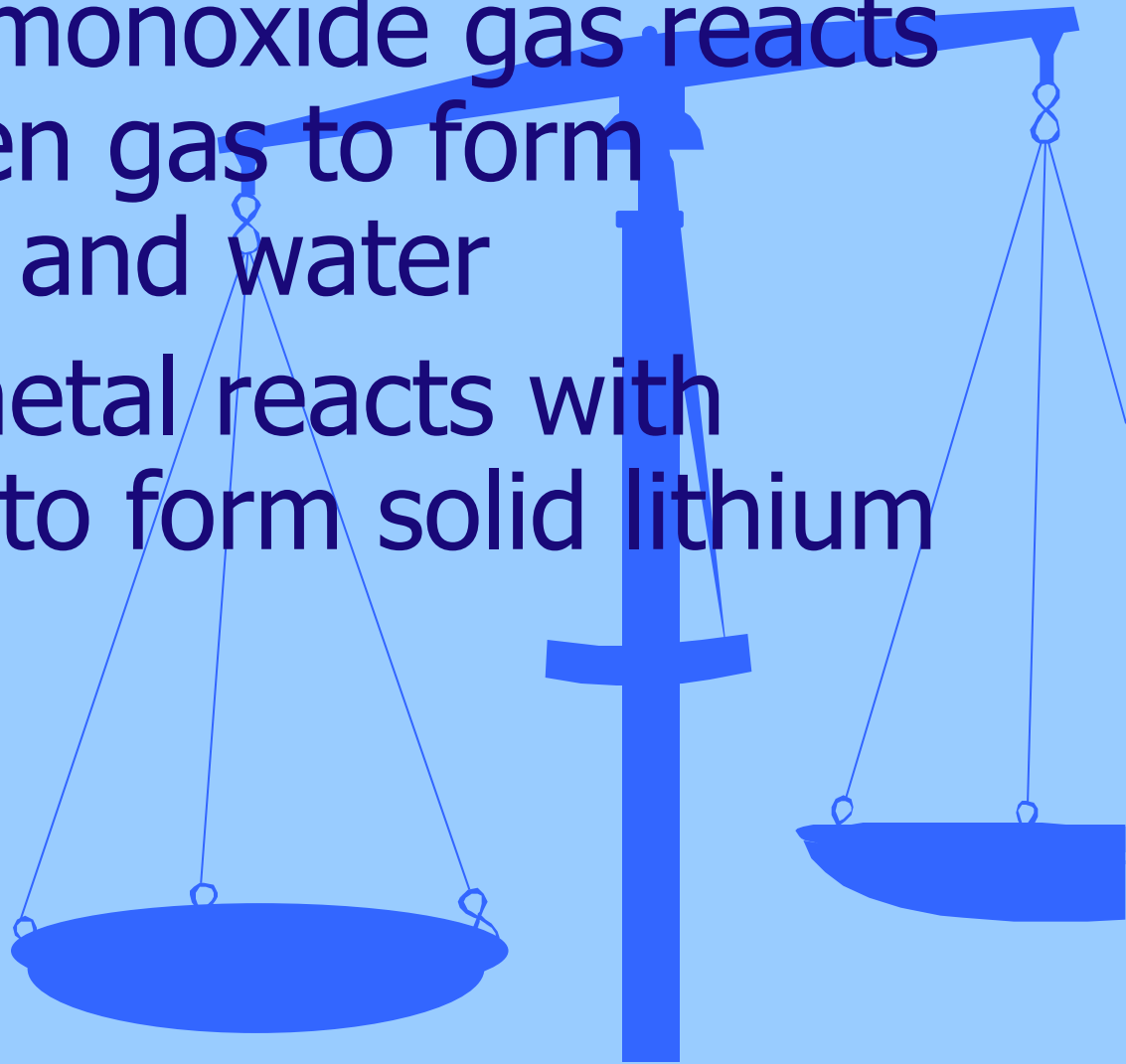
Practice

- 5) Solid magnesium reacts with liquid water to form solid magnesium hydroxide and hydrogen gas
- 6) Gaseous ammonia reacts with gaseous oxygen to form gaseous nitrogen monoxide and gaseous water



Practice

- 7) Nitrogen monoxide gas reacts with hydrogen gas to form nitrogen gas and water
- 8) Lithium metal reacts with chlorine gas to form solid lithium chloride



11.1 Section Quiz.

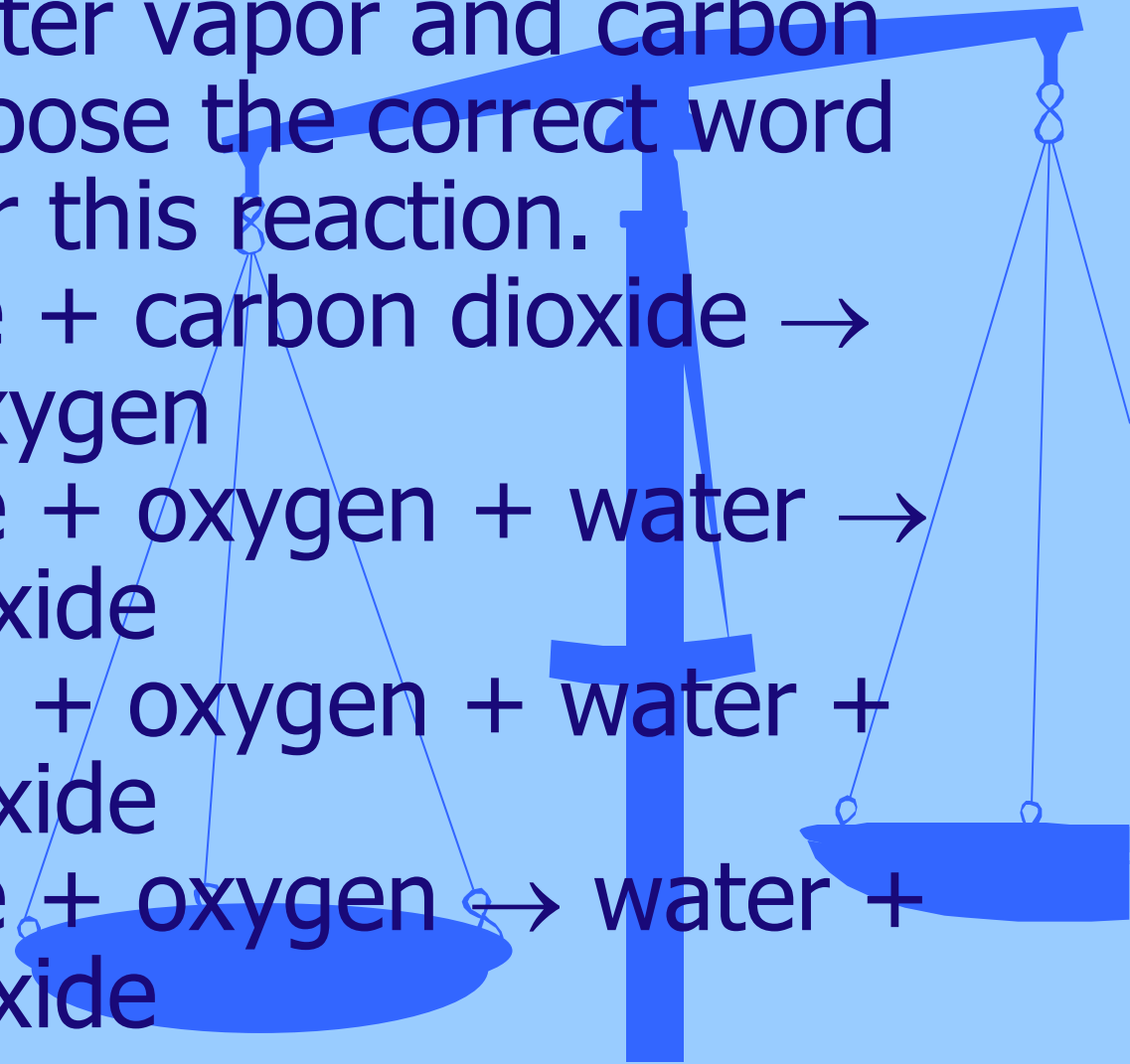
■ 1. Propane gas reacts with oxygen to produce water vapor and carbon dioxide. Choose the correct word equation for this reaction.

a) propane + carbon dioxide → water + oxygen

b) propane + oxygen + water → carbon dioxide

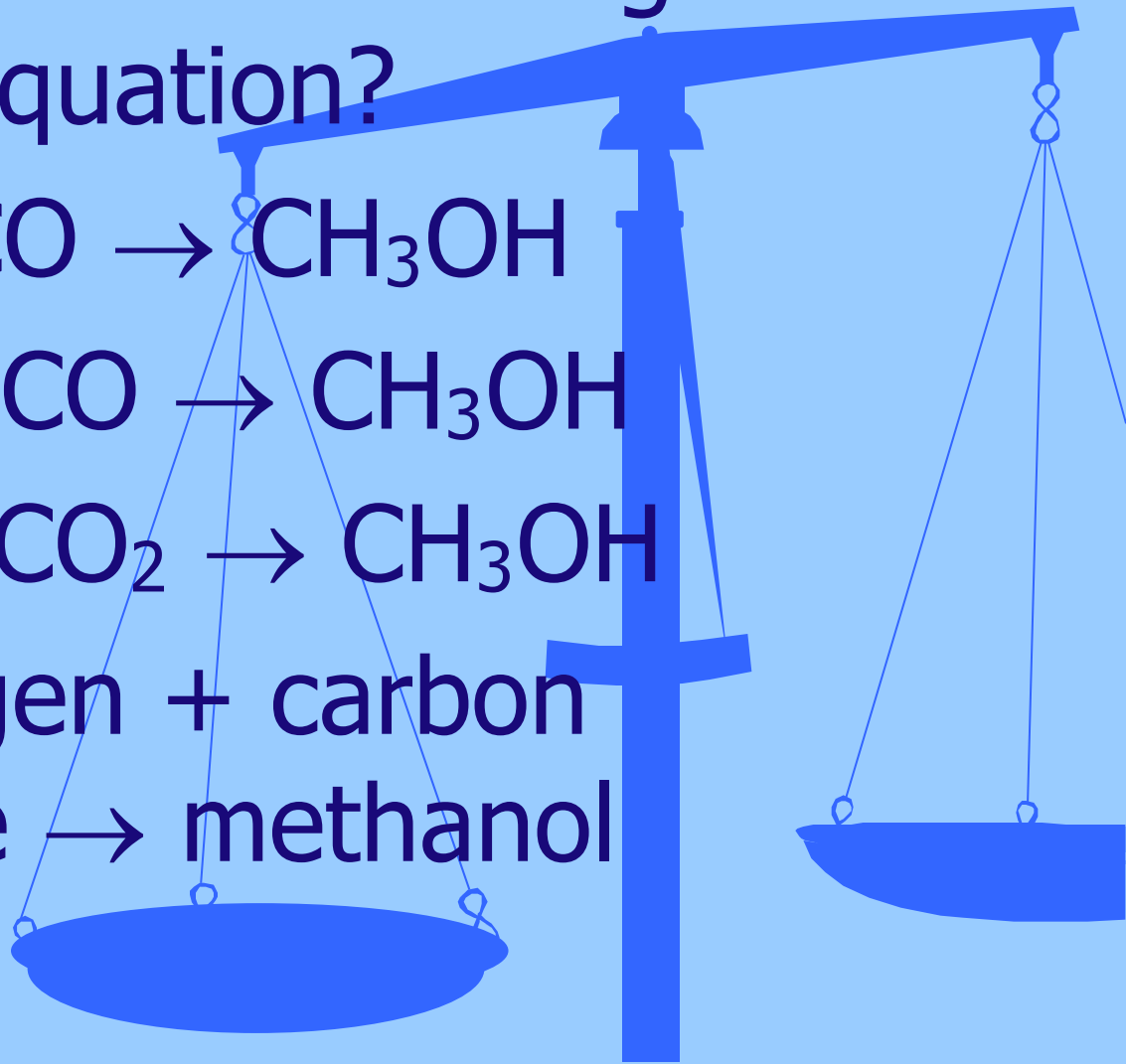
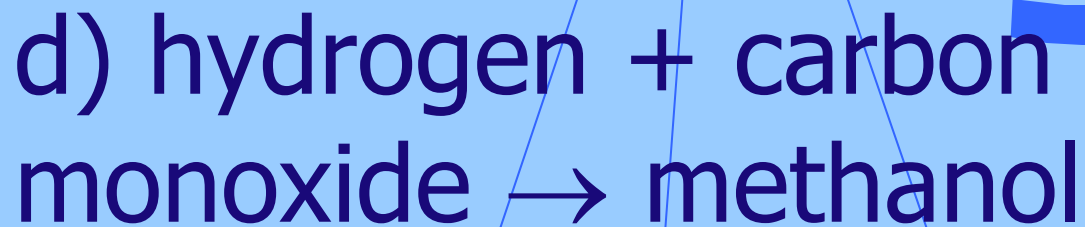
c) propane + oxygen + water + carbon dioxide

d) propane + oxygen → water + carbon dioxide



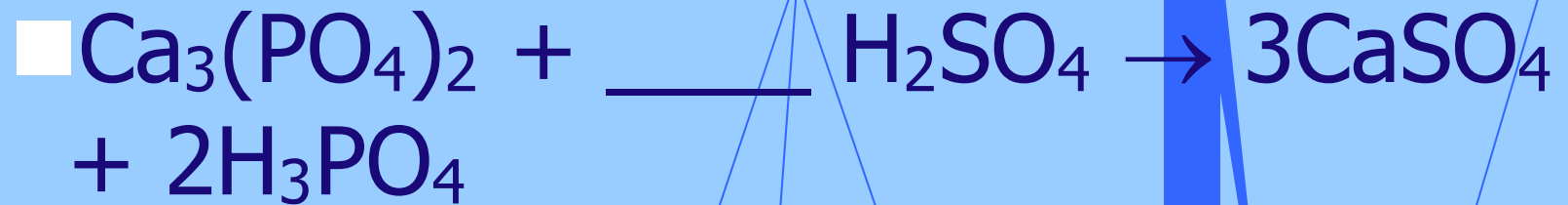
11.1 Section Quiz.

■ 2. Which of the following is a skeleton equation?



11.1 Section Quiz.

■ 3. What coefficient for H_2SO_4 is required to balance the following equation?

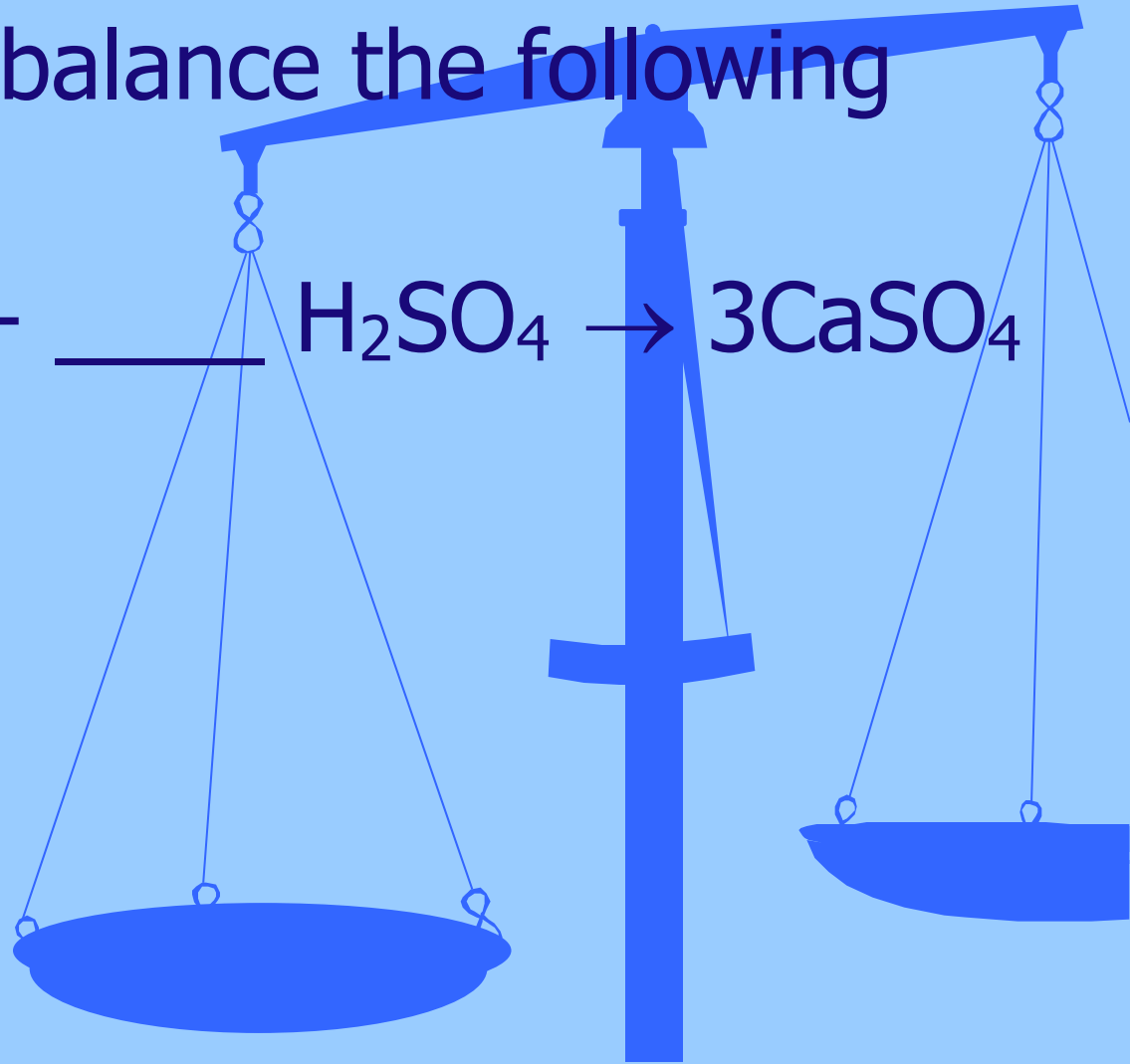


a) 1

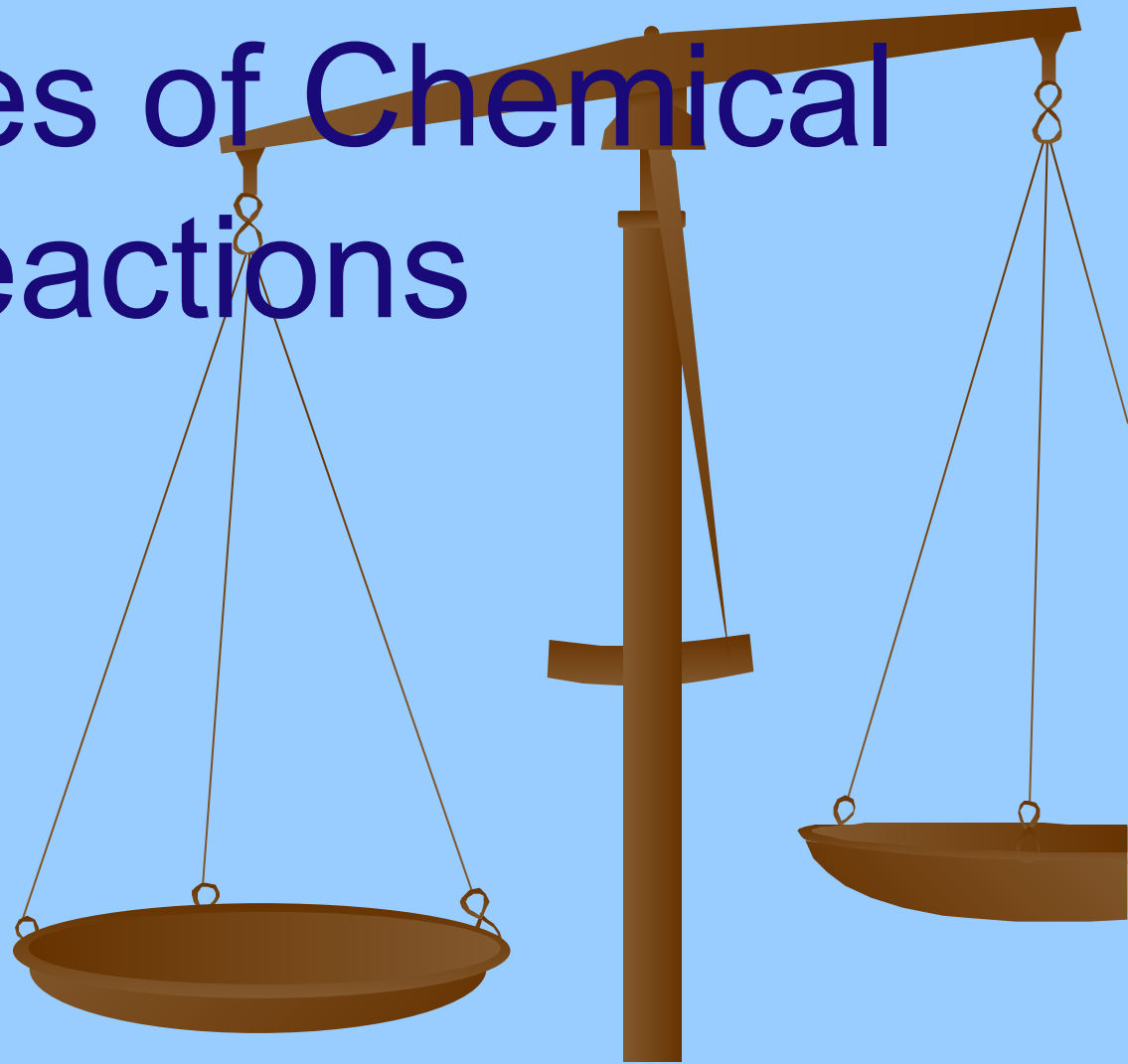
b) 2

c) 3

d) 4

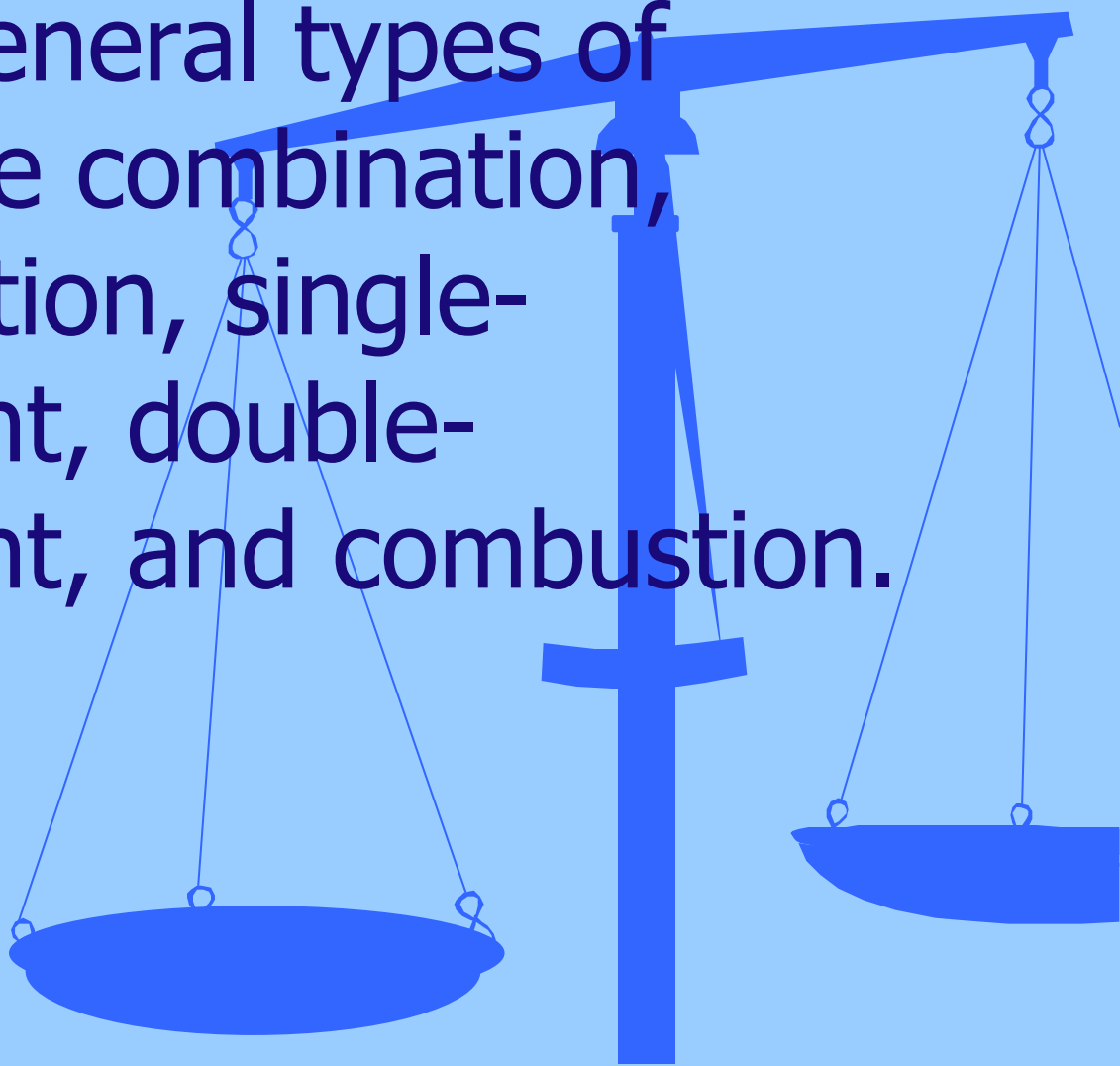


11.2 Types of Chemical Reactions



Classifying Reactions

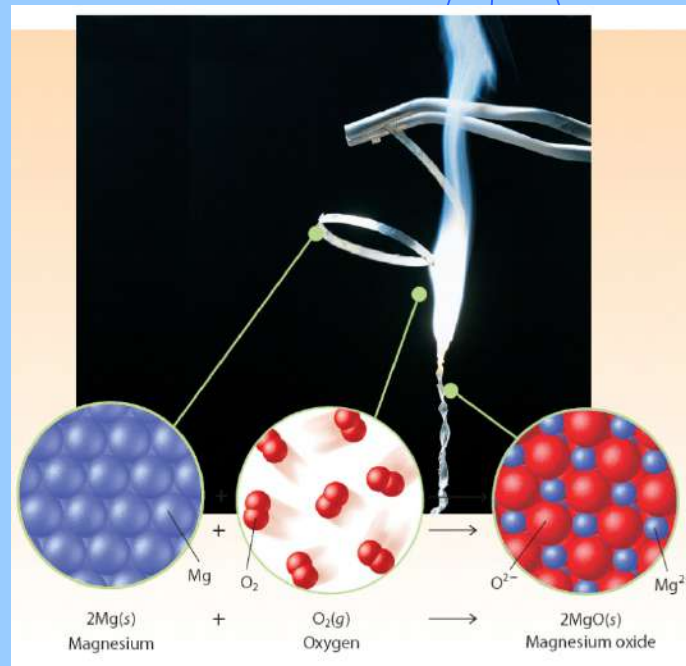
- The five general types of reaction are combination, decomposition, single-replacement, double-replacement, and combustion.



11.2

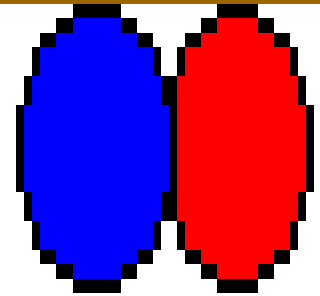
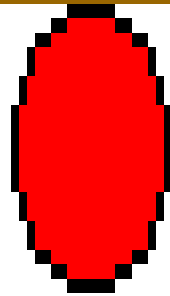
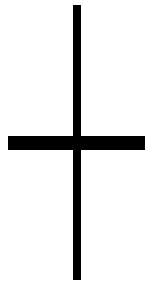
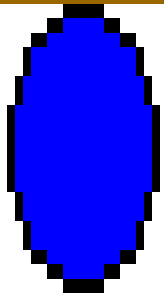
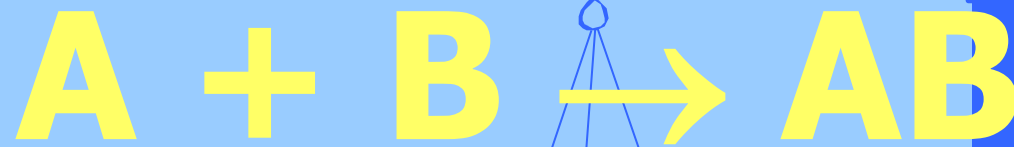
Classifying Reactions

- A **combination (synthesis) reaction** is a chemical change in which two or more substances react to form a single new substance.



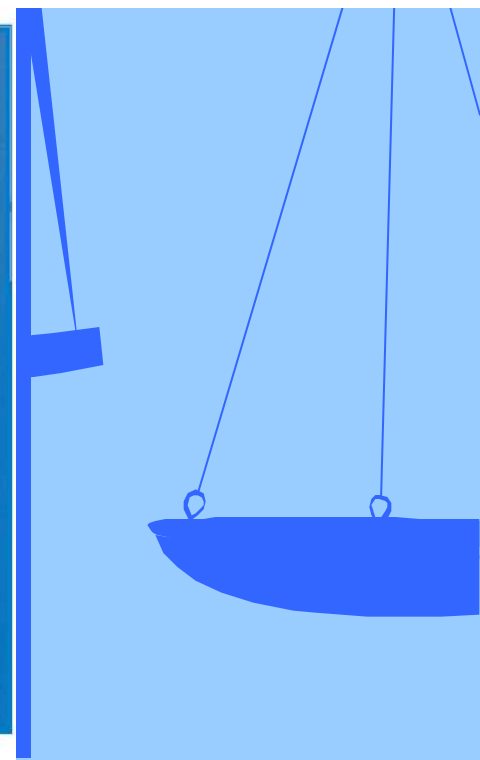
Combination

- only one product



Writing Equations for Combination Reactions

Copper and sulfur, shown in the photo, are the reactants in a combination reaction. Complete the equation for the reaction.

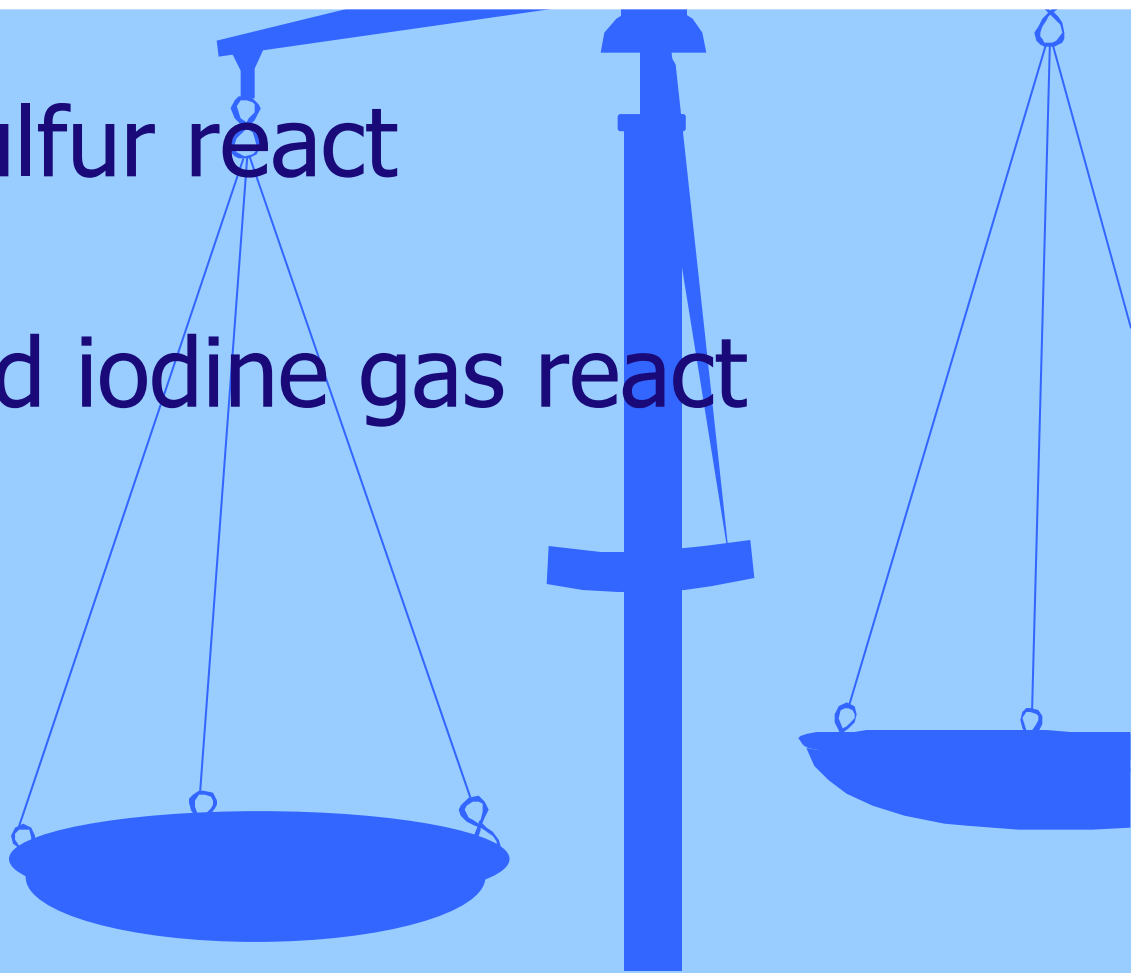


for Conceptual Problem 11.4

14. Write and balance the equation for the formation of magnesium nitride (Mg_3N_2) from its elements.

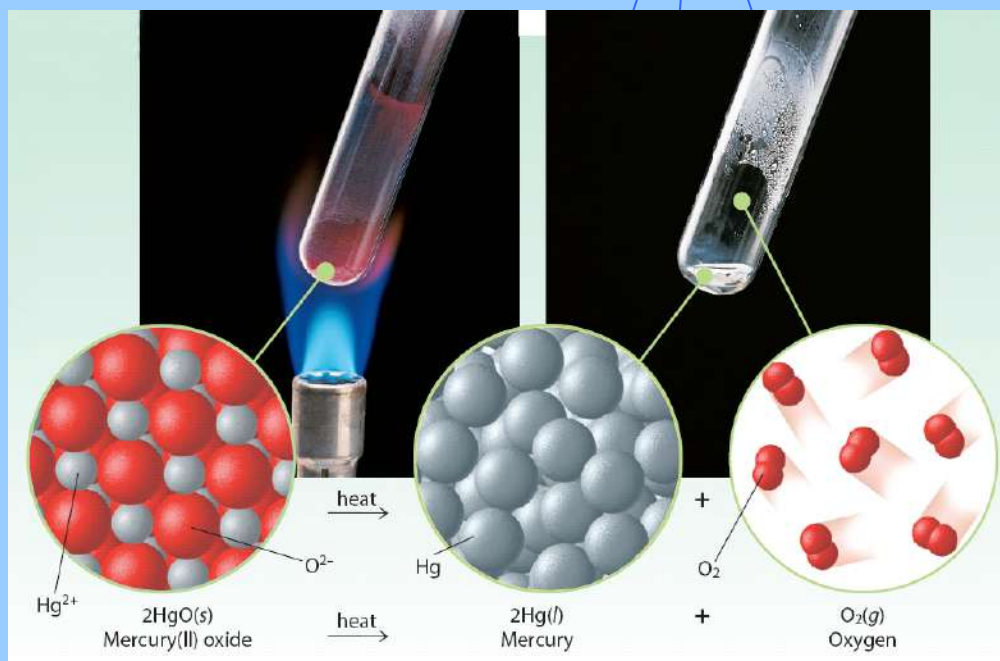
Aluminum and sulfur react

Sodium metal and iodine gas react



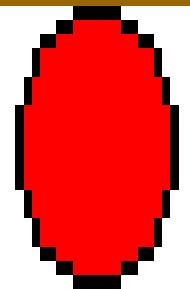
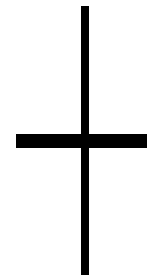
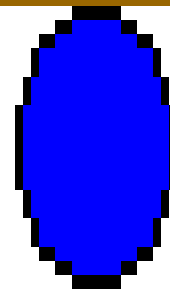
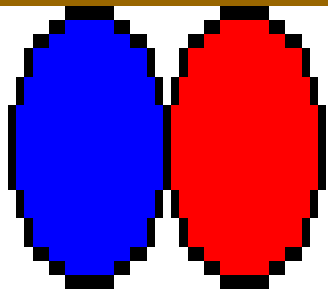
Classifying Reactions

- A **decomposition reaction** is a chemical change in which a single compound breaks down into two or more simpler products.



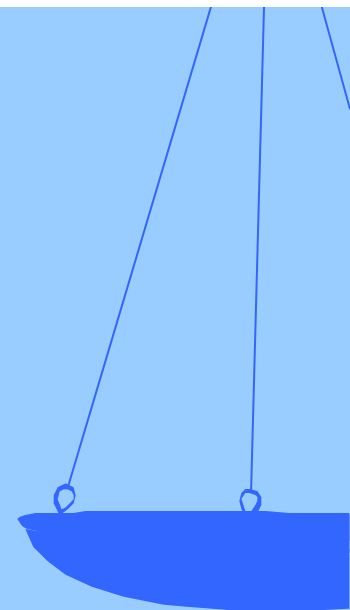
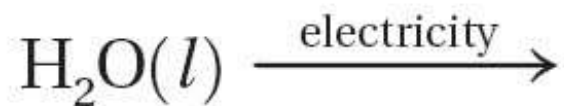
Decomposition

- only one reactant



Writing the Equation for a Decomposition Reaction

Decomposition reactions that produce gases and heat are sometimes explosive, as the photo shows. Write a balanced equation for the following decomposition reaction.



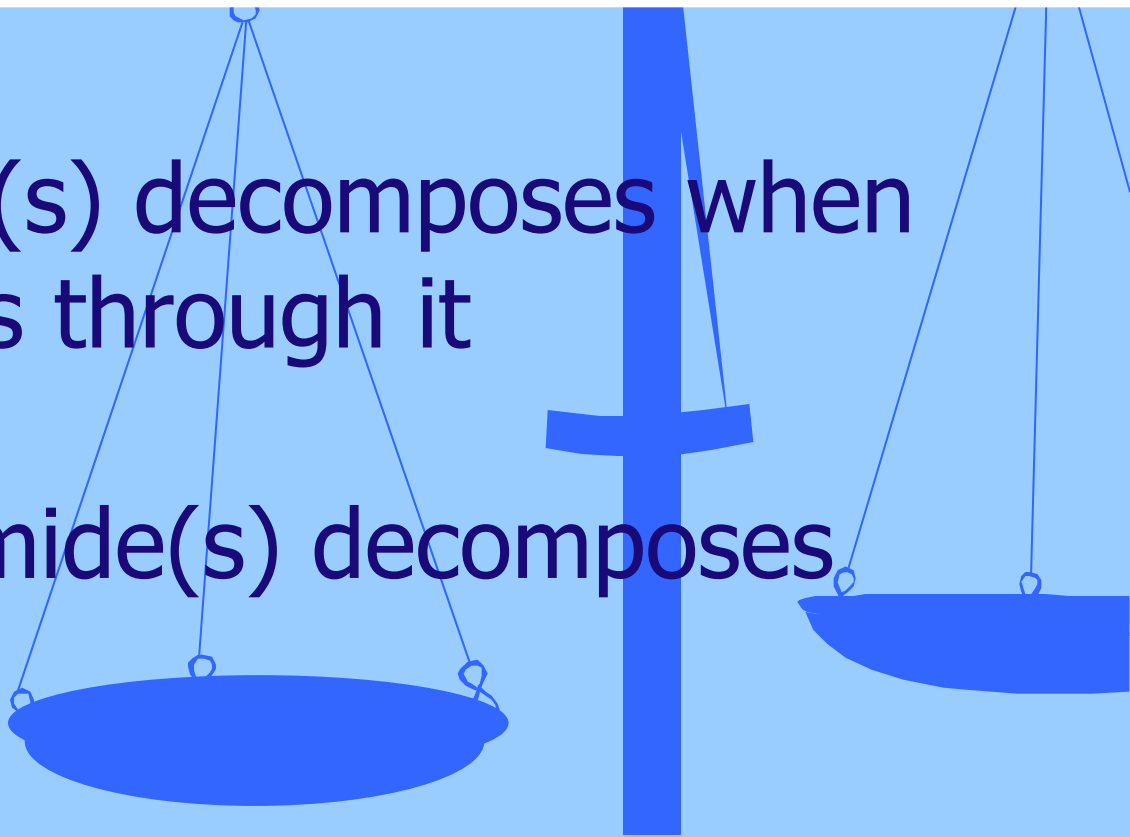
for Conceptual Problem 11.5

15. Complete and balance this decomposition reaction.



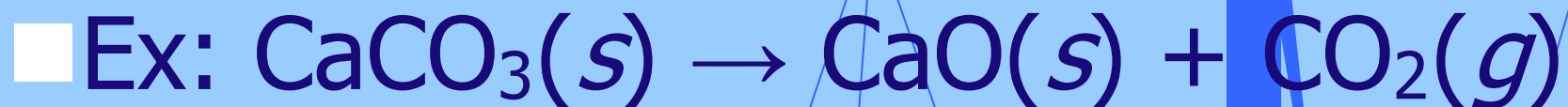
Aluminum oxide(s) decomposes when electricity passes through it

Magnesium bromide(s) decomposes

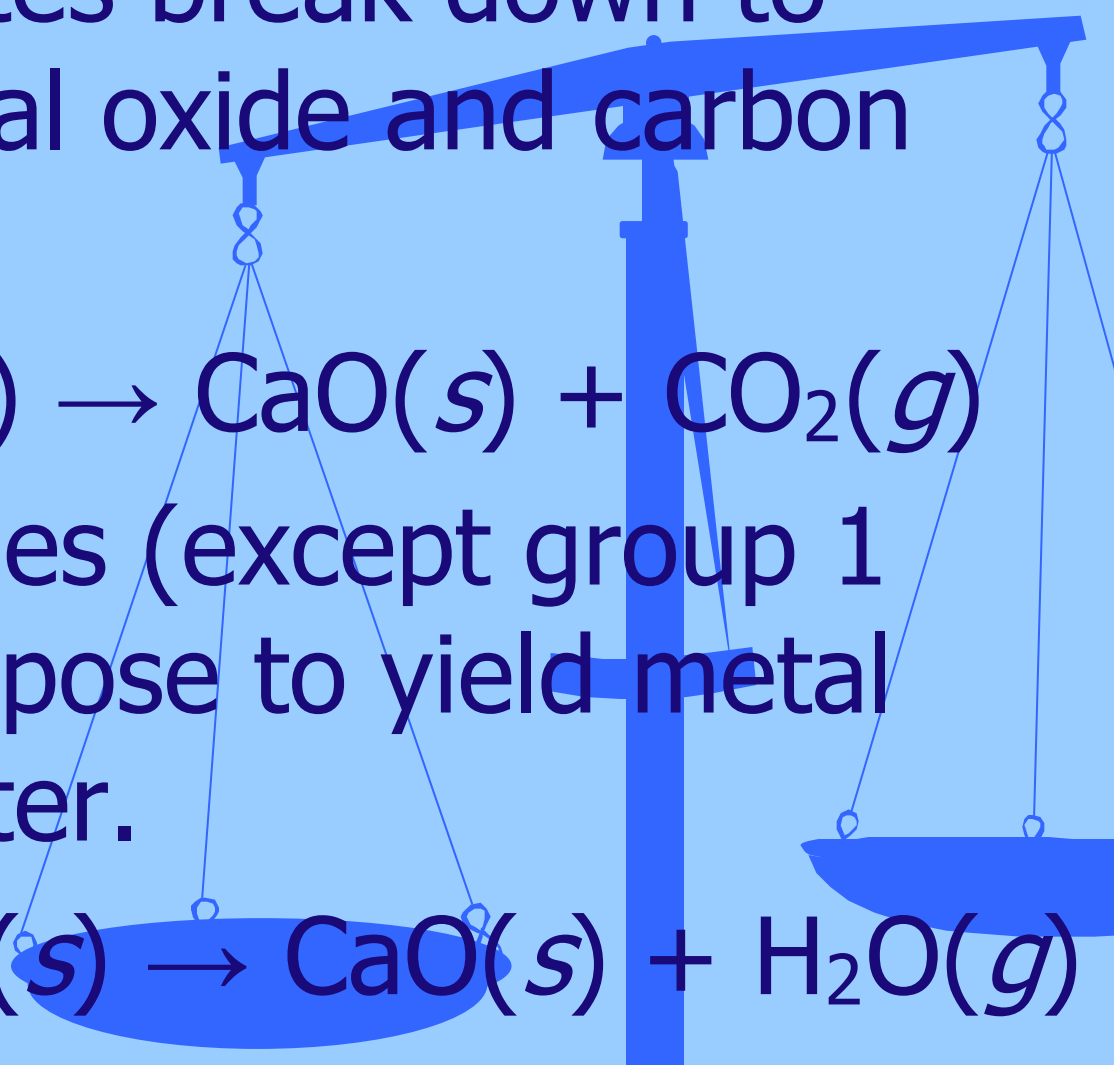


Decomposition Patterns

- Metal carbonates break down to produce a metal oxide and carbon dioxide gas.

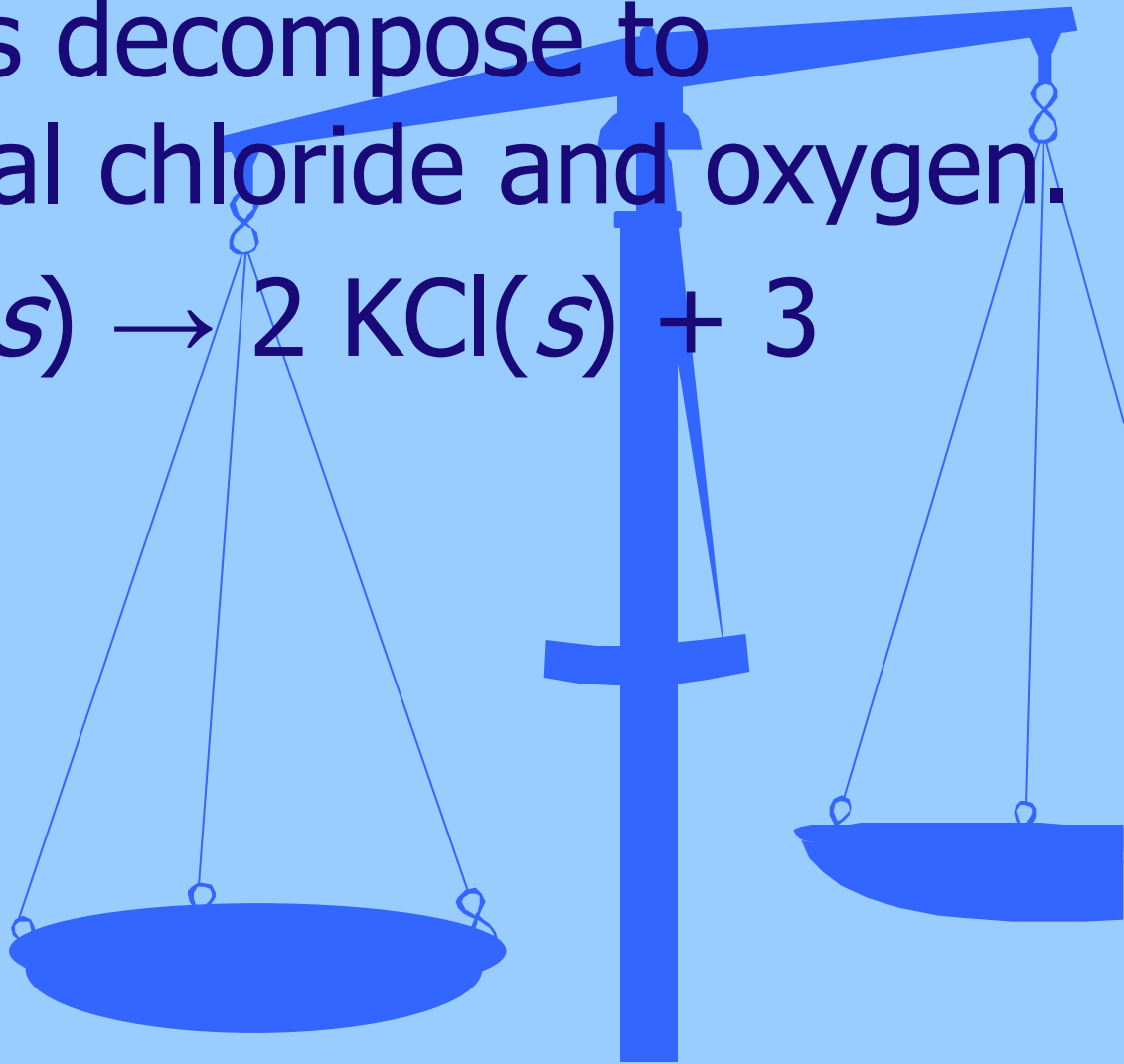
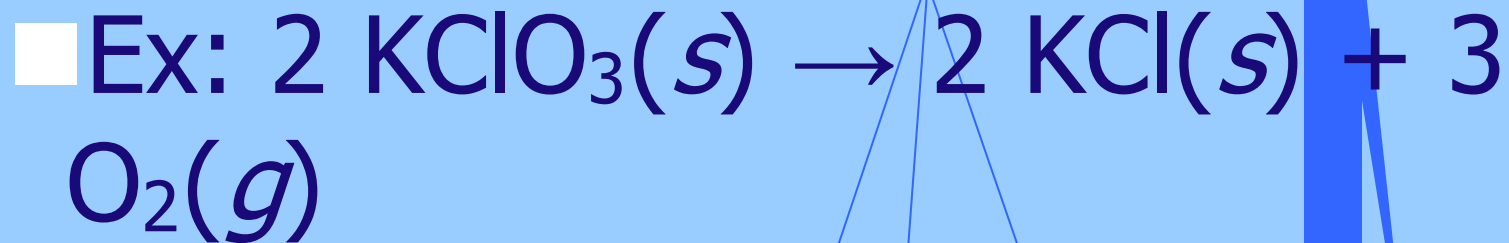


- Metal hydroxides (except group 1 metals) decompose to yield metal oxides and water.



Decomposition Patterns

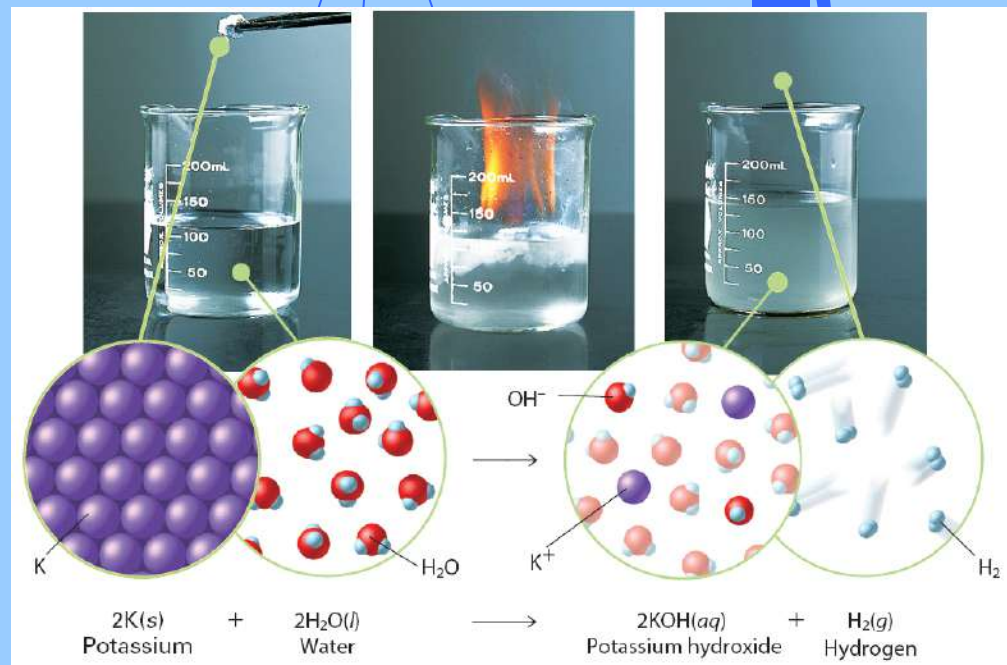
■ Metal chlorates decompose to produce a metal chloride and oxygen.



11.2

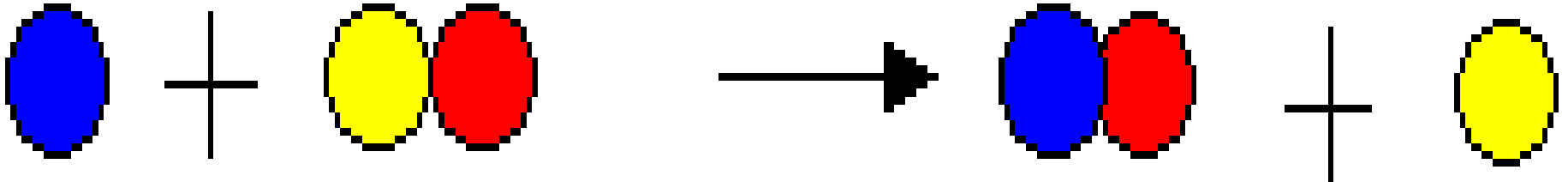
Classifying Reactions

- A **single-replacement reaction** is a chemical change in which one element replaces a second element in a compound.



Single Replacement

- metal replaces metal
- nonmetal replaces nonmetal



11.2

Classifying Reactions

- The **activity series** of metals lists metals in order of decreasing reactivity.

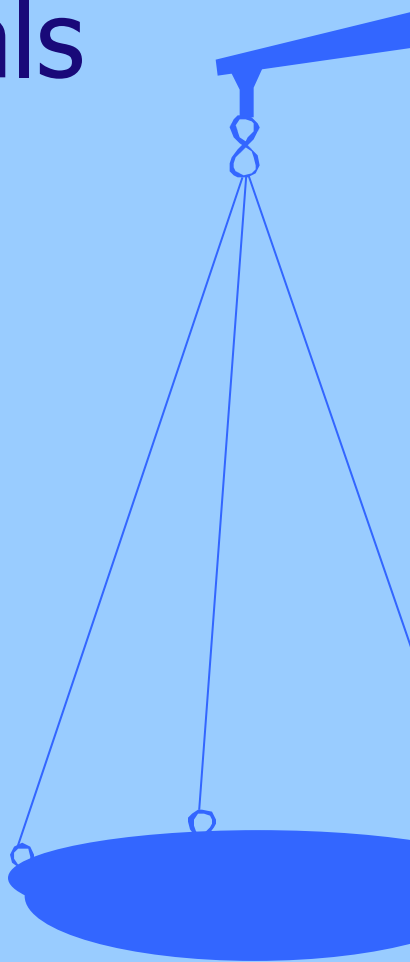


Table 11.2

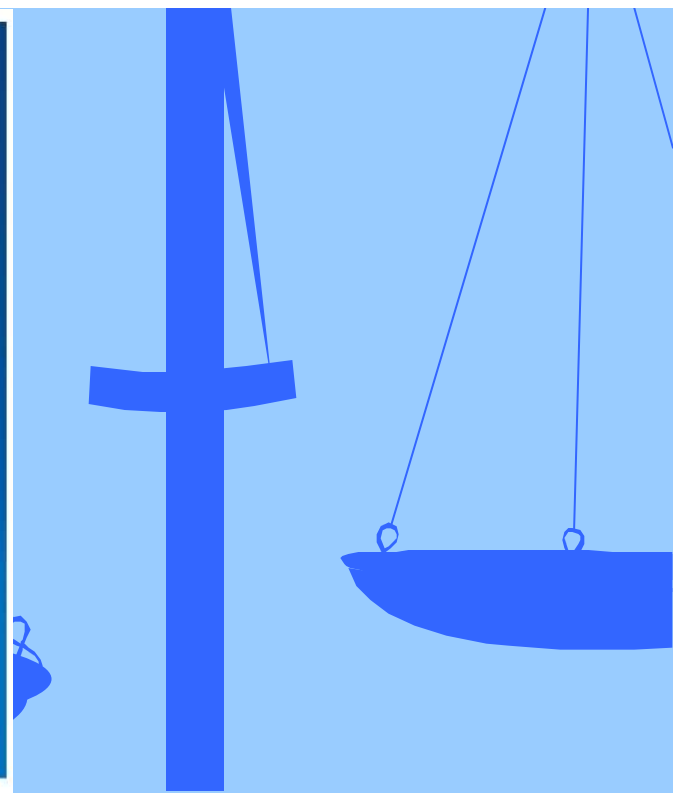
Activity Series of Metals

| | Name | Symbol |
|----------------------------|------------|--------|
| Decreasing reactivity ↓ | Lithium | Li |
| | Potassium | K |
| | Calcium | Ca |
| | Sodium | Na |
| | Magnesium | Mg |
| | Aluminum | Al |
| | Zinc | Zn |
| | Iron | Fe |
| | Lead | Pb |
| | (Hydrogen) | (H)* |
| | Copper | Cu |
| | Mercury | Hg |
| | Silver | Ag |

*Metals from Li to Na will replace H from acids and water; from Mg to Pb they will replace H from acids only.

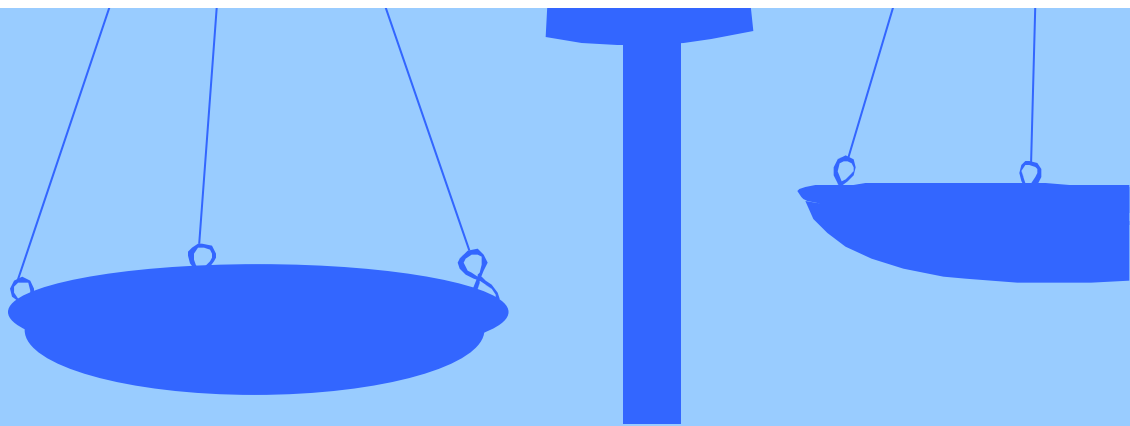
Writing Equations for Single-Replacement Reactions

The photo shows the reaction between $\text{Zn}(s)$ and $\text{H}_2\text{SO}_4(aq)$. Write a balanced chemical equation for each single-replacement reaction. The reactions take place in aqueous solution.



for Conceptual Problem 11.6

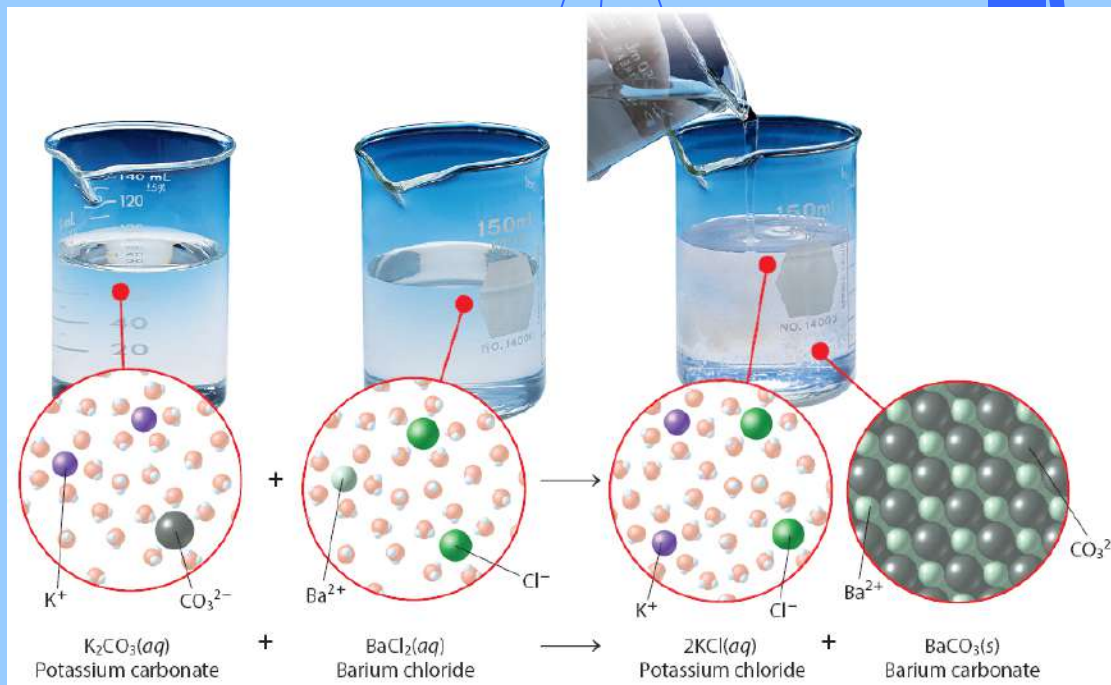
17. Complete the equations for these single-replacement reactions in aqueous solution. Balance each equation. Write “no reaction” if a reaction does not occur.



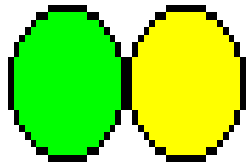
11.2

Classifying Reactions

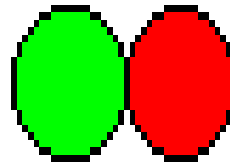
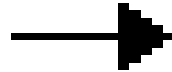
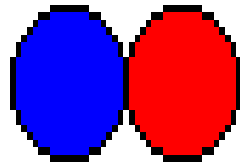
- A **double-replacement reaction** is a chemical change involving an exchange of positive ions between two compounds.



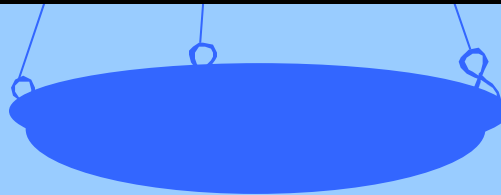
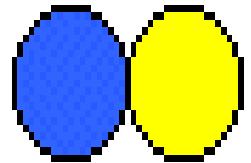
Double Replacement



+



+

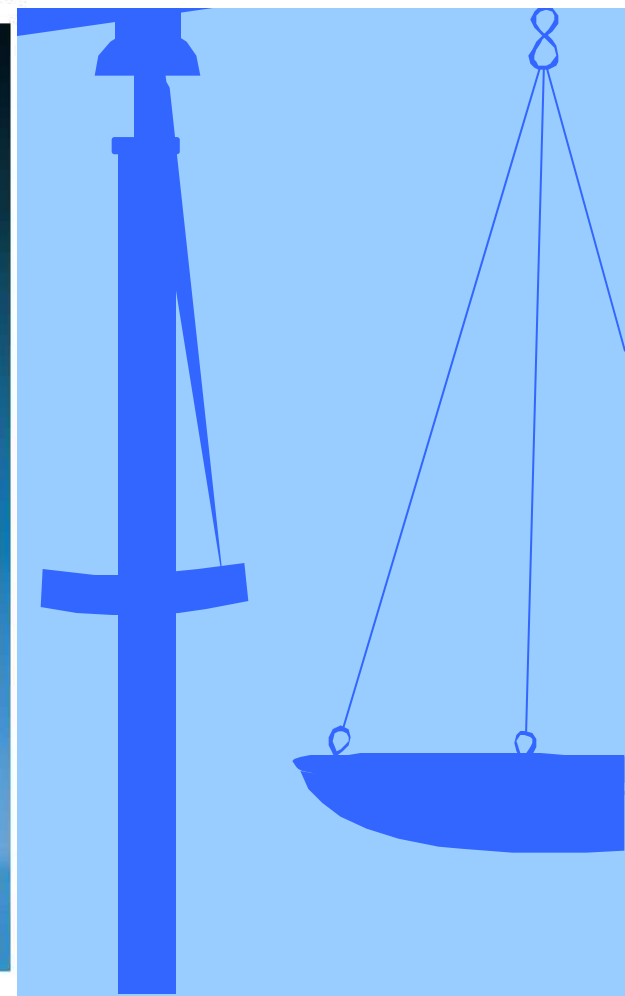


Writing Equations for Double-Replacement Reactions

Write a balanced chemical equation for each double-replacement reaction.

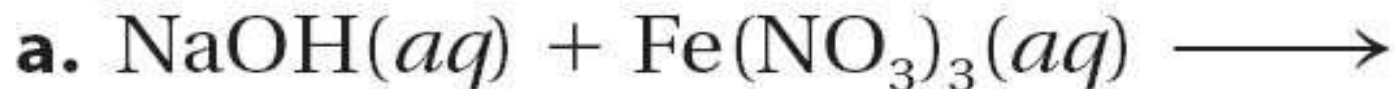
a. $\text{CaBr}_2(aq) + \text{AgNO}_3(aq) \longrightarrow$ (A precipitate of silver bromide is formed.)

b. $\text{FeS}(s) + \text{HCl}(aq) \longrightarrow$ (Hydrogen sulfide gas (H_2S) is formed.)

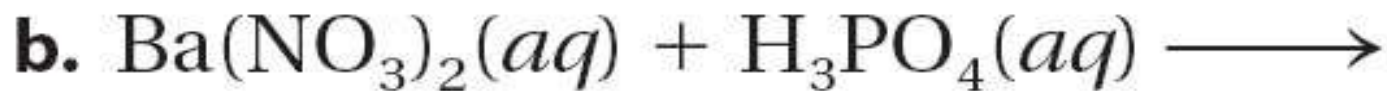


for Conceptual Problem 11.7

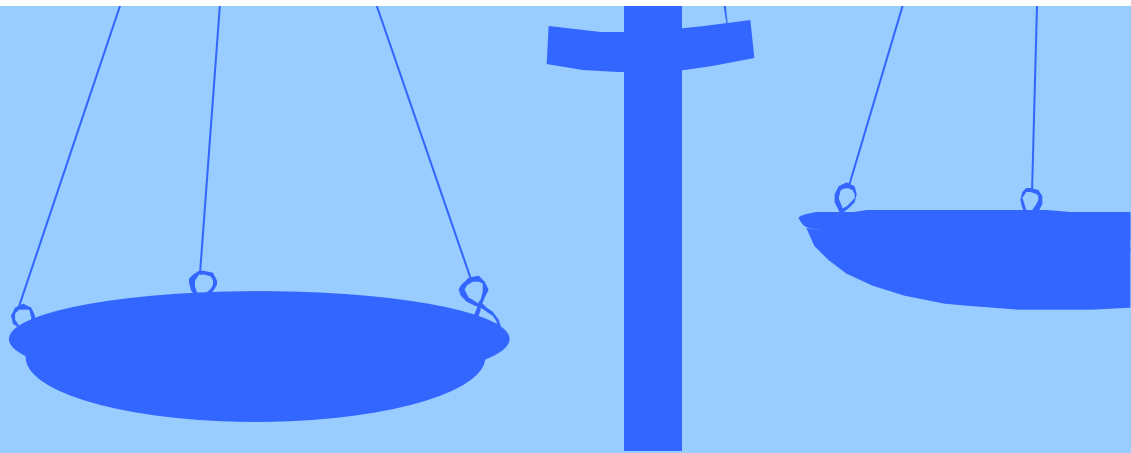
18. Write the products of these double-replacement reactions. Then balance each equation.



(Iron(III) hydroxide is a precipitate.)



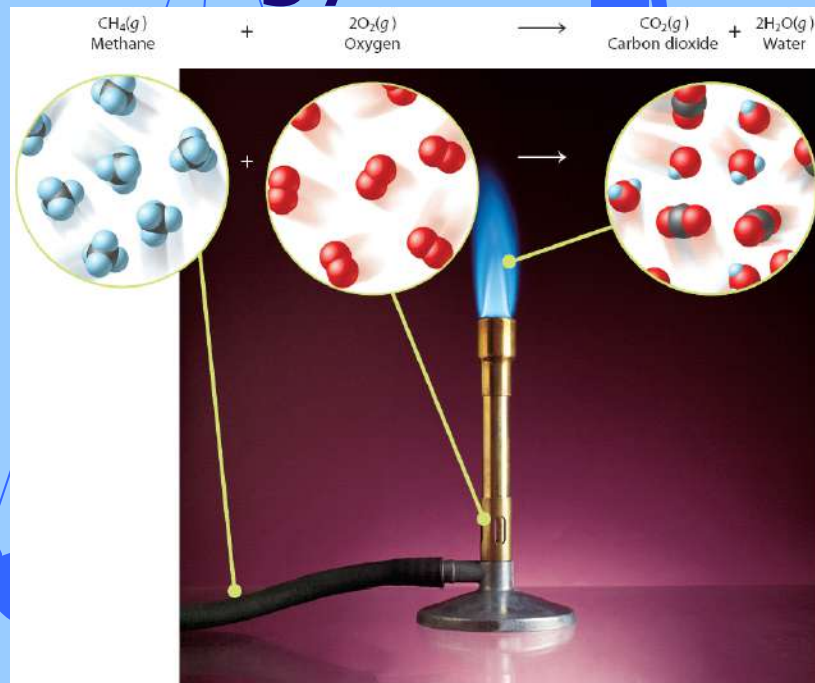
(Barium phosphate is a precipitate.)



11.2

Classifying Reactions

- A **combustion reaction** is a chemical change in which an element or a compound reacts with oxygen, often producing energy in the form of heat and light.

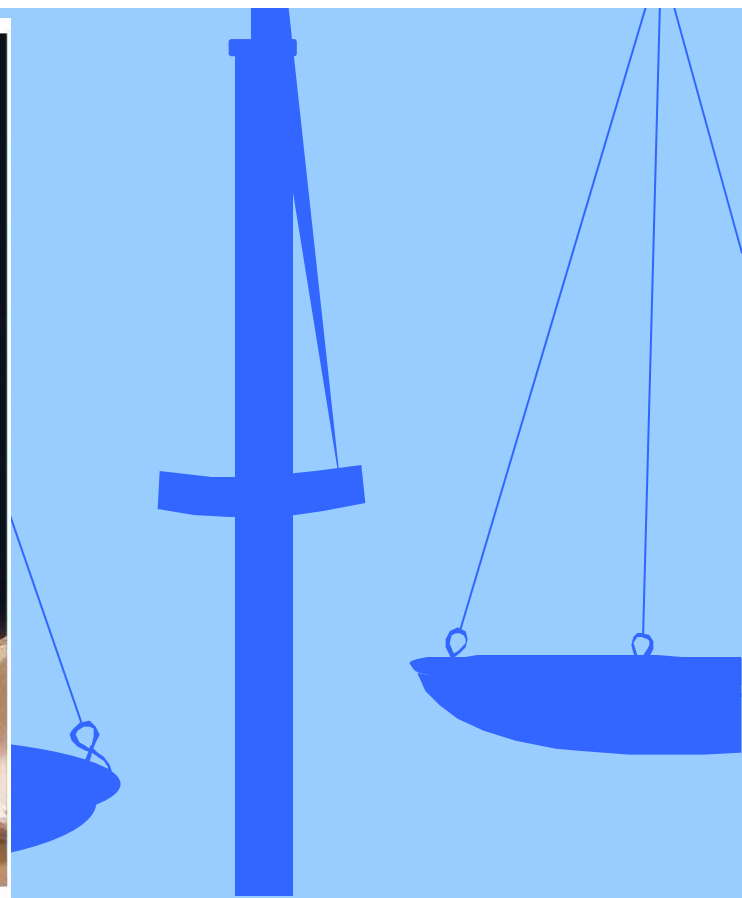


Writing Equations for Combustion Reactions

An alcohol lamp often uses ethanol as its fuel. Write balanced equations for the complete combustion of these compounds.

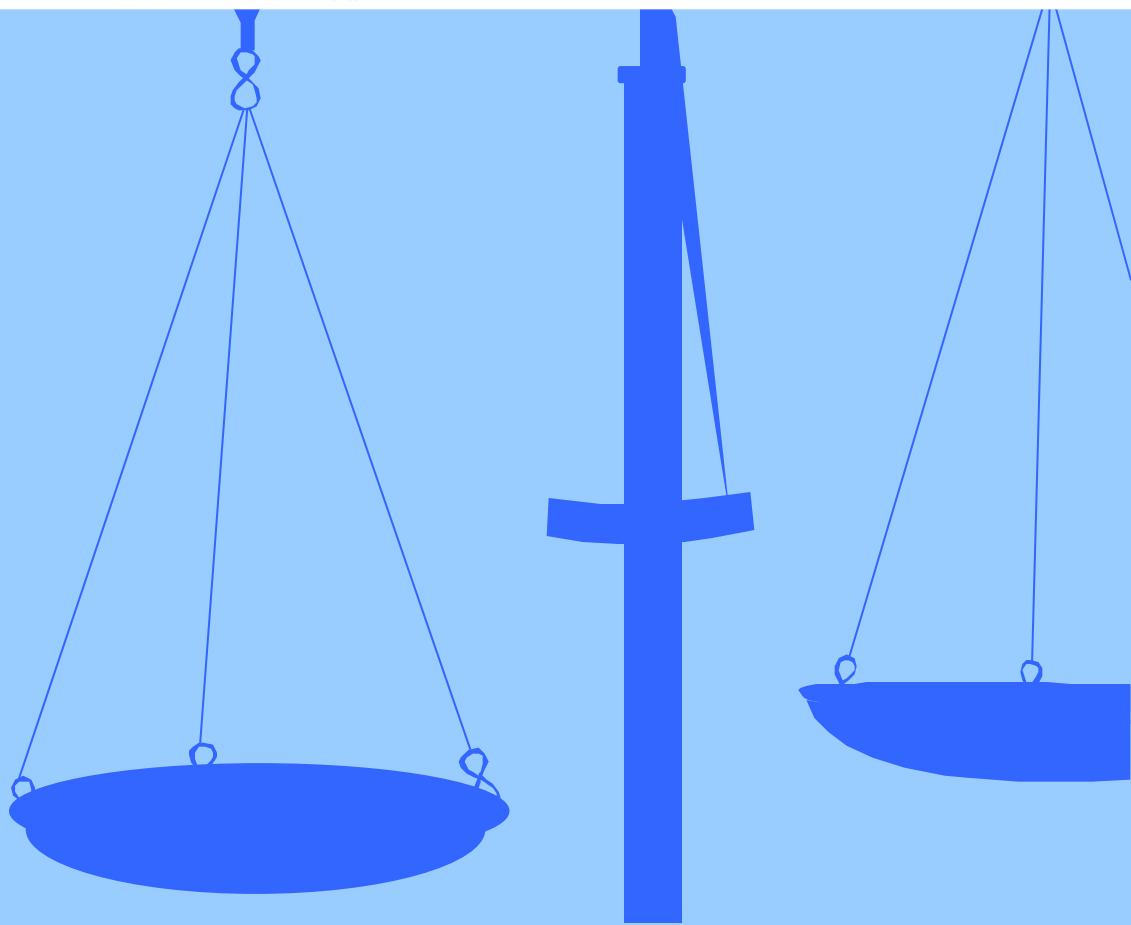
a. benzene ($\text{C}_6\text{H}_6(l)$)

b. ethanol ($\text{CH}_3\text{CH}_2\text{OH}(l)$)

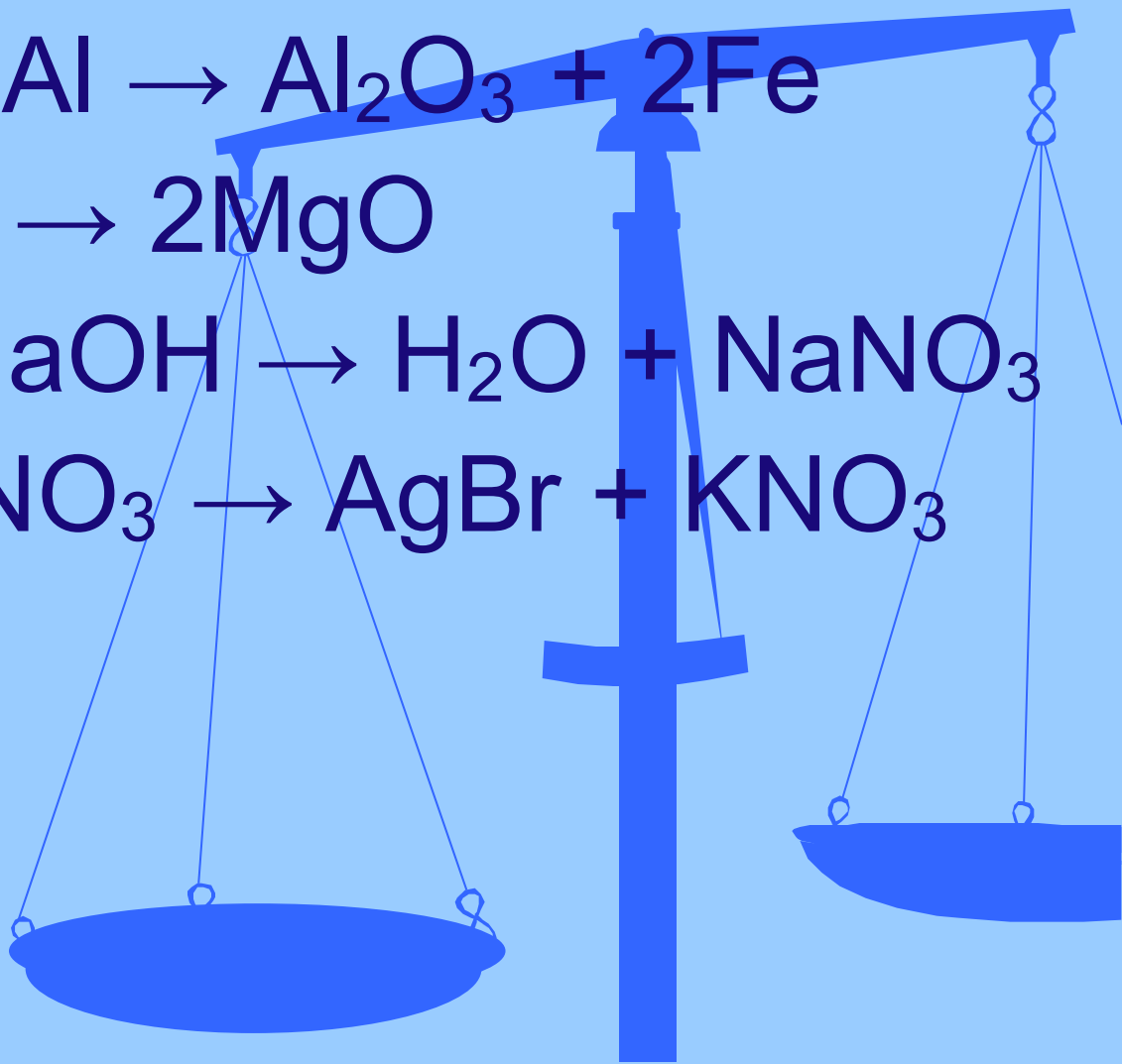


for Conceptual Problem 11.8

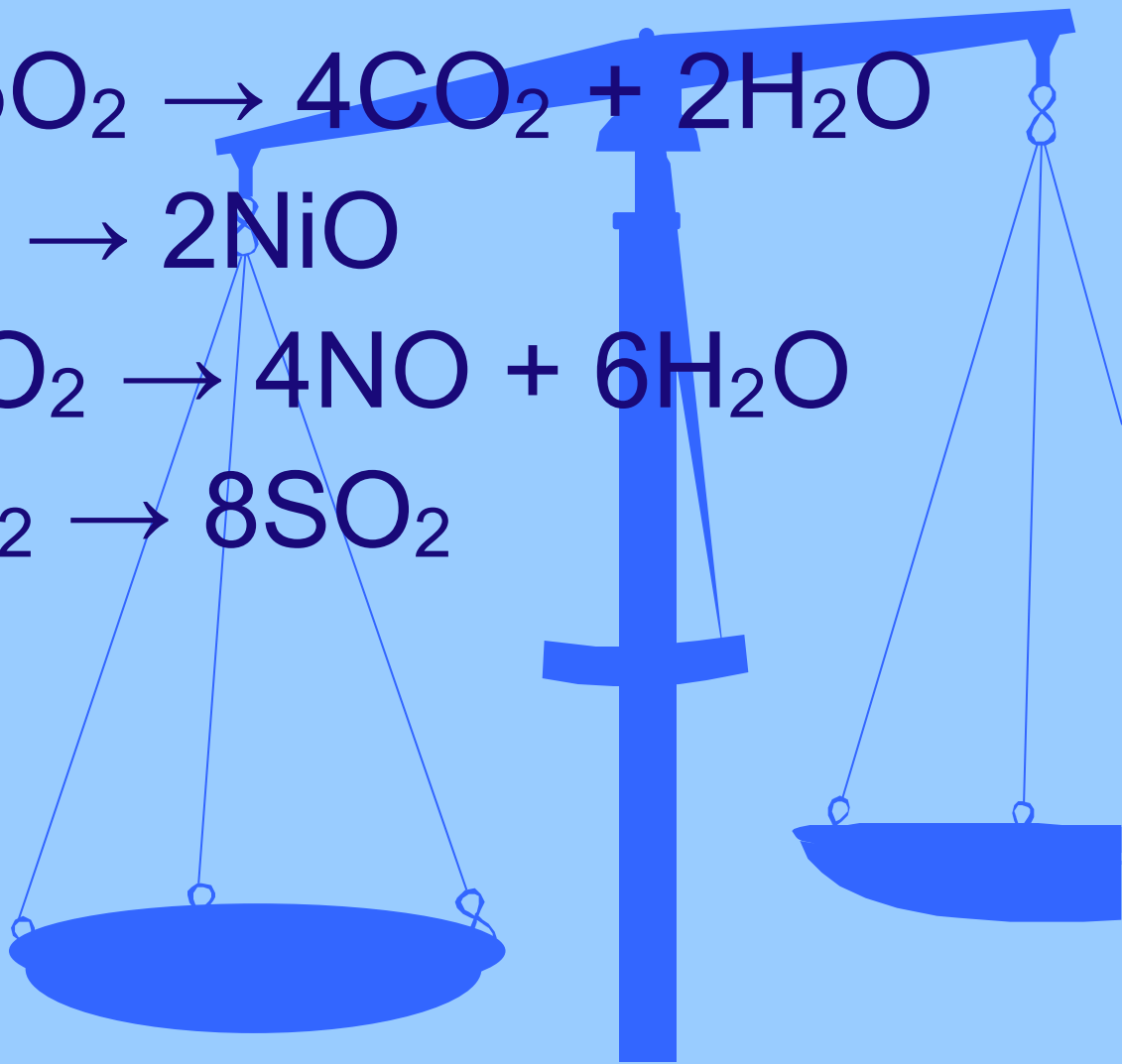
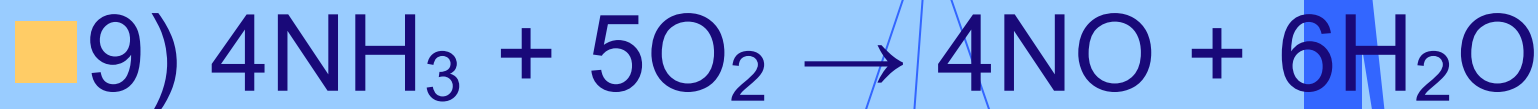
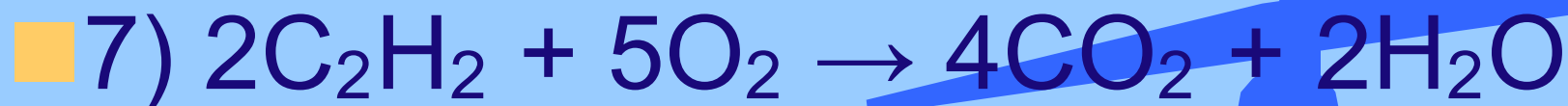
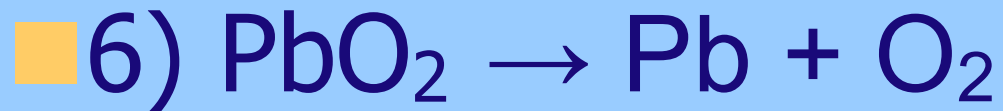
21. Write a balanced equation for the complete combustion of glucose ($\text{C}_6\text{H}_{12}\text{O}_6$).



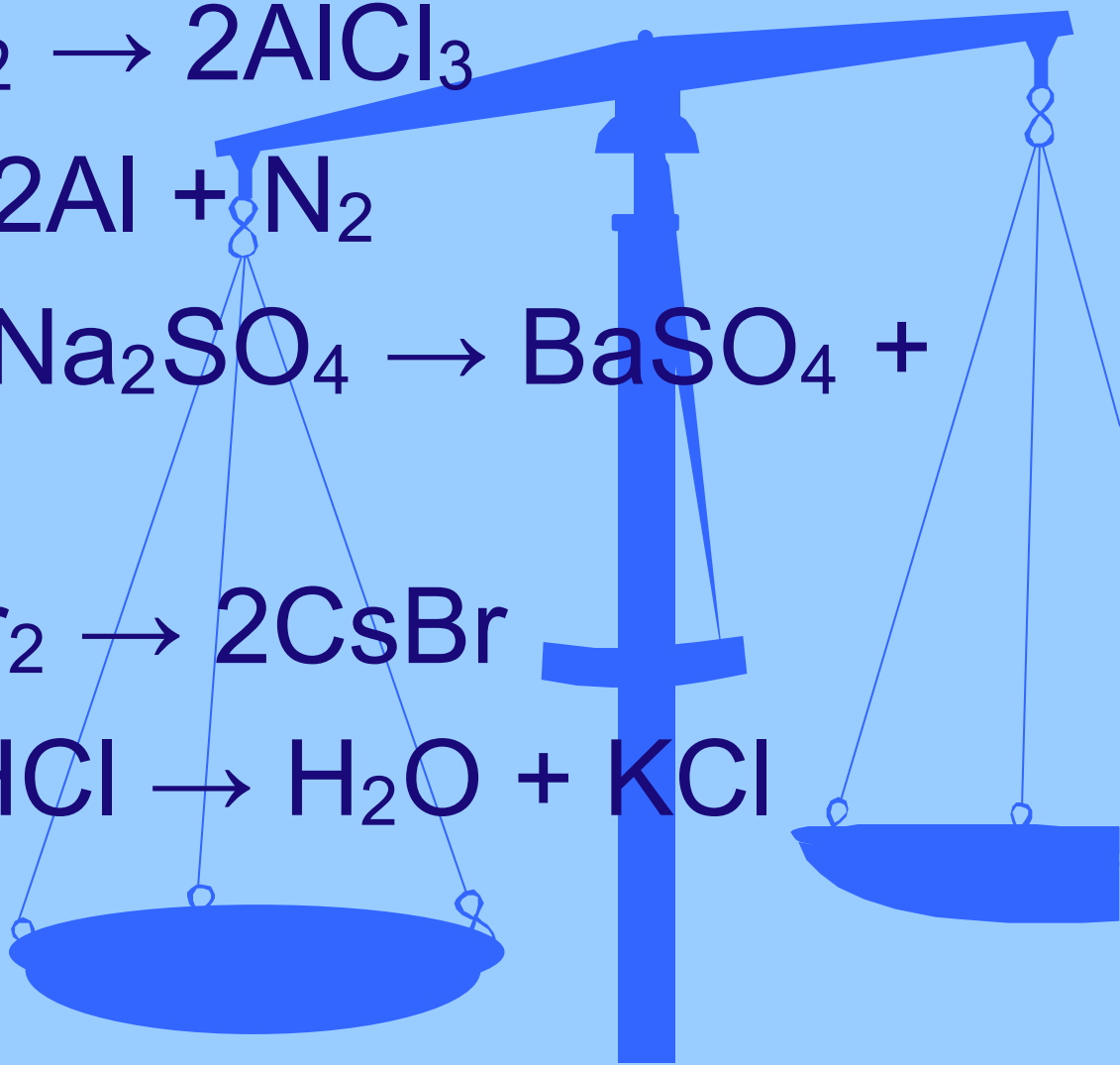
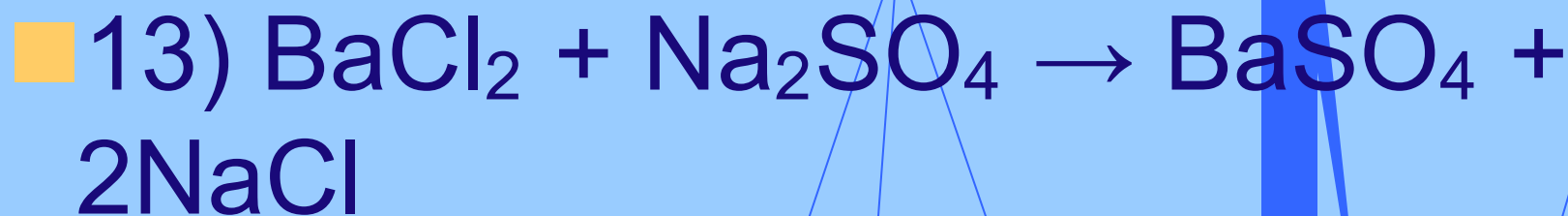
Classify



Classify

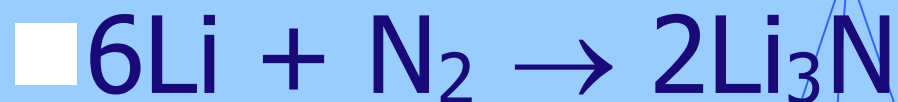


Classify



11.2 Section Quiz.

■ 1. What type of reaction is described by the following equation?

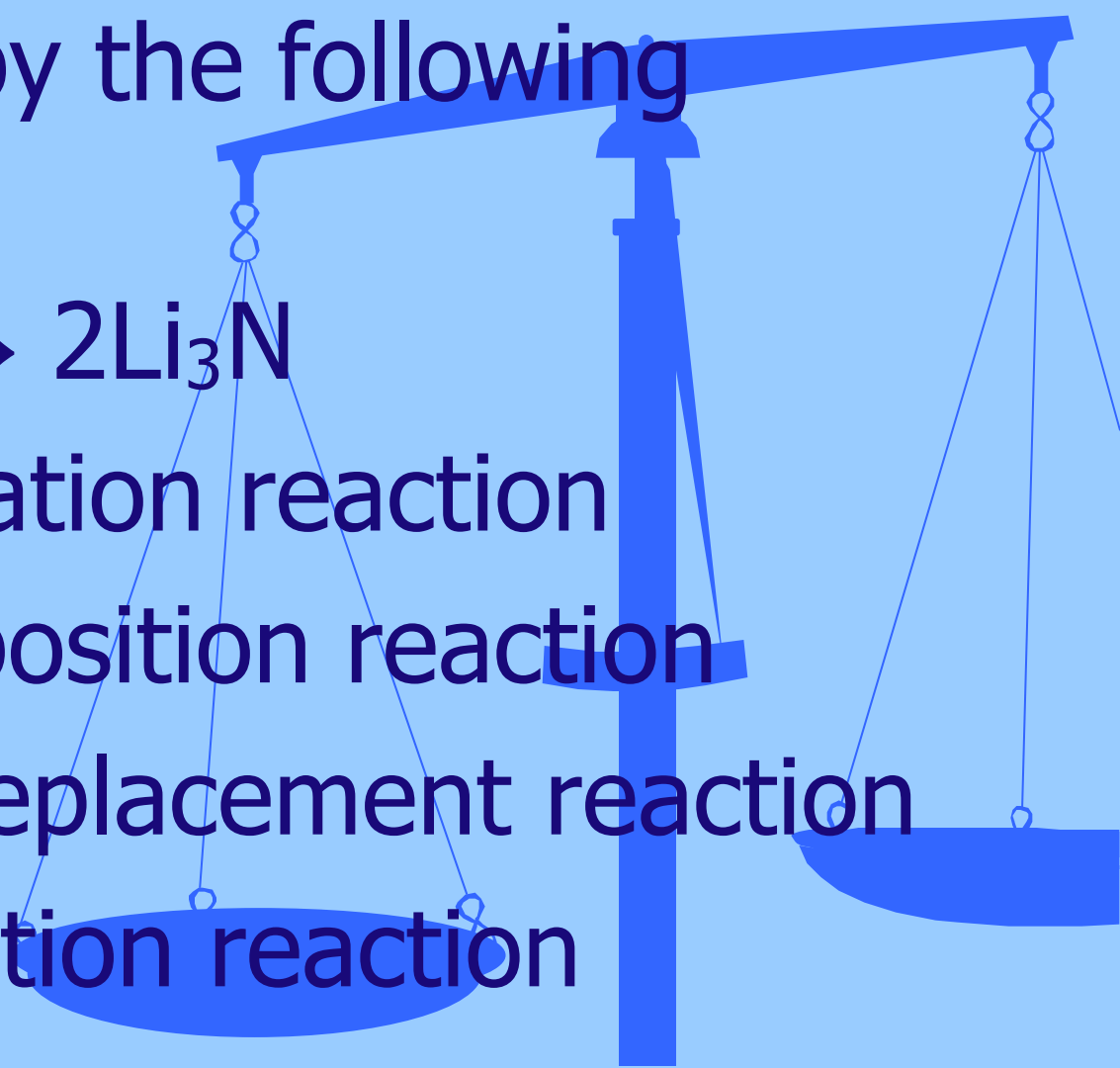


a) combination reaction

b) decomposition reaction

c) single-replacement reaction

d) combustion reaction



11.2 Section Quiz.

■ 2. Balance and indicate reaction type.

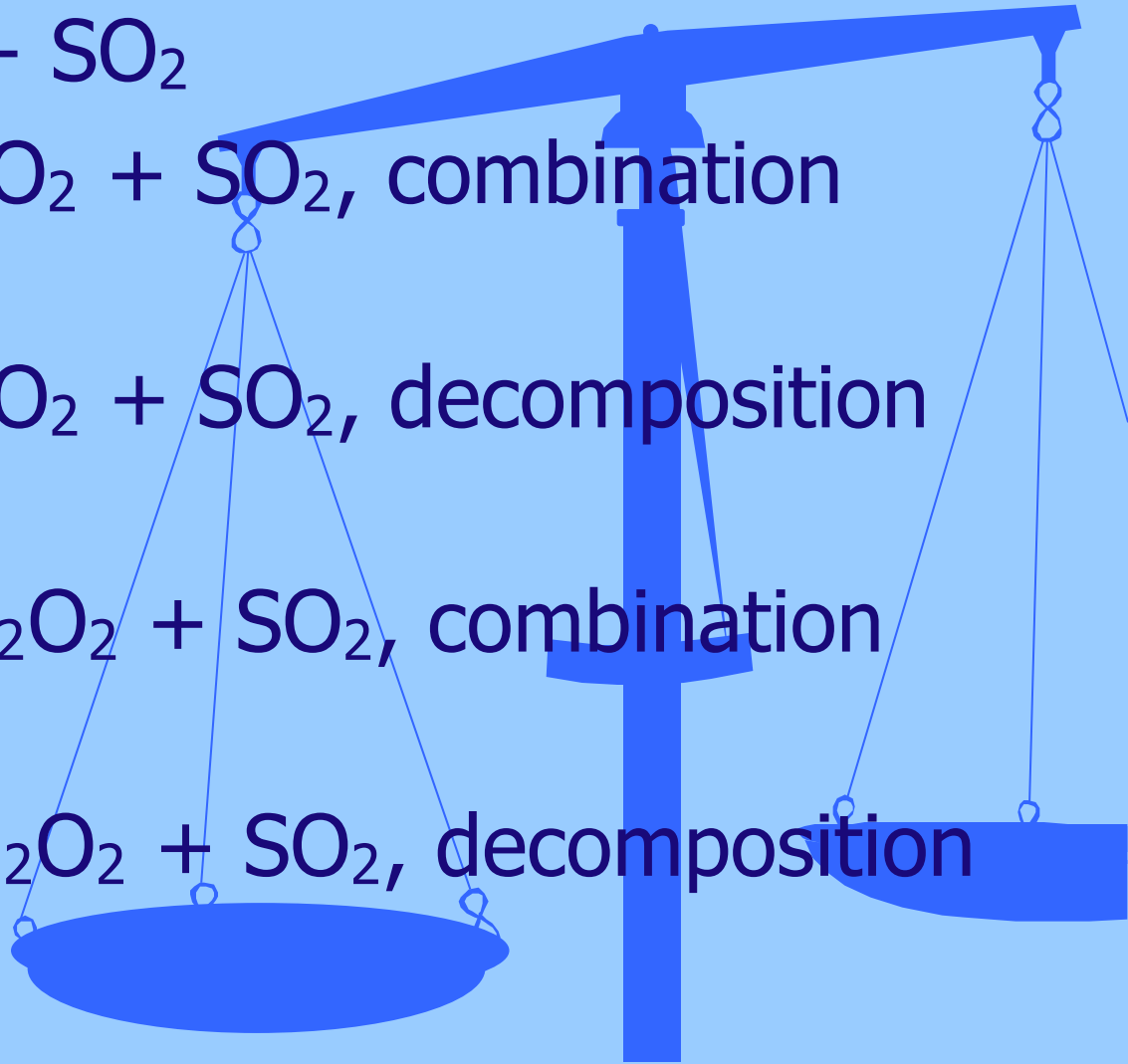


a) $\text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{O}_2 + \text{SO}_2$, combination reaction

b) $\text{H}_2\text{SO}_4 \rightarrow \text{H}_2\text{O}_2 + \text{SO}_2$, decomposition reaction

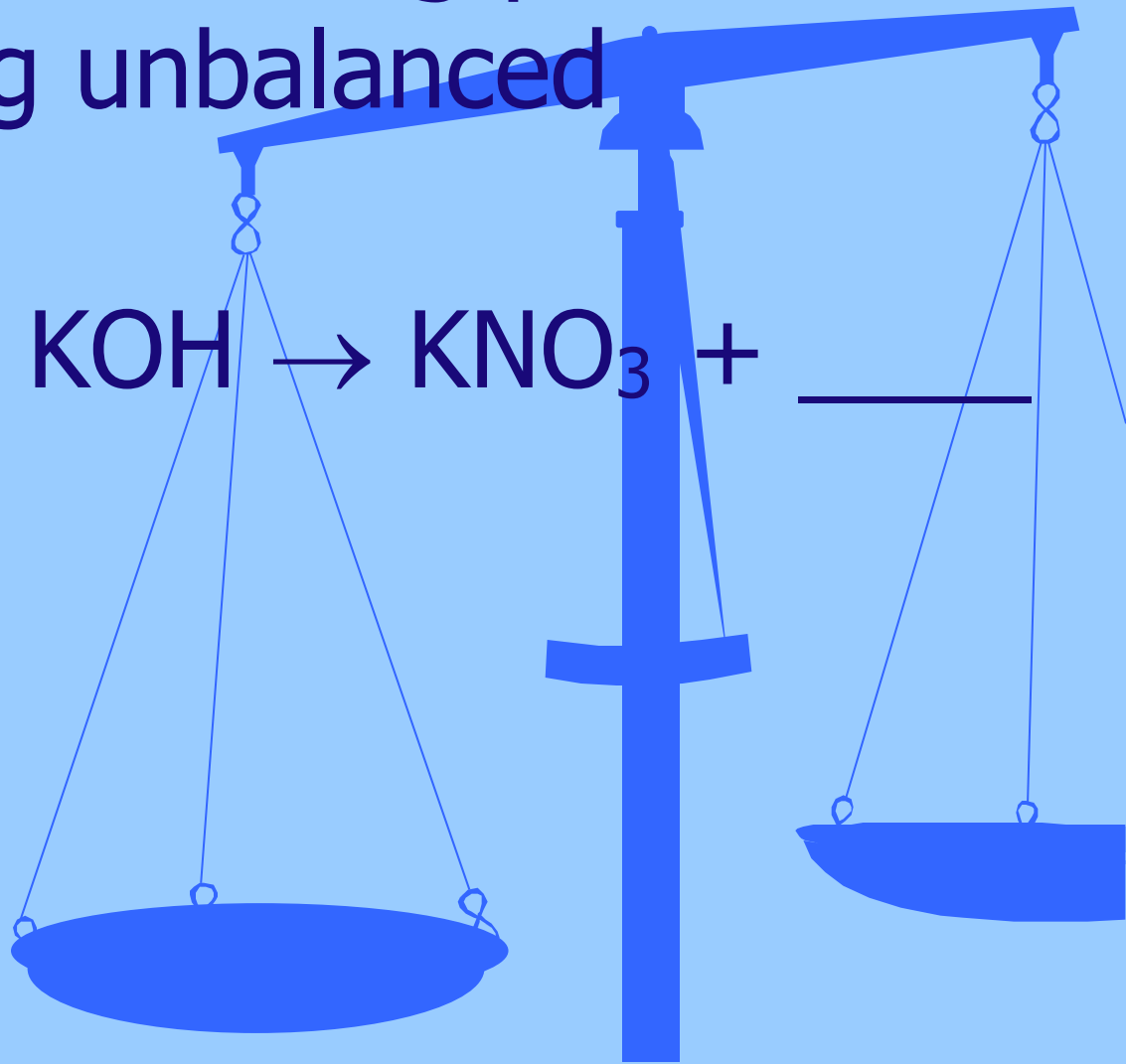
c) $\text{H}_2\text{SO}_4 \rightarrow 2\text{H}_2\text{O}_2 + \text{SO}_2$, combination reaction

d) $\text{H}_2\text{SO}_4 \rightarrow 2\text{H}_2\text{O}_2 + \text{SO}_2$, decomposition reaction

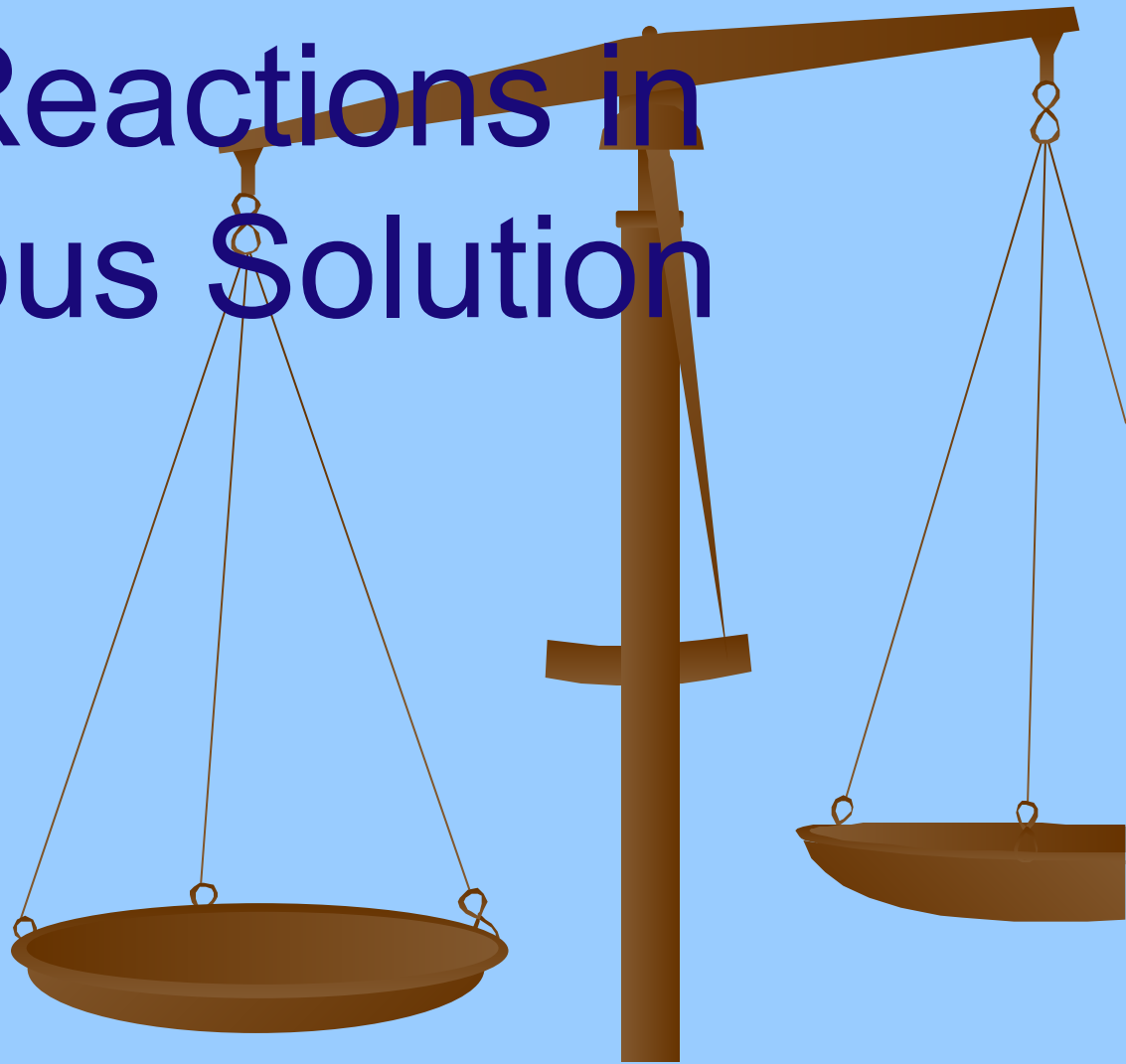


11.2 Section Quiz.

■ 3. Predict the missing product in the following unbalanced equation.

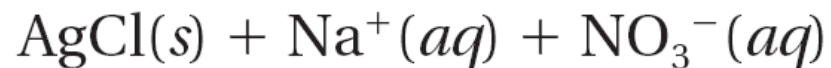


11.3 Reactions in Aqueous Solution

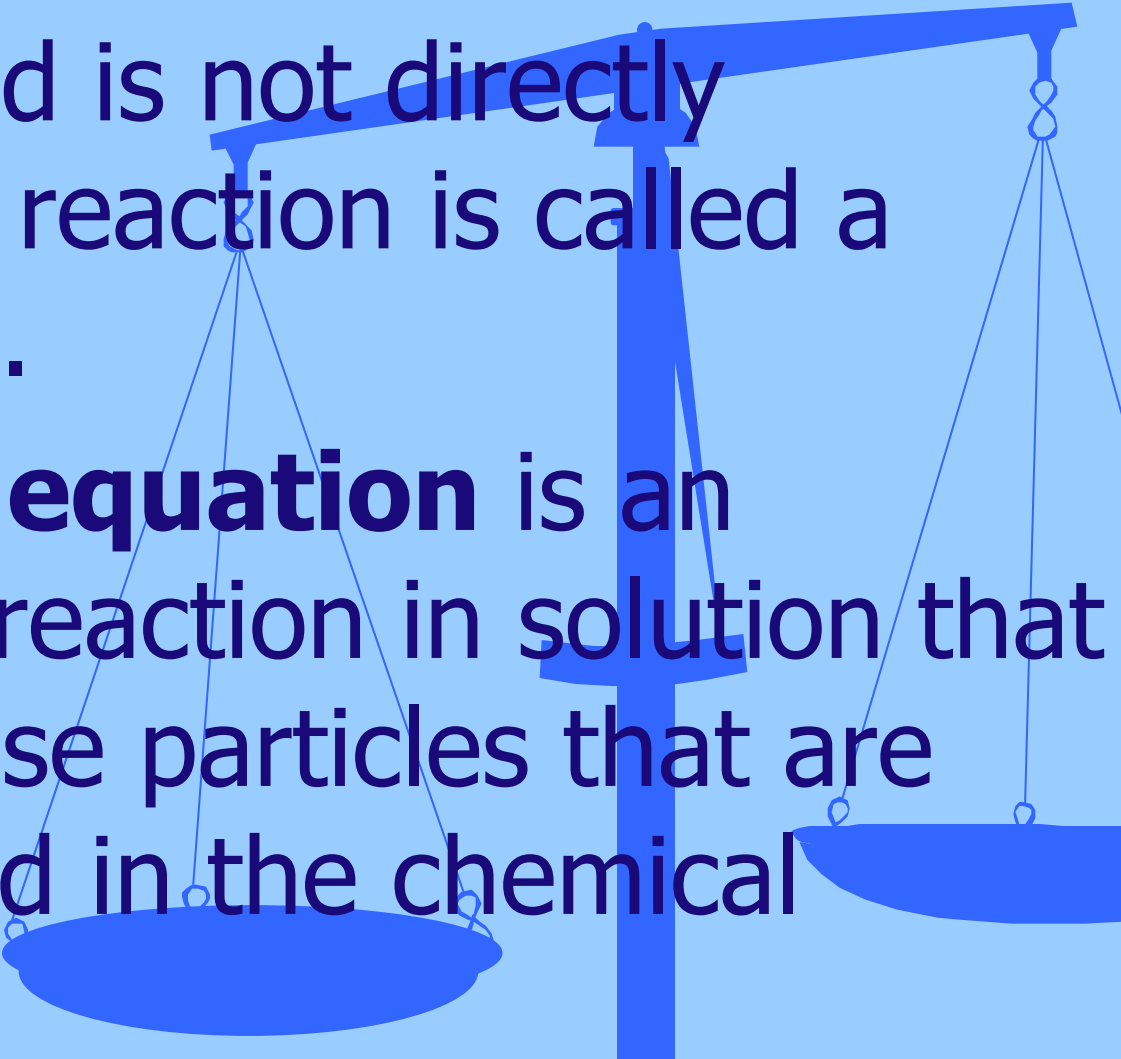


Net Ionic Equations

- A **complete ionic equation** is an equation that shows dissolved ionic compounds as dissociated free ions.

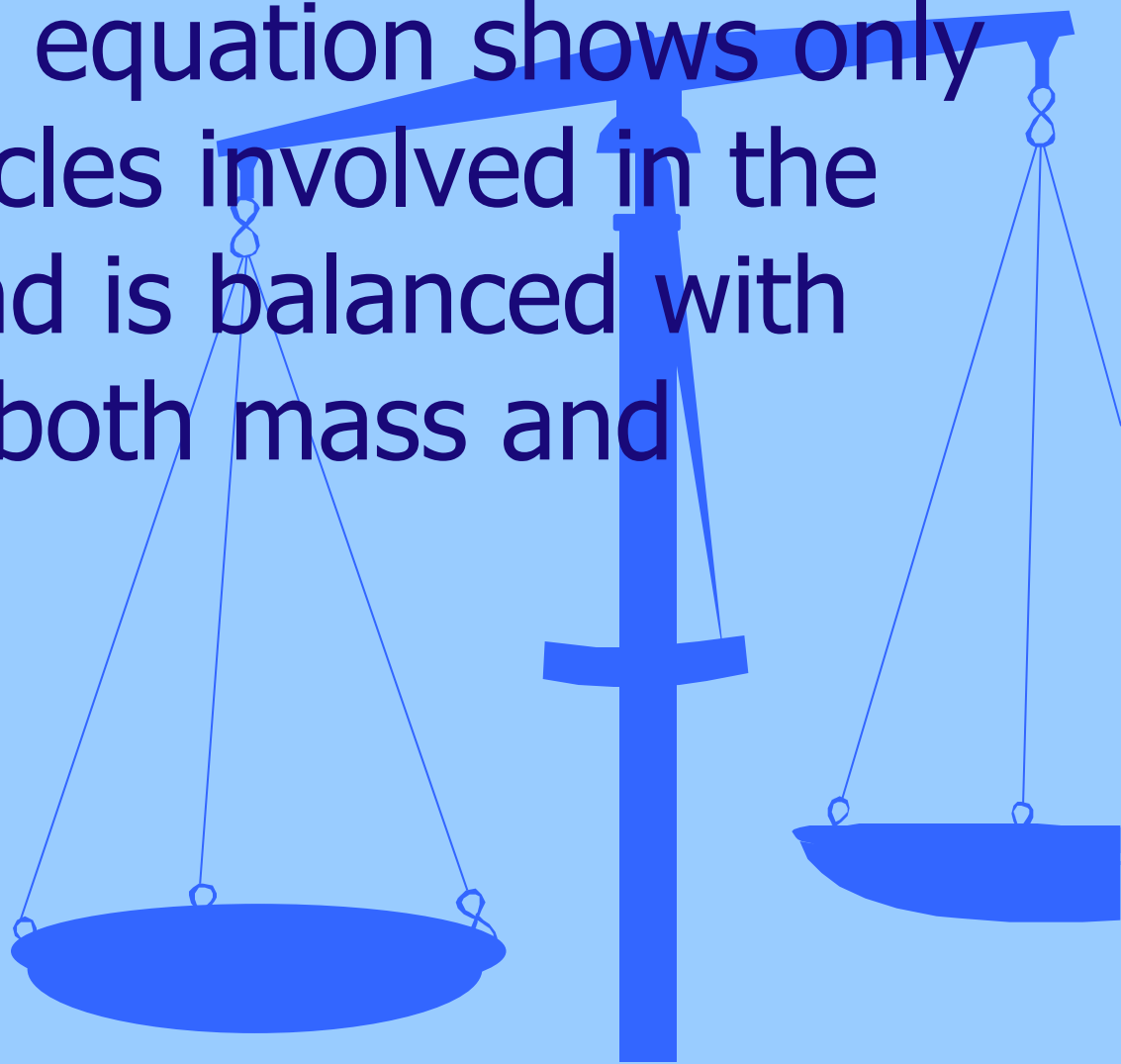


Net Ionic Equations

- An ion that appears on both sides of an equation and is not directly involved in the reaction is called a **spectator ion**.
 - The **net ionic equation** is an equation for a reaction in solution that shows only those particles that are directly involved in the chemical change.
- 

Net Ionic Equations

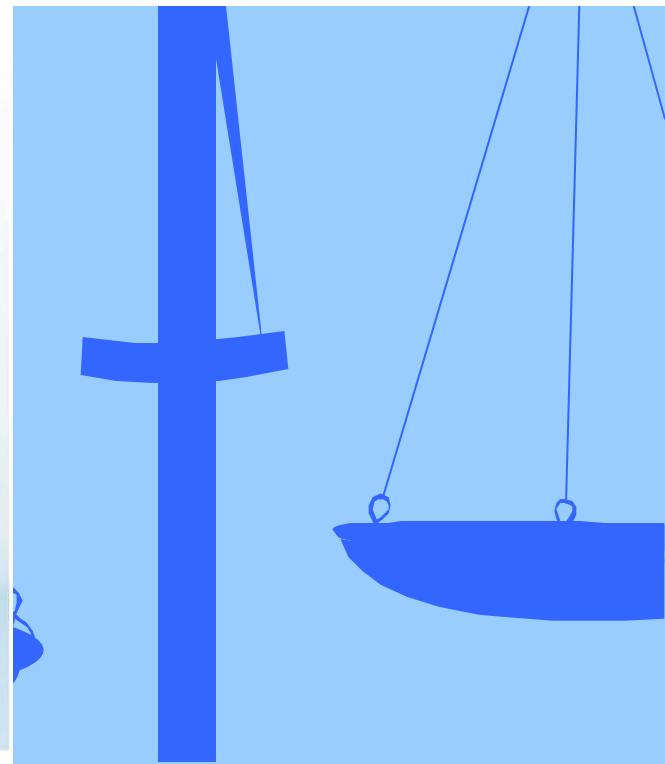
- A net ionic equation shows only those particles involved in the reaction and is balanced with respect to both mass and charge.



Conceptual Problem 11.9

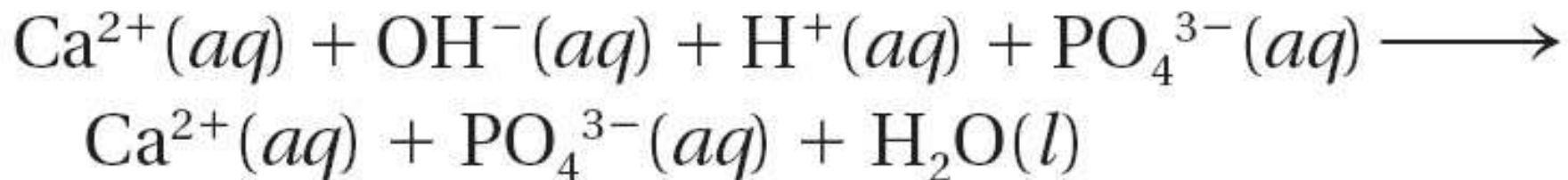
Writing and Balancing Net Ionic Equations

In the photograph, aqueous solutions of iron(III) chloride and potassium hydroxide are mixed. A precipitate of iron(III) hydroxide forms. Identify the spectator ions and write a balanced net ionic equation for the reaction.

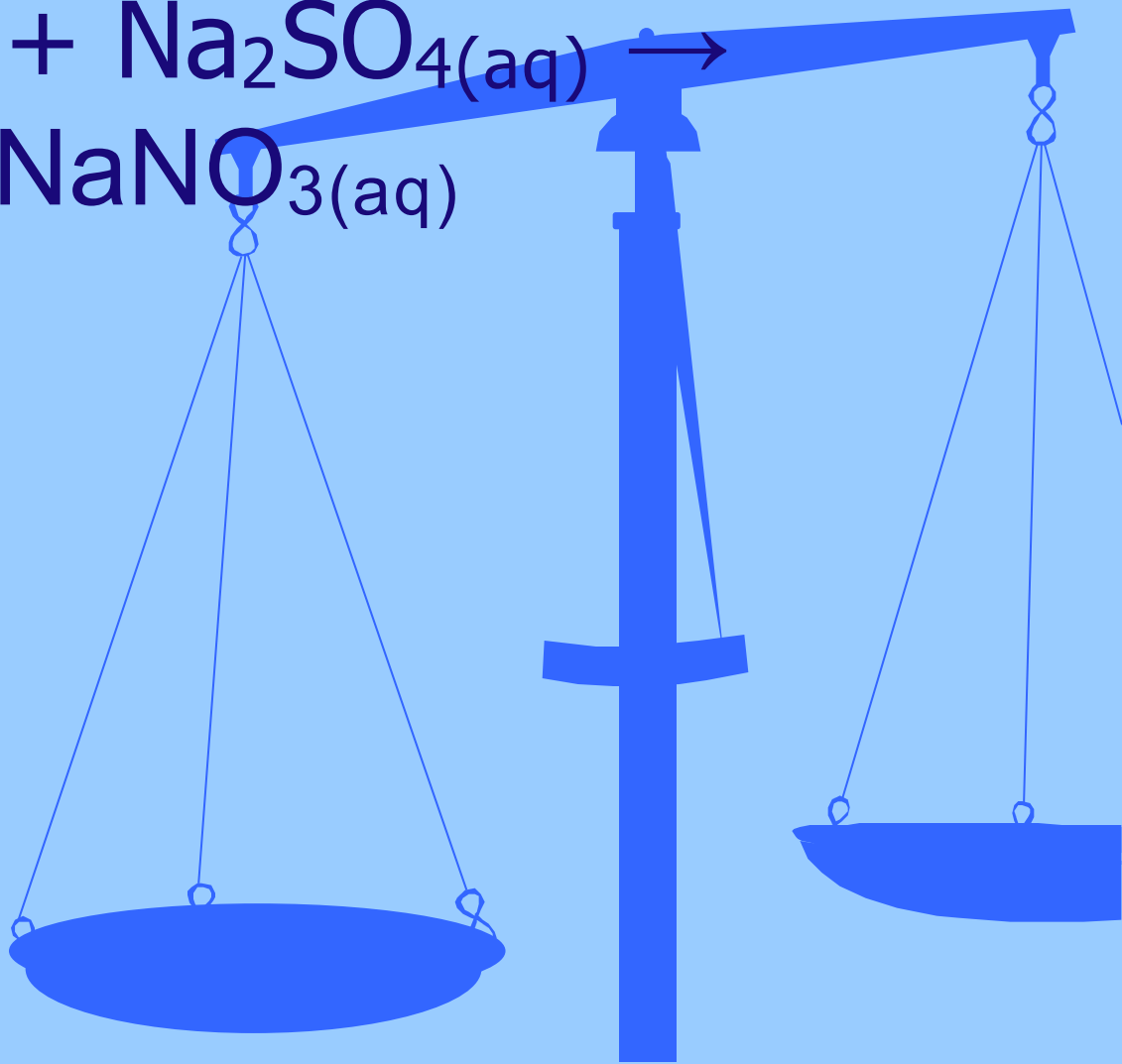
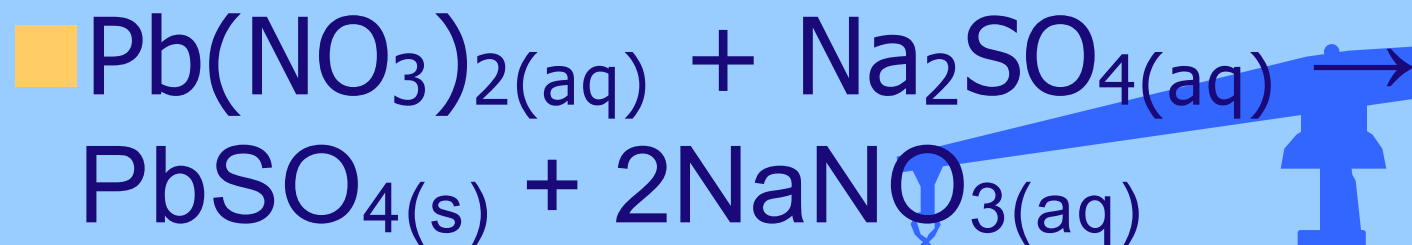


for Conceptual Problem 11.9

28. Write the balanced net ionic equation for this reaction.



Example – Write the Complete and Net Ionic Equations

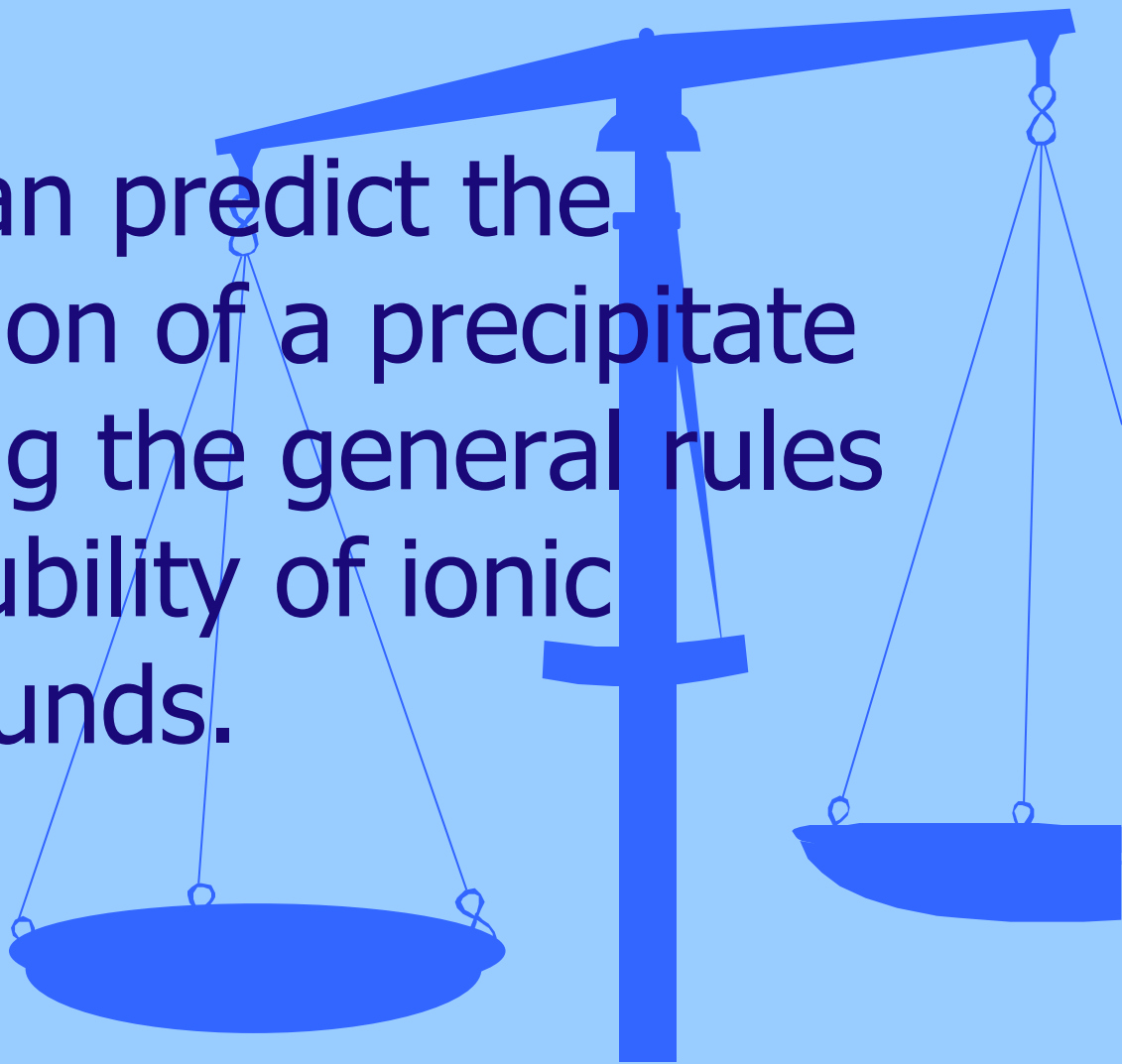


11.3

Predicting the Formation of a Precipitate

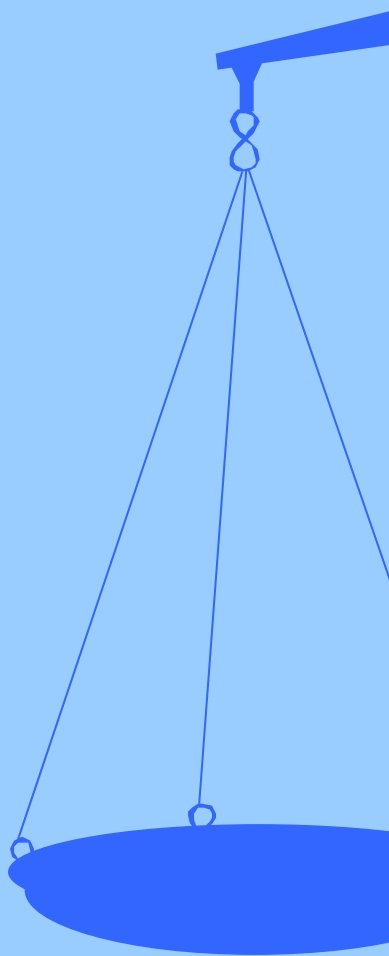


- You can predict the formation of a precipitate by using the general rules for solubility of ionic compounds.



11.3

Predicting the Formation of a Precipitate

**Table 11.3****Solubility Rules for Ionic Compounds**

| Compounds | Solubility |
|---|--------------------|
| Salts of alkali metals and ammonia | Soluble |
| Nitrate salts and chlorate salts | Soluble |
| Sulfate salts, except compounds with Pb^{2+} , Ag^+ , Hg_2^{2+} , Ba^{2+} , Sr^{2+} , and Ca^{2+} | Soluble |
| Chloride salts, except compound with Ag^+ , Pb^{2+} , and Hg_2^{2+} | Soluble |
| Carbonates, phosphates, chromates, sulfides, and hydroxides | Most are insoluble |

11.3

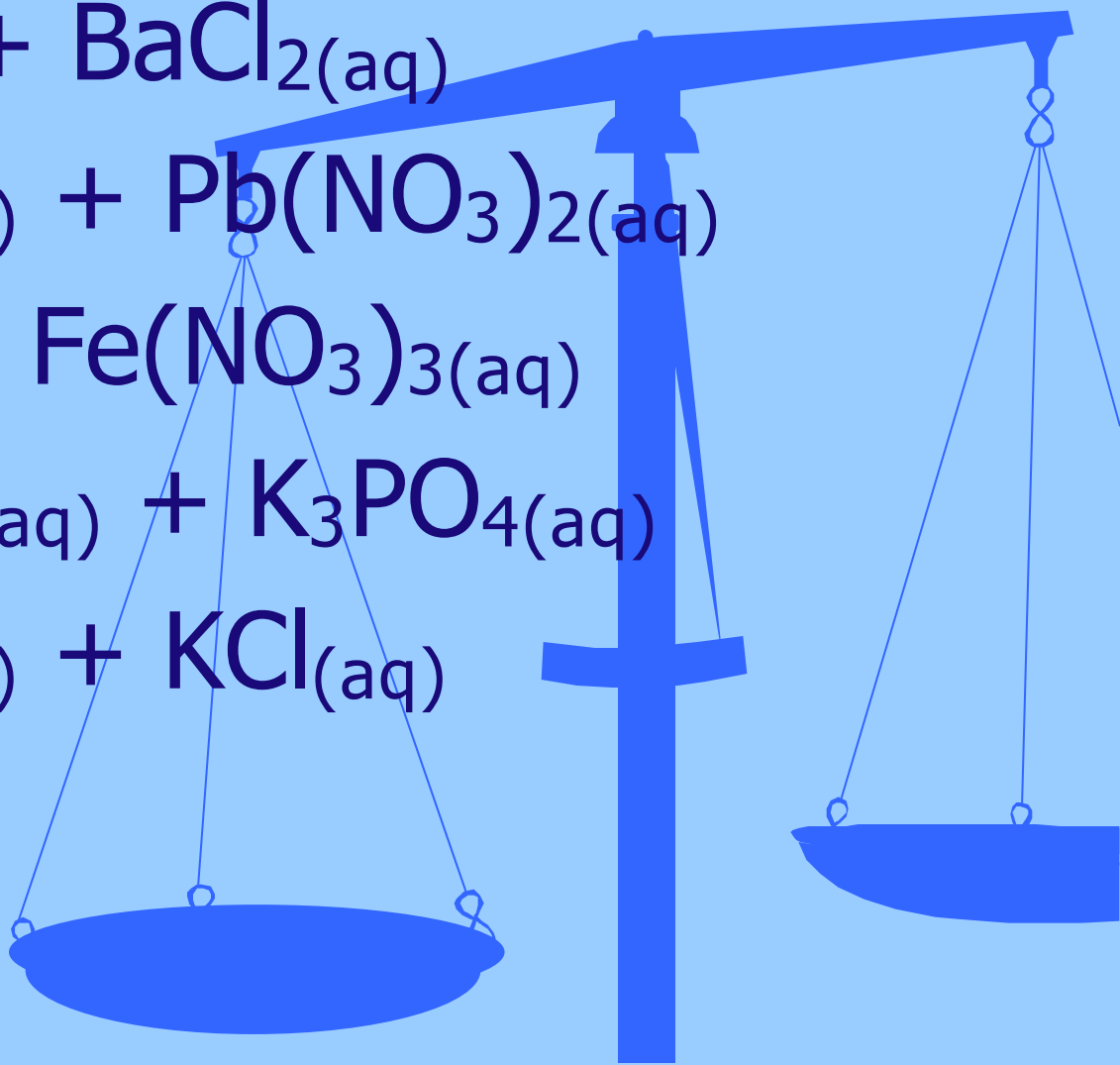
Predicting the Formation of a Precipitate

- Will a precipitate form when a sodium carbonate solution is mixed with a barium nitrate solution?



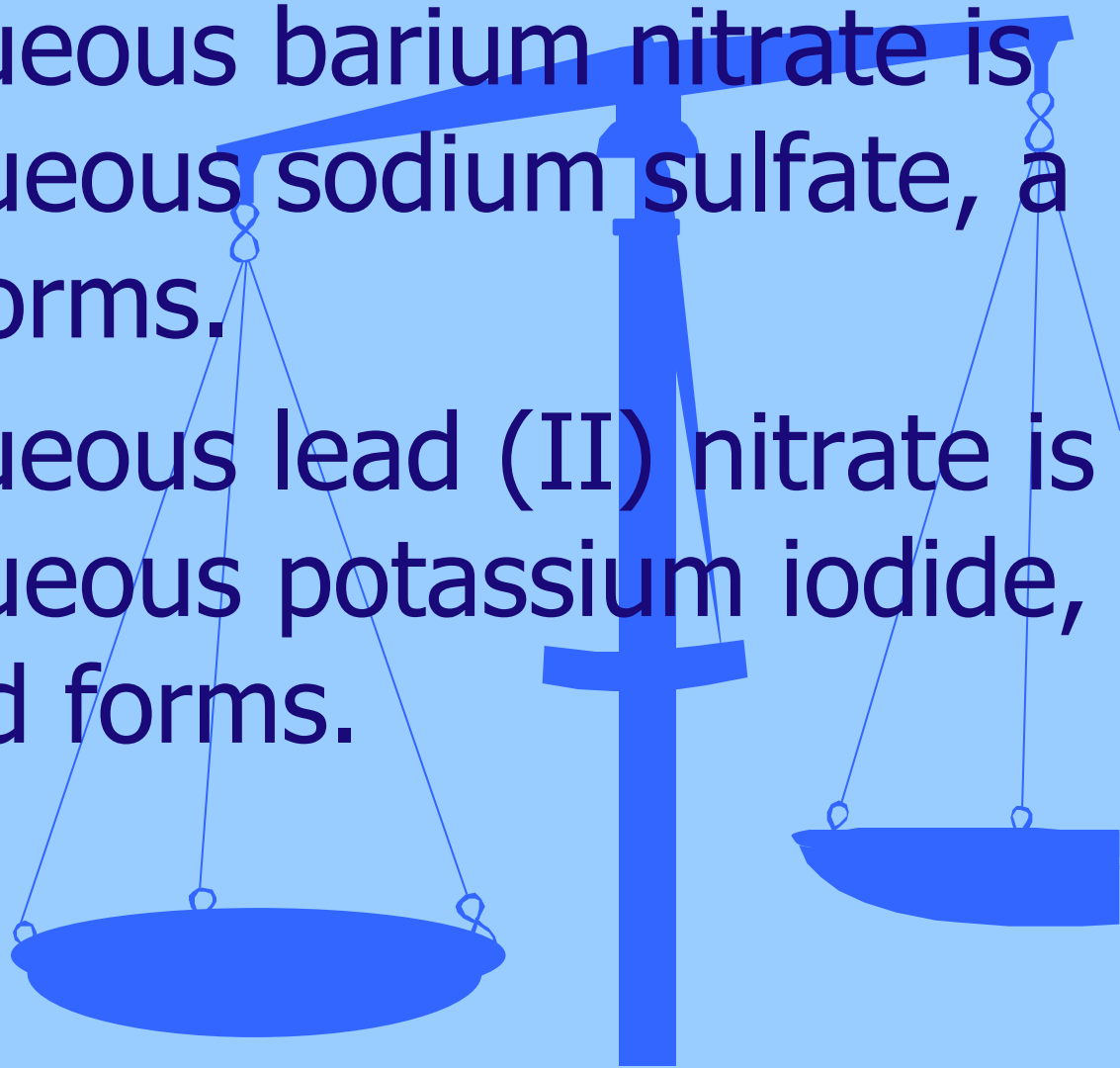
Practice – predict products and determine solubility

- 1) $\text{KNO}_{3(\text{aq})} + \text{BaCl}_{2(\text{aq})}$
- 2) $\text{Na}_2\text{SO}_{4(\text{aq})} + \text{Pb}(\text{NO}_3)_{2(\text{aq})}$
- 3) $\text{KOH}_{(\text{aq})} + \text{Fe}(\text{NO}_3)_3(\text{aq})$
- 4) $\text{Ba}(\text{NO}_3)_2(\text{aq}) + \text{K}_3\text{PO}_4(\text{aq})$
- 5) $\text{Na}_2\text{SO}_{4(\text{aq})} + \text{KCl}_{(\text{aq})}$



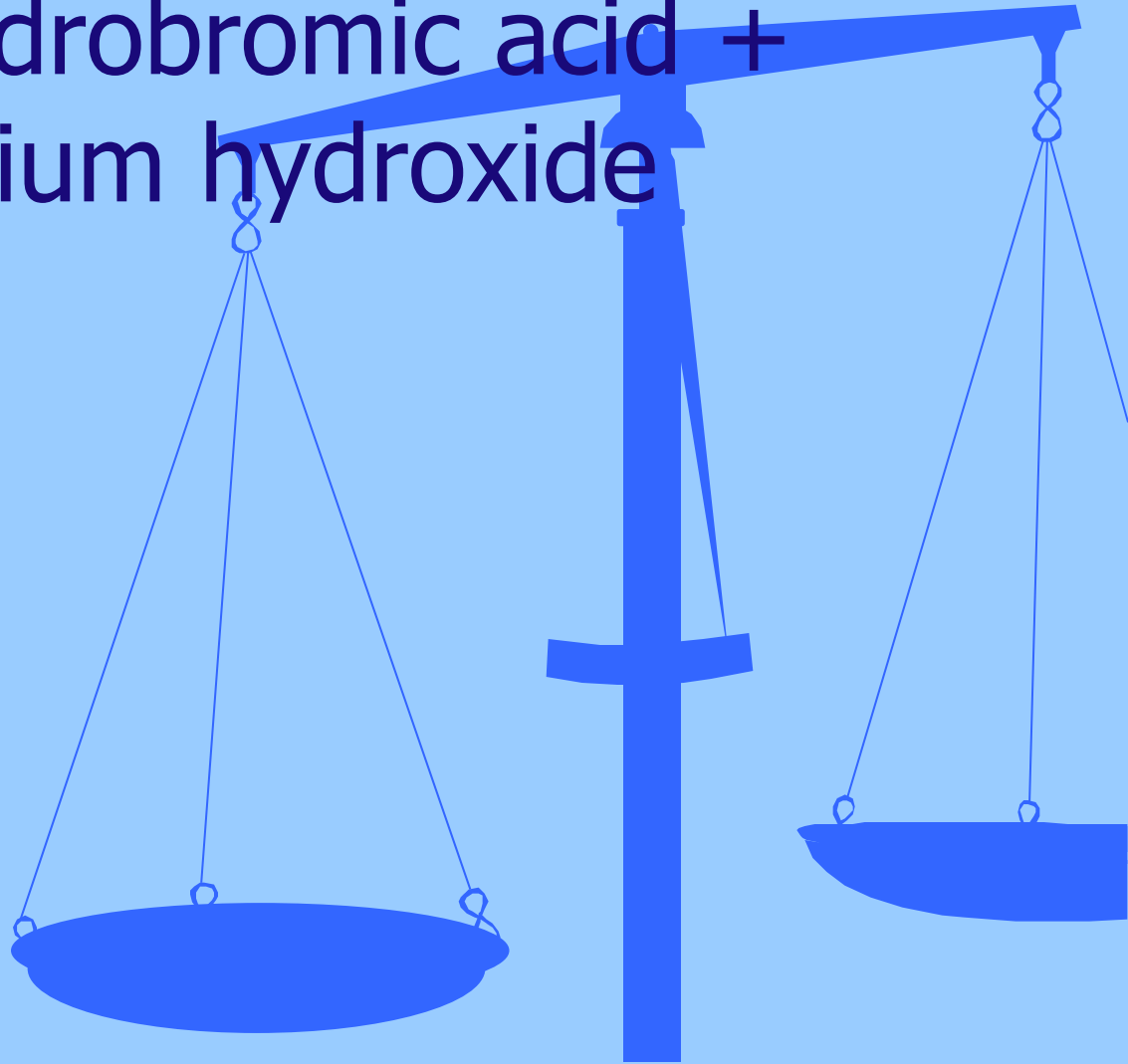
Practice

- 1) When aqueous barium nitrate is added to aqueous sodium sulfate, a white solid forms.
- 2) When aqueous lead (II) nitrate is added to aqueous potassium iodide, a yellow solid forms.



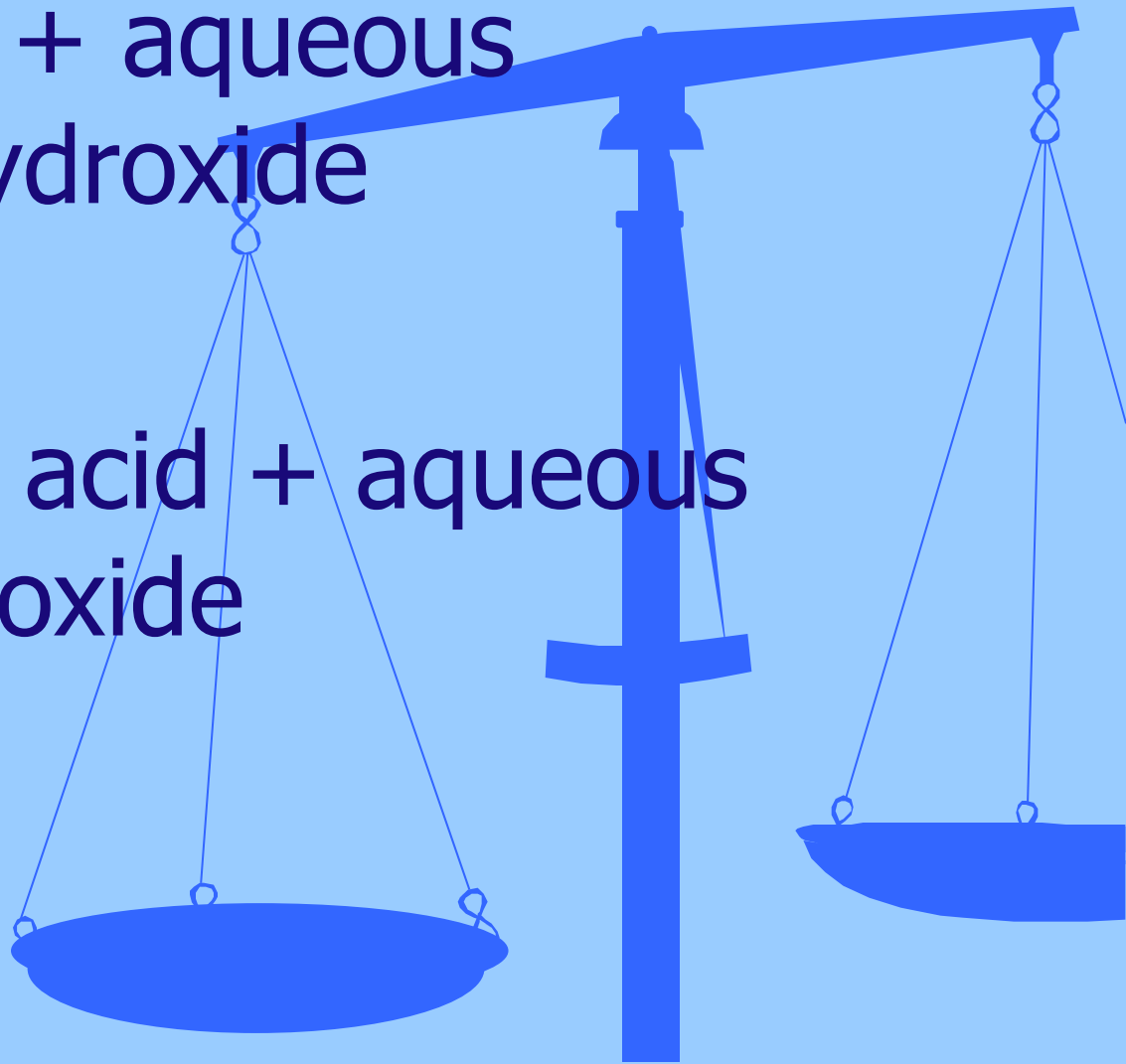
Reactions that form water

- Example: hydrobromic acid + aqueous sodium hydroxide



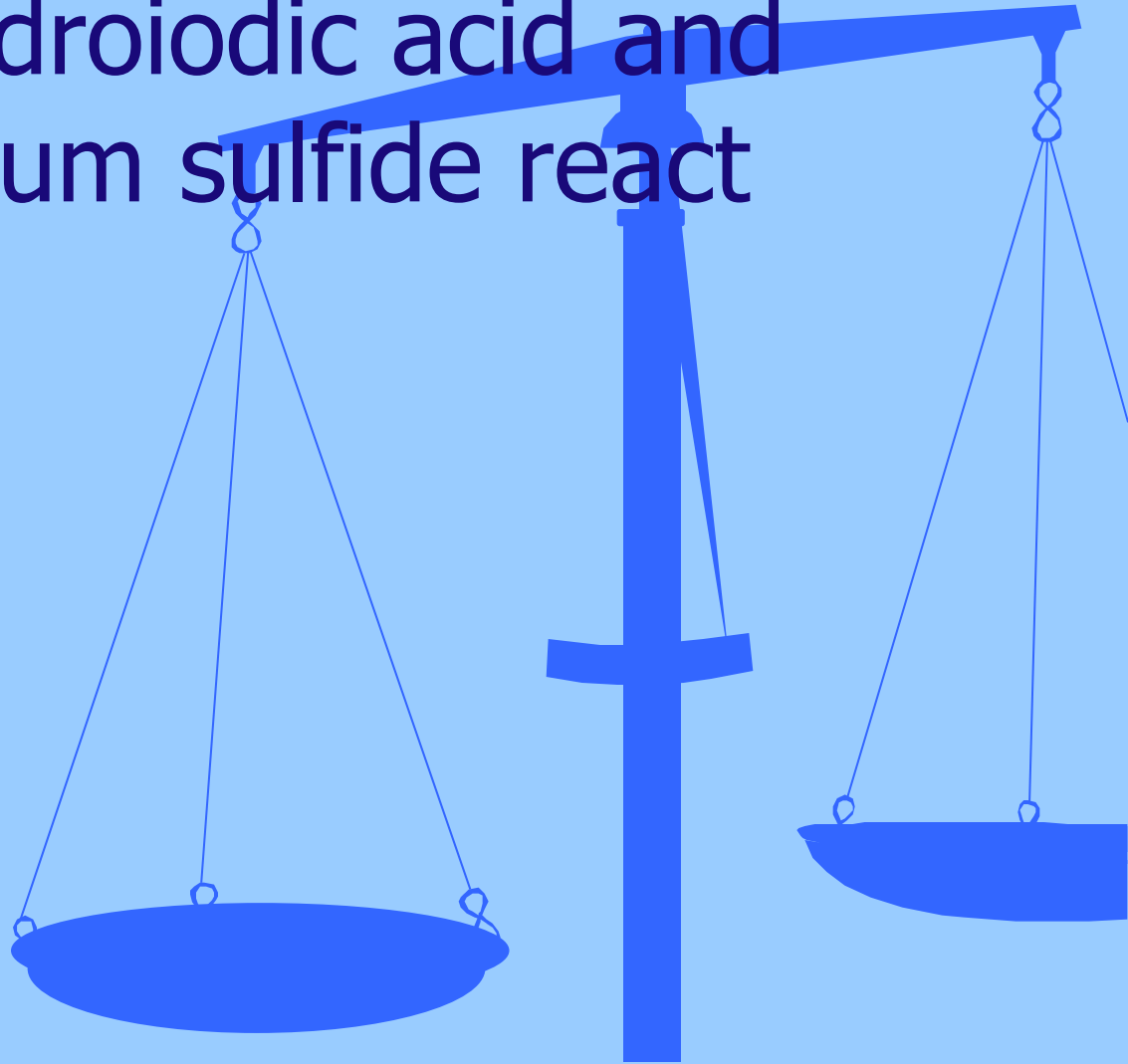
Reactions that form water

- Sulfuric acid + aqueous potassium hydroxide
- Hydrochloric acid + aqueous calcium hydroxide



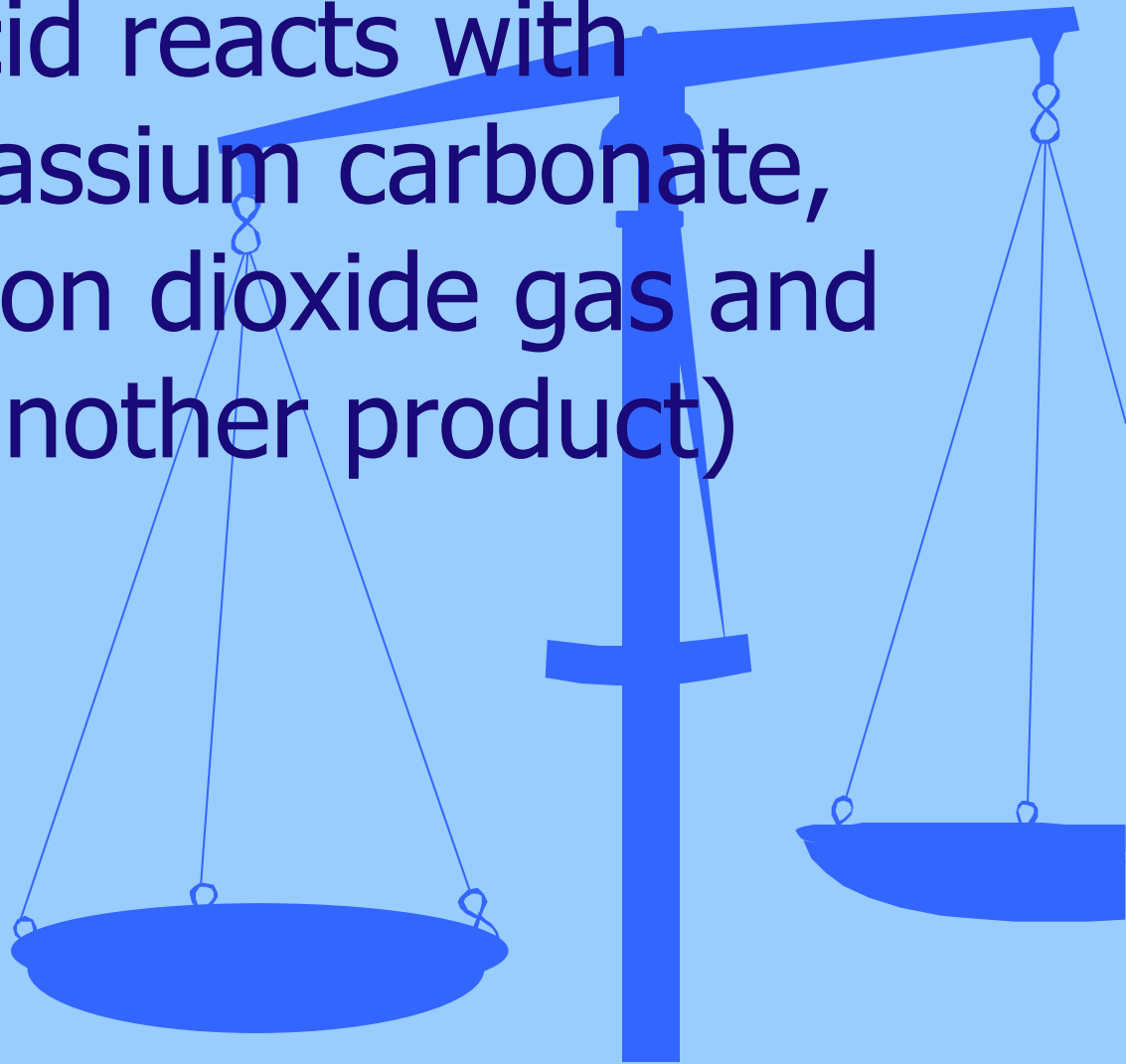
Reactions that form gases

- Example: hydroiodic acid and aqueous lithium sulfide react



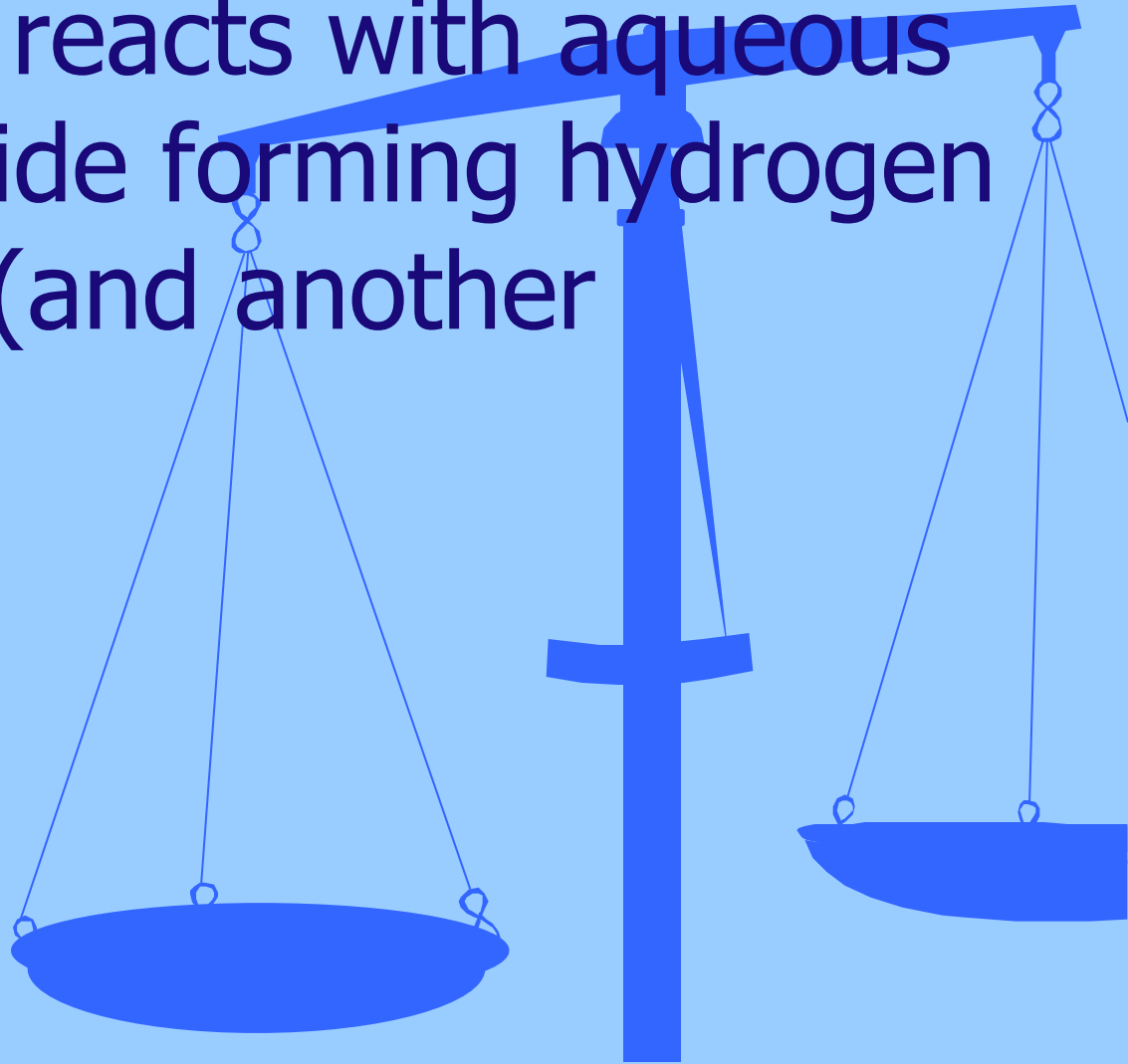
Reactions that form gases

- Perchloric acid reacts with aqueous potassium carbonate, forming carbon dioxide gas and water (and another product)



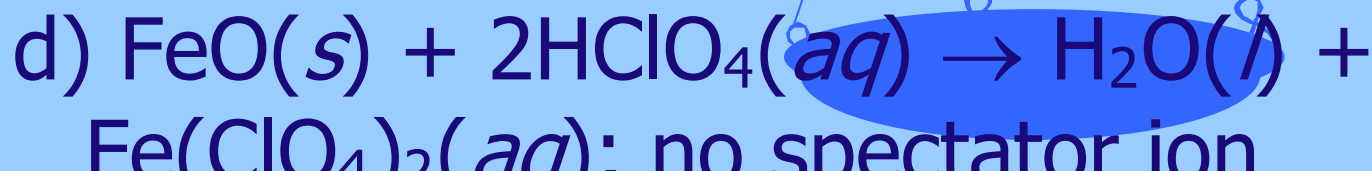
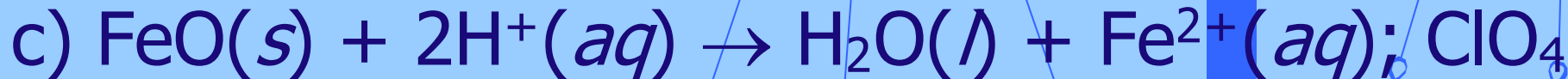
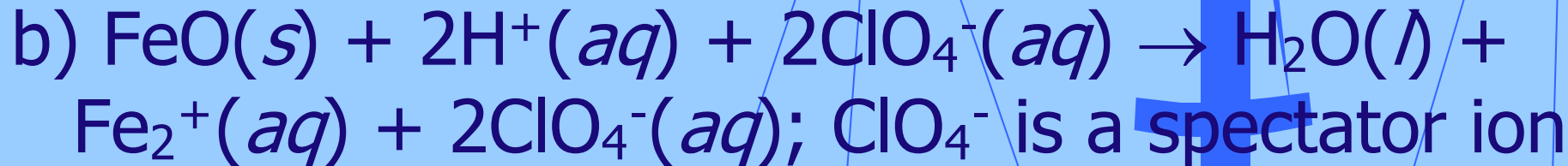
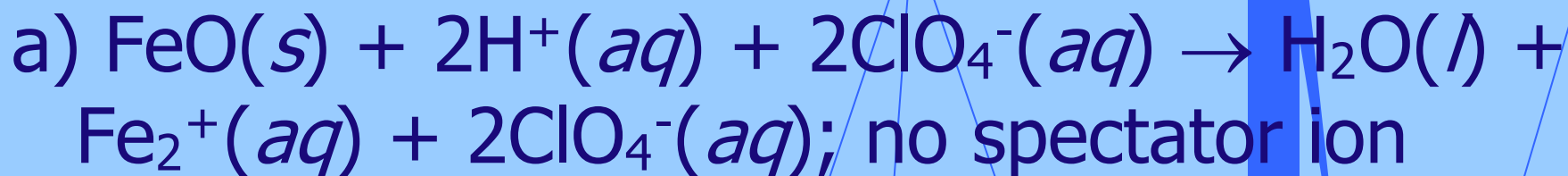
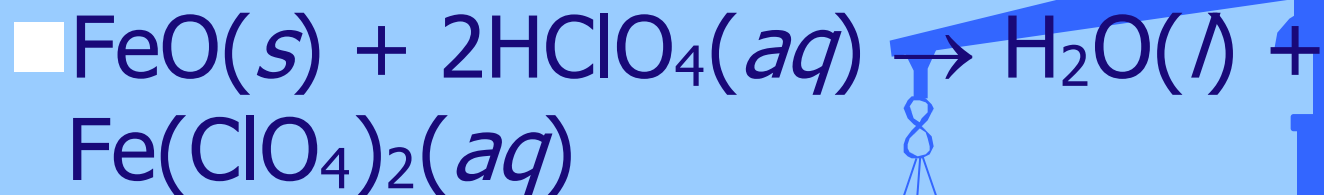
Reactions that form gases

- Sulfuric acid reacts with aqueous sodium cyanide forming hydrogen cyanide gas (and another product)



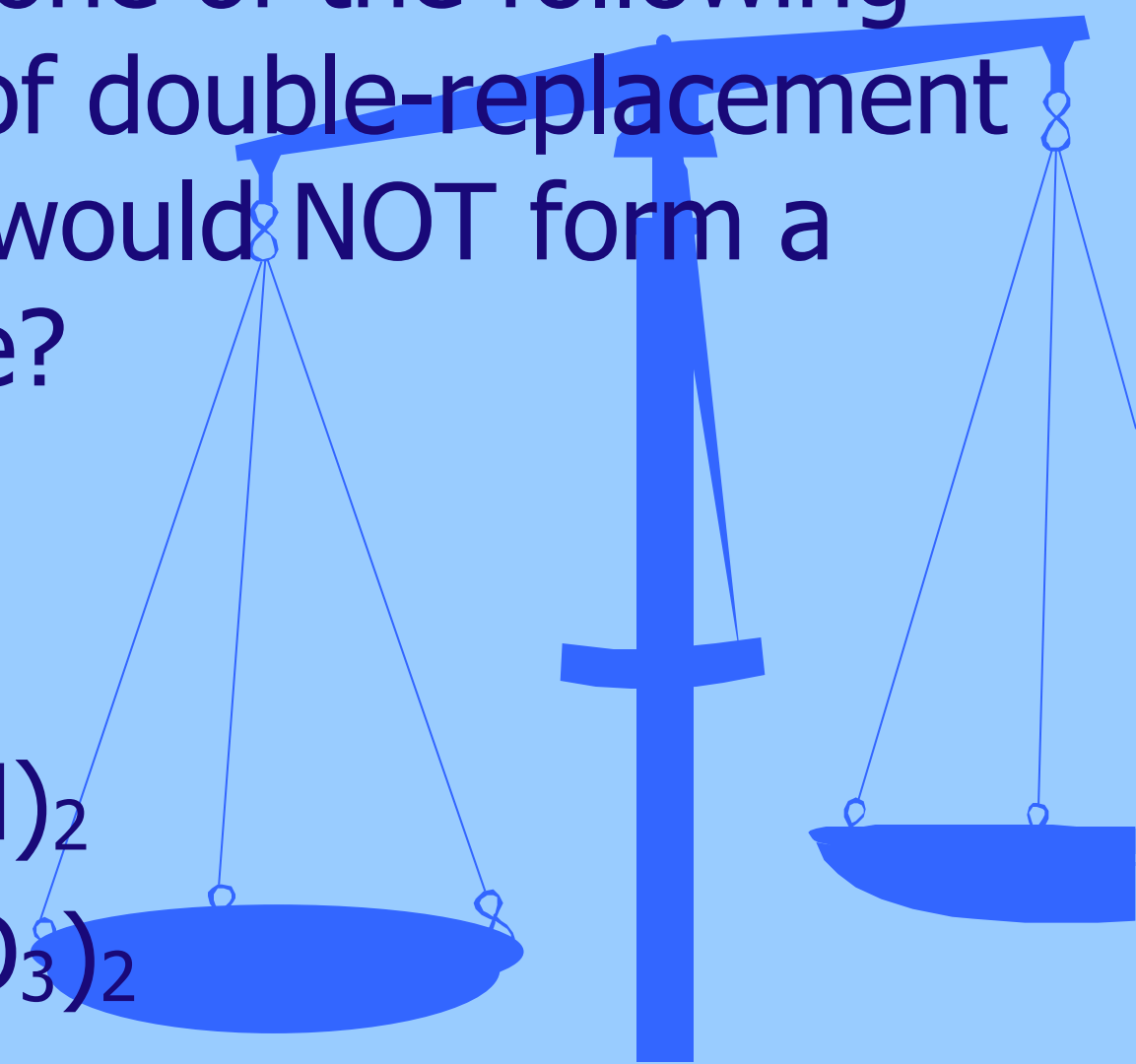
11.3 Section Quiz.

1. Identify the correct net ionic equation and any spectator ions.



11.3 Section Quiz.

2. Which one of the following products of double-replacement reactions would NOT form a precipitate?



11.3 Section Quiz

■ 3. Which reaction will NOT produce a precipitate from aqueous solution?

