02

Yr 11 Chemistry

Module 3
Reactive Chemistry

Book 2: Chemical Reactions and Reactivity

PROFECTUS

Overview

Syllabus Dot Points:

- Conduct investigations to predict and identify the products of a range of reactions for example:
  - Synthesis
  - Decomposition
  - Combustion
  - Precipitation
  - Acid/base reactions
  - Acid/carbonate reactions
- Conduct practical investigations to compare the reactivity of a variety of metals in:
  - Water
  - Dilute acid
  - Oxygen
  - Other metal ions in solution

Chemical Reactions

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Synthesis Reactions

A synthesis reaction refers to a reaction where multiple reactants combine to form **a single product**. These reactants may be smaller compounds of elements.

$$A + B \rightarrow AB$$

Some examples of synthesis include the production of water, from hydrogen and oxygen atoms.

$$Hydrogen + Oxygen \rightarrow Water$$

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

An example of synthesis reactions with small compounds is:

$$Calcium\ Oxide + Water \rightarrow Calcium\ Hydroxide$$

$$CaO(s) + H_2O\,(l) \rightarrow Ca(OH)_2\,(S)$$

Synthesis reactions release energy in the form of light and heat, so they are exothermic.

Decomposition Reactions

A decomposition reaction is the opposite of a synthesis reaction where there is one reactant that is broken down into two or more products.

$$AB \rightarrow A + B$$

It is the intramolecular forces that hold the molecule together that break forming different products. The breaking of bonds requires energy and so most decomposition reactions are endothermic – they require an external input of energy. This energy can be provided in a number of ways. A catalyst may also be used to speed up the reaction.

Thermal Decomposition:

Thermal decomposition refers to when heat is provided as the energy for the reaction to occur. Most carbonates (CO_3^{2-}) compounds like $CaCO_3$ will decompose when heated releasing carbon dioxide and a salt.

Calcium Carbonate → Calcium Oxide + Carbon Dioxide

$$CaCO_3\ (s) \rightarrow CaO\ (s) + CO_2\ (g)$$

A very common and important example of decomposition is what happens in car air bags when they inflate. The compound Sodium Azide undergoes thermal decomposition, producing large volumes of nitrogen has which inflate the balloon.

Sodium Azide → Sodium + Nitrogen

$$2NaN_3\ (s) \rightarrow 2Na\ (s) + 3N_2\ (g)$$

Decomposition by Electrical Energy:

Electrical energy can also be used to decompose compounds into smaller compounds or elements. This is known as photolysis. An example of this is the decomposition of water into its elements, hydrogen and oxygen gas.

Write the word and balanced chemical equation for this decomposition reaction:

Combustion Reactions

Combustion is one of the most useful processes that has been used for hundreds of millions of years for the survival of humans. A combustion reaction is defined as when a fuel combines with or burns in the presence of oxygen gas. There are two types of combustion: complete and incomplete combustion. This depends on the amount of oxygen that is present for the reaction.

Complete Combustion:

Complete combustion refers to when there is plentiful oxygen available for the combustion reaction. The products of this reaction are carbon dioxide and water. It is essential to make sure that all of the chemical equations are properly.

$$Fuel + Oxygen \rightarrow Carbon\ Dioxide + Water$$

$$Methane + Oxygen \rightarrow Carbon\ Dioxide + Water$$

$$CH_4\ (l) + 2O_2\ (g) + \rightarrow CO_2\ (g) + 2H_2O\ (g)$$

$$Octane + Oxygen \rightarrow Carbon\ Dioxide + Water$$

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

Incomplete Combustion:

Incomplete combustion refers to when there is not enough oxygen and so the products of this reaction are carbon monoxide, carbon soot and water.

Fuel + Oxygen (not enough) → Carbon Monoxide/Carbon + Water

Methane + Oxygen → Carbon + Water

$CH_4\ (l) + O_2\ (g) + \rightarrow C\ (g) + 2H_2O\ (g)$

Octane + Oxygen → Carbon Monoxide + Water

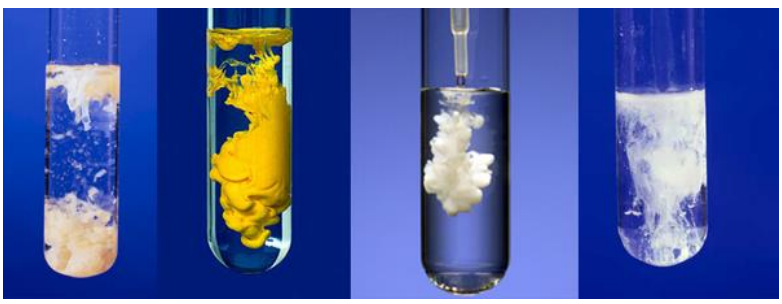
$2C_8H_{18}\ (l) + 17O_2\ (g) + \rightarrow 16CO\ (g) + 18H_2O\ (g)$

An easy way to understand this is by using a Bunsen Burner. We can control the amount of oxygen received by the flame by opening and closing the air hole. When the hole is open, the amount of oxygen is plentiful and so we get a strong clean, blue flame. When we are not using the Bunsen burner, we close the air hole, making the flame yellow. This flame – the safety flame – is often quite dirty since it produced soot, not that hot and may produce carbon monoxide gas.

Precipitation Reactions

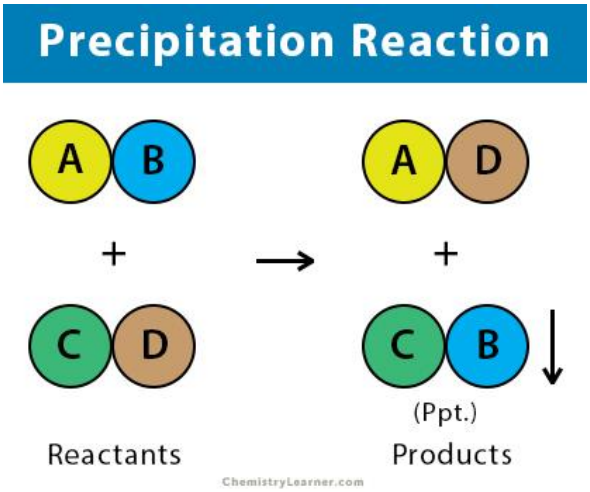
A precipitation reaction is one where two clear salt solutions are mixed and react to form a precipitate.

Precipitate: a solid compound formed when two solutions are mixed. This solid is insoluble in the solvent (usually water).



In precipitation reactions, the aqueous solutions contain ions dissolved in them. When two of these solutions are mixed, the ions in the reaction interact with each other and may

collide to form new compounds which will precipitate. The products form by where the cation from the first solution joins with the anion of the second solution and the anion from the first solution joins with the cation from the second solution.



One of these compounds will be insoluble in water and will form the precipitate while the other will remain dissolved in solution

The first step is to identify the reactants and the ions present in the two aqueous solutions.

Let's consider the example of the precipitation reaction between silver nitrate and magnesium chloride.

	Magnesium Chloride	Silver Nitrate
Chemical Formula		
Cation		
Anion		

Based on this we can balanced we can write the reactants side of our chemical equation.

Now based on this we can predict the two compounds that will be produced.

	Product 1	Product 2
Cation		
Anion		
Chemical Formula		
Name		

Now we can write the entire word and chemical equation:

To determine which product produced is the precipitate we used a set of rules that tell us which ionic solid is soluble in water. These rules are often arranged into solubility tables.

Ion	General Solubility Rule
NO_3^-	All nitrates are soluble
$C_2H_3O_2^-$	All acetates are soluble ($AgC_2H_3O_2$ only moderately)
Cl^-, Br^-, I^-	All chlorides, bromides and iodides are soluble except Ag^+, Pb^+ and Hg_2^{2+}. ($PbCl_2$ is slightly soluble in cold water and moderatel soluble in hot water.)
SO_4^{2-}	All sulfates are soluble except those of Ba^{2+}, Pb^{2+}, Ca^{2+} and Sr^{2+}
CO_3^{2-} and PO_4^{3-}	All carbonates and phosphates are insoluble except those of Na^+, K^+ and NH_4^+. (Many acid phosphates are soluble).
OH^-	All hydroxides are insoluble except those of Na^+ and K^+. Hydroxides of Ba^{2+} and Ca^{2+} are slightly soluble.
S^{2-}	All sulfides are insoluble except those of Na^+, K^+, NH_4^+ and those of the alkaline earths: Mg^{2+}, Ca^{2+}, Sr^{2+} and Ba^{2+}. (Sulfides of Al^{3+} and Cr^{3+} hydrolyze and precipiate as the corresponding hydroxides.
Na^+, K^+ and NH_4^+	All salts of sodium ion, potassium ion and ammonium ion are soluble except several uncommon ones.

Based on this table which product from the above reaction will form the precipitate? _____

Ionic Equations:

For each precipitation reaction, we can write an ionic equation. we do this by writing out the equation in ionic form. Make sure here that every compound except the solid precipitate is written as ionic. The precipitate does not dissolve in water and so doesn't separate into ions.

We can then cross out the ions that are present on both sides of the equation. These ions are called spectator ions and do not play a major role in the reaction. Now we are left with a net ionic equation for the reaction. For ionic equations you need to make sure that the atoms and charges on both sides of the equation are balanced.

Ionic Equation:

Net Ionic Equation:

Reactions of Acids and Bases

Acid and Reactive Metals:

When a dilute acid reacts with a main group metal and some transition metals, hydrogen gas is released, and a salt is formed. This salt is usually soluble and dissolves in water.

Acid + Metal → Salt + Hydrogen Gas

Hydrochloric acid + Iron → Iron (II) Chloride + Hydrogen

$2HCl\ (aq) + Fe\ (s) + \rightarrow \ FeCl_2(aq) + H_2\ (g)$

In the lab, a strip of magnesium was put into a solution of concentrated nitric acid (HNO_3). Bubbles were observed. Write the word and balanced chemical equation to show represent this reaction:

The presence of hydrogen gas can be confirmed by conducting the pop-test. The pop-test involves lighting a match and placing it near the opening of a test

tube or beaker where ethe hydrogen gas is supposedly being produced. If hydrogen is present the match will pop.

Acid and Base:

This reaction is referred to as a Neutralisation reaction, where the acid reacts with a base (usually a metal hydroxide) to produce water and a salt.

Acid + Metal Hydroxide → Salt + Water

An example of this the reaction of hydrochloric acid (HCl) with sodium hydroxide (NaOH).

This reaction can be represented through ionic equations as well. Think about the ions present in the reactants and the products. Remember anything non-ionic is written as is.

To test if a neutralisation reaction has occurred, we can check the pH of the final solution and it should come out to be close to 7. This is because water is neutral and has a pH of 7.

Acid and Metal Carbonates:

What is the carbonate ion? _____

Acids can react with metal carbonates and metal hydrogen carbonates to produce carbon dioxide, water and a salt.

$$Acid + Metal\ Carbonate \rightarrow Salt + Carbon\ Dioxide + Water$$

$$Hydrochloric\ acid + Sodium\ Carbonate \rightarrow Sodium\ Chloride + Carbon\ Dioxide + Water$$

$$2HCl\ (aq) + Na_2CO_3(aq) + \rightarrow \quad 2NaCl\ (aq) + CO_2\ (g) + H_2O\ (l)$$

This reaction can be written in ionic form as follows:

$$2H^+\ (aq) + 2Cl^-\ (aq) + 2Na^+\ (aq) + CO_3^{2--}\ (aq) \rightarrow \quad 2Na^+\ (aq) + 2Cl^-\ (aq) + CO_2\ (g) + H_2O\ (l)$$

Net ionic Equation:

$$2H^+\ (aq) + CO_3^{2--}\ (aq) \rightarrow CO_2\ (g) + H_2O\ (l)$$

You can detect the presence of carbonate salts by detecting if any carbon dioxide is produced. This is done through the limewater test. When carbon dioxide is added to limewater, the clear solution will turn milky or cloudy.

Homework and Practice Questions

Question 1:

Balance the equations then classify the following reactions as neutralisation, combustion (incomplete or complete), precipitation, acid/metal, acid/carbonate, synthesis and decomposition.

$PbCl_2\ (aq) + AgNO_3\ (aq) \rightarrow Pb(NO_3)_2\ (aq) + AgCl\ (s)$	
$NH_3 + HCl \rightarrow NH_4Cl$	
$Zn\ (s) + S\ (s) \rightarrow ZnS\ (s)$	
$C_{12}H_{22}O_{11}\ (l) + O_2\ (g) \rightarrow CO_2\ (g) + H_2O\ (g)$	
$Mg(OH)_2\ (s) + H_2SO_4\ (aq) \rightarrow MgSO_4\ (aq) + H_2O\ (l)$	
$Fe\ (s) + O_2\ (g) \rightarrow Fe_2O_3\ (s)$	
$C_4H_{10}\ (l) + O_2\ (g) \rightarrow H_2O\ (l) + CO\ (g)$	

Question 2:

Translate each scenario into chemical equations by identifying the reactants and products and balancing.

a. Sodium reacts with water forming sodium hydroxide and hydrogen gas

b. Barium chloride and sodium sulphate reacting to form a salt and precipitate

c. Hexane (C_6H_{14}) burns in oxygen gas. Complete combustion occurs

d. Sulphuric Acid (H_2SO_4) undergoes a neutralisation reaction with silver hydroxide

e. Hydrochloric Acid reacts with nitric acid (HNO_3)