

1.3 Types of Chemical Reactions

At the end of this section, students will be able to

- ☞ list the four types of chemical reactions;
- ☞ define combination reaction and give examples;
- ☞ conduct experiments on combination reactions in groups;
- ☞ define decomposition reaction and give examples;
- ☞ conduct some experiments on decomposition reactions in groups;
- ☞ define single - displacement reaction and give examples;
- ☞ conduct some experiments on simple displacement reactions in groups;
- ☞ define double - displacement reaction and give examples;
- ☞ conduct some experiments on double - displacement reactions in group.



Activity 1.2

In your group, discuss about the following processes and share your conclusion with the rest of the class.

1. What are the final products of digestive protein and starch? Is protein and starch digestion a building up or breaking down process?
2. What is alcohol fermentation and its process? What are the two important chemical compounds produced during the fermentation of "Teji" or "Tella"? What is the main ingredient (starting material) for the production of "Teji" and "Tella"?
3. What are the two major chemical reactants and the two chemical products of photosynthesis? Is photosynthesis a breaking down or a building up process? Compare this process with cellular respiration.
4. What are the combustion products of kerosene? Is the combustion of kerosene a building up or a breaking down process?

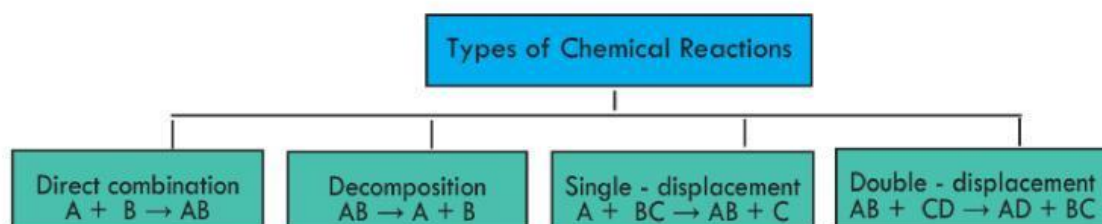


Figure 1.1 Classification of chemical reactions.



Experiment 1.1

Investigation of Combination Reaction

Objective: To investigate the reaction between sulphur and iron.

Apparatus: Test tube, stand, burner, watch glass

Chemicals: Sulphur powder, iron filings

Procedure:

1. Mix about 3 g of iron filings and 2 g of powdered sulphur in a watch glass.
2. Transfer the mixture in a glass test tube.
3. Mount the test tube in a sloping position on a stand as shown in **Figure 1.2**.
4. Heat the test tube until the mixture in the glass glows red hot.
5. Remove the test tube from the flame and observe the result.

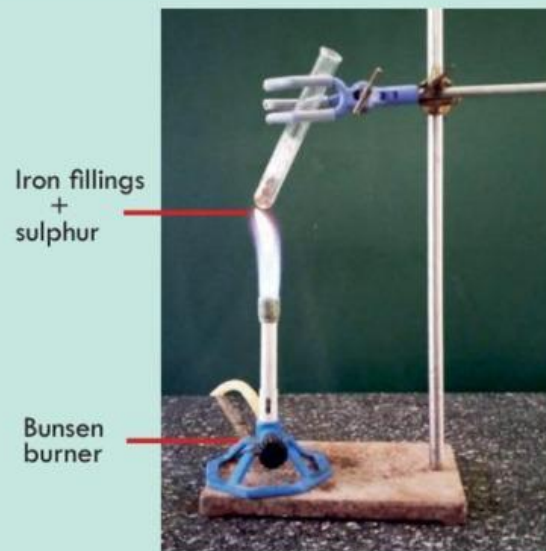


Figure 1.2 The reaction between iron and sulphur.

Questions

1. What were the colors of iron filings and sulphur before the reaction?
2. What was the color of the resulting compound after the reaction?
3. Write a balanced chemical equation for the reaction.

B. Decomposition Reactions

A decomposition reaction (or analysis) is a reaction that involves the breaking down of a single compound into two or more elements or simpler compounds. A decomposition reaction can be carried out using heat (thermal decomposition), light (photo decomposition), electricity (electrical decomposition) or a catalyst. But most decomposition reactions are carried out when heat is supplied and this heat energy is indicated by a 'delta' (Δ) symbol above the arrow. The general form of equation for a decomposition reaction is:



where the reactant AB must be a compound and the products A and B could be elements or compounds.

The simplest kind of decomposition reaction is when a binary compound decomposes into its elements. For example, mercury (II) oxide, a red solid, decomposes when heated to produce mercury and oxygen gas, similarly a colorless potassium perchlorate decomposes to potassium chloride and oxygen gas.



Experiment 1.2

Investigation of Decomposition Reaction

Objective: To investigate the decomposition of copper (II) carbonate (CuCO_3).

Apparatus: Test tube, stand, burner, cork, delivery tube.

Chemicals: CuCO_3 and lime water.

Procedure:

Put 1 g of CuCO_3 powder in a glass test-tube. Mount the test tube in a sloping position on a stand as shown in **Figure 1.3**. Fit a cork and a delivery tube to the test tube. Put another test tube containing lime water at the end of the delivery tube. Heat the CuCO_3 with a burner.

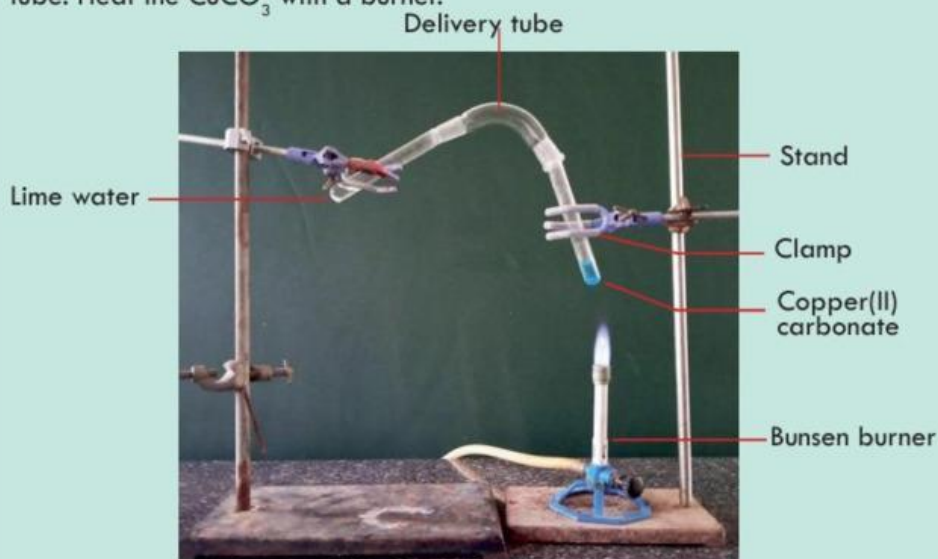


Figure 1.3 Decomposition of copper (II) carbonate.

C. Single Displacement Reactions

A reaction in which one element displaces another element from its compound is known as **single displacement or replacement reaction**. Such a reaction is represented by the following two general forms.



If A is a metal, it will displace B to form AC, provided A is a more active metal than B.

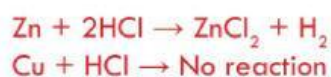


If A is a non-metal, it will displace C to form BA, provided A is a more active non-metal than C. In general, a more reactive element displaces a less reactive element from a compound.

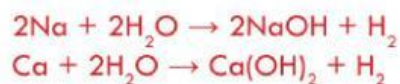
Examples of single-displacement reactions

1. Active metals displace hydrogen from acids

Reactive metals such as potassium, calcium, sodium, and zinc displace hydrogen gas from dilute acids. For example, zinc is an active metal, and it displaces hydrogen from hydrochloric acid; but copper metal cannot do so.



2. Reactive metals, such as potassium, calcium, and sodium react vigorously with water to displace hydrogen:



3. A more active metal displaces a less active metal

Zinc displaces copper from copper (II) sulphate solutions



Iron displaces copper from copper (II) sulphate solutions





Experiment 1.3

Investigation of Single Displacement Reaction

Objective: To investigate the displacement reaction between iron and copper (II) Sulphate (CuSO_4)

Apparatus: Iron rod and beaker

Chemicals: CuSO_4

Procedure:

1. Clean a piece of iron rod or iron knife with emery paper to remove any rust.
2. Take saturated CuSO_4 solution in a beaker.
3. Dip the iron rod into the CuSO_4 solution as shown in **Figure 1.5** and wait for a few minutes. What did you observe on the iron rod?
4. Allow the reactants to stand for one day and observe any change on the iron rod.

Questions

1. What did you observe on the iron rod after one day?
2. Write a balanced chemical equation for the reaction.
3. Write the conclusion for the experiment.



Figure 1.5 Reaction between iron and copper (II) sulphate.



Exercise 1.3

Complete the following single displacement reactions:



D. Double Displacement Reactions

A double displacement reaction is a reaction in which two compounds react together to form two new compounds by exchange of the positive and negative ions of each reactant. Such a reaction is also known as double replacement reaction or metathesis. This type of reaction can be written in the following general form of equation:





Experiment 1.4

Investigation of Double Displacement Reaction

Objective: To observe the displacement reaction between Na_2SO_4 and $\text{Ba}(\text{NO}_3)_2$.

Apparatus: Beaker, stirrer, filter paper, filter funnel.

Chemicals: Na_2SO_4 , $\text{Ba}(\text{NO}_3)_2$ and water.

Procedure:

1. Take solution of $\text{Ba}(\text{NO}_3)_2$ into a beaker and add drop-wise Na_2SO_4 solution as shown in **Figure 1.6**. Then stir it continuously.
2. Filter the precipitate using a filter paper and funnel. Collect the filtrate or the solution in a clean beaker.

Questions

1. Write the names of the compounds that are formed as a precipitate and as solution at the end of the reaction.
2. What was the colour of the precipitate.
3. Write the balanced chemical equation for the reaction.



Example 1.6:

The two soluble compounds AgNO_3 and NaCl react to produce an insoluble precipitate of AgCl and a soluble NaNO_3 solution.



When aqueous solutions of BaCl_2 and Na_2SO_4 react, a precipitate of BaSO_4 is formed.



When dilute hydrochloric acid is added to sodium carbonate double displacement reaction takes place. In this reaction carbon dioxide gas is produced.





Exercise 1.4

Give the correct answers for the following questions.

1. What type of reaction does usually take place in each of the following reactions?
 - a. An active metal reacting with water
 - b. A metal reacting with a non-metal
 - c. An acid reacting with a metal hydroxide
 - d. Heating of a metal hydrogen carbonate
2. Classify the following reactions as combination, decomposition, single or double displacement reactions.
 - a. $\text{FeO} + \text{C} \rightarrow \text{Fe} + \text{CO}$
 - b. $2\text{NH}_3 + \text{H}_2\text{SO}_4 \rightarrow (\text{NH}_4)_2\text{SO}_4$
 - c. $\text{CaCO}_3 + 2\text{HCl} \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$
 - d. $2\text{Cu}(\text{NO}_3)_2 \rightarrow 2\text{CuO} + 4\text{NO}_2 + \text{O}_2$
 - e. $2\text{Na}_3\text{PO}_4 + 3\text{Ca}(\text{OH})_2 \rightarrow \text{Ca}_3(\text{PO}_4)_2 + 6\text{NaOH}$
 - f. $\text{CuSO}_4 \cdot 5\text{H}_2\text{O} \rightarrow \text{CuSO}_4 + 5\text{H}_2\text{O}$

Question 1

Which of the following general equations represents a direct combination reaction?

- A. $A + B \rightarrow AB$
- B. $AB + CD \rightarrow AD + CB$
- C. $A + BC \rightarrow AC + B$
- D. $AB \rightarrow A + B$

Question 2

What is another common name used for a combination reaction?

- A. Replacement reaction
- B. Analysis reaction
- C. Metathesis reaction
- D. Synthesis reaction

Question 3

In a thermal decomposition reaction, what type of energy is primarily supplied to break down the compound, and how is it commonly represented in equations?

- A. Electrical energy, indicated by a battery symbol above the arrow
- B. Sound energy, indicated by a wave symbol above the arrow
- C. Light energy, indicated by a sun symbol above the arrow
- D. Heat energy, indicated by a delta symbol (Δ) above the arrow

Question 4

Which of the following processes is classified as a decomposition reaction?

- A. $2Na_{(s)} + Cl_{2(g)} \rightarrow 2NaCl_{(s)}$
- B. $Zn_{(s)} + CuSO_{4(aq)} \rightarrow ZnSO_{4(aq)} + Cu_{(s)}$
- C. $CuCO_{3(s)} \xrightarrow{\Delta} CuO_{(s)} + CO_{2(g)}$
- D. $BaCl_{2(aq)} + Na_2SO_{4(aq)} \rightarrow BaSO_{4\downarrow} + 2NaCl_{(aq)}$

Question 5

Why does copper metal fail to displace hydrogen gas when added to dilute hydrochloric acid (HCl), whereas zinc successfully does so?

- A. Hydrochloric acid only reacts with transition metals belonging to the first period
- B. Copper forms a protective oxide layer instantly that prevents any chemical contact with acids
- C. Zinc is a more active metal than hydrogen, whereas copper is less active than hydrogen
- D. Copper reacts exclusively with water rather than dilute acids

Question 6

What is observed when an iron nail is dipped into a blue copper (II) sulphate solution for an extended period?

- A. The solution turns bright pink, and silver crystals form on the container walls
- B. The blue solution turns green due to iron (II) sulphate formation, and reddish-brown copper deposits on the nail
- C. No visible changes occur because iron and copper have identical reactivities
- D. The solution remains completely blue, and the iron nail dissolves entirely into a gas

Question 7

Which general equation correctly depicts a double displacement reaction?

- A. $AB \rightarrow A + B$
- B. $A + BC \rightarrow AC + B$
- C. $AB + CD \rightarrow AD + CB$
- D. $A + B \rightarrow AB$

Question 8

What alternative scientific term is frequently used to describe a double displacement reaction?

- A. Sublimation
- B. Hydrogenation
- C. Polymerization
- D. Metathesis

Question 9

In the reaction between aqueous sodium sulphate (Na_2SO_4) and barium nitrate ($\text{Ba}(\text{NO}_3)_2$), what insoluble precipitate is formed?

- A. Sodium nitrate (NaNO_3)
- B. Barium sulphate (BaSO_4)
- C. Sodium sulphide (Na_2S)
- D. Barium nitrate ($\text{Ba}(\text{NO}_3)_2$)

Question 10

What gas is produced when dilute hydrochloric acid is added to sodium carbonate (Na_2CO_3)?

- A. Carbon dioxide (CO_2)
- B. Oxygen gas (O_2)
- C. Hydrogen gas (H_2)
- D. Chlorine gas (Cl_2)

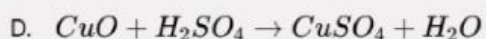
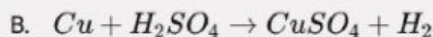
Question 11

How is the reaction classification for $\text{FeO} + \text{C} \rightarrow \text{Fe} + \text{CO}$ best described?

- A. Single displacement reaction
- B. Decomposition reaction
- C. Direct combination reaction
- D. Double displacement reaction

Question 12

Which of the following chemical equations represents a decomposition reaction involving hydrated copper (II) sulphate?



Question 13

When potassium metal reacts with water, what type of reaction occurs and what gas is liberated?

A. Double displacement reaction, liberating oxygen gas

B. Single displacement reaction, liberating hydrogen gas

C. Combination reaction, liberating chlorine gas

D. Decomposition reaction, liberating carbon dioxide gas

Question 14

What primary feature distinguishes a combination reaction from a decomposition reaction?

A. Combination reactions require catalysts, whereas decomposition reactions never require external energy

B. Combination reactions always absorb heat, whereas decomposition reactions always release heat

C. Combination reactions yield a single product from multiple reactants, while decomposition reactions yield multiple products from a single reactant

D. Combination reactions only involve gases, whereas decomposition reactions only involve solids

Question 15

In the reaction $Cl_{2(g)} + 2KI_{(aq)} \rightarrow 2KCl_{(aq)} + I_{2(s)}$, what type of reaction is taking place?

- A. Single displacement reaction
- B. Double displacement reaction
- C. Direct combination reaction
- D. Thermal decomposition reaction