CHEMICAL REACTIONS

CONTENTS

- INTRODUCTION
- CHEMICAL EQUATIONS
- COVALENT BOND
- BONDING IN METALS

INTRODUCTION

In the previous class, you have read about physical an chemical changes. Chemical changes result from chemical reaction taking placed between substances. In this chapter we shall deal with the chemical reactions and their representation in the form of chemical equations.

The processes in which a substance or substances undergo change to produce new substances with new properties are known as chemical reactions. for example, when calcium carbonate is heated, calcium oxide (lime) and carbon dioxide are formed. The breaking up of calcium carbonate into calcium oxide and carbon dioxide is, thus, a chemical reaction because calcium carbonate changes into new substances, calcium oxide and carbon dioxide.

❖ Reactant :

The substance which takes part in a chemical reaction is called reactant. For example, in the breaking up of calcium carbonate into calcium oxide and carbon dioxide, calcium carbonate is the reactant. Similarly, sodium and water are the reactants when they react.

❖ Product :

A product is a new substance formed in a chemical reaction. For example, hydrogen and sodium hydroxide are the products of the reaction between sodium and water.

$$\underset{\text{sodium}}{Na} + \underset{\text{water}}{H_2O} \rightarrow \underset{\text{sodiumhy droxide}}{NaOH} + \underset{\text{hydrogen}}{H_2}$$

Similarly, in the breaking up of calcium carbonate, calcium oxide and carbon dioxide are the products.

$$\underset{\text{calcium carbonate}}{CaCO_3} \rightarrow \underset{\text{calcium oxide}}{CaO} + \underset{\text{carbon dioxide}}{CO_2}$$

You know, atoms in a molecule are held together by a force of attraction called bond. The molecules do not participate directly in a chemical reaction. First they break down into atoms and these atoms then take part in the reaction. New bonds are formed between the atoms to form the products. That is, there take place rearrangement or regroupings of atoms in various ways to give products. For example, when ammonium cyanate is heated, different bonds in ammonium cyanate molecules are broken and new bonds are formed to produce urea.

$$\underset{\text{ammonium cyanate}}{H_4N - N = C = O} \rightarrow \underset{\text{urea}}{H_2N - \overset{\overset{\displaystyle O}{\|}}{C} - NH_2}$$

Here, we see that the molecular formulae of both ammonium cyanate and urea are the same, but their properties are quite different and they are two different compounds. Such compounds are known as isomers of each other and the reactions that produce such isomers are called isomerization reactions.

- **Valency :**

The number of electrons shared by an atom is called its valency. It is also called the combining capacity of an atom, e.g., Cl atom can share one valence electron, its valency is 1, Oxygen can share two valence electrons, its valency is 2. Nitrogen can share 3 valence electrons, its valency is 3, Carbon can share 4 valency electrons, therefore its valency is 4 and so on.

It means if carbon combines with Chlorine, Carbon will share four valence electrons with four chlorine atoms, therefore the molecular formula of the covalent compound will be

Element C Cl

Valency 4 1 i.e., CCl_4 is formula

Some more examples are :

Element	H O	H Cl	H S	N H	P Cl	N O
Valency	1 2	1 1	1 2	3 1	3 1	5 2
	H_2O	HCl	H_2S	NH_3	PCl_3	N_2O_5

Some Common Monoatomic Ions

+1 Charge	Formula	+2Charge	Formula	+3 Charge	Formula
Name of ion		**Name of ion**		**Name of ion**	
Copper ion	Cu^+	Barium ion	Ba^{2+}	Aluminium ion	Al^{3+}
(Cuprous ion)		Cobalt ion	Co^{2+}	Auric ion	Au^{3+}
Potassium ion	K^+	Strontium ion	Sr^{2+}	Chromium (III) ion	Cr^{3+}
Silver ion	Ag^+	Iron (II) ion	Fe^{2+}	Iron (III) ion	Fe^{3+}
		(Ferrous ion)		(Ferric ion)	
Sodium ion	Na^+	*Copper (II) ion	Cu^{2+}	Scandium ion	Sc^{3+}
Lithium ion	Li^+	*Lead (II) ion	Pb^{2+}	Arsenic ion	As^{3+}
		Cadmium ion	Cd^{2+}	Bismuth ion	Bi^{3+}
		Magnesium ion	Mg^{2+}	Antimony ion	Sb^{3+}
Aurous	Au^+	Manganese (II) ion	Mn^{2+}		
		*Mercury (I) ion	Hg_2^{2+}		
		Zinc ion	Zn^{2+}		

– 1 Charge	Formula	– 2Charge	Formula	– 3 Charge	Formula
Name of ion		**Name of ion**		**Name of ion**	
Bromide ion	Br^-	Oxide ion	O^{2-}	Nitride ion	N^{3-}
Chloride ion	Cl^-	Sulphide ion	S^{2-}	Phosphide ion	P^{3-}
Fluoride ion	F^-			Boride ion	B^{3-}
Iodide ion	I^-				

- These elements show more than one valency. So a Roman numeral shows their valency in a bracket.

Some Common Polyatomic Ions

– 1 Charge	Formula	– 2Charge	Formula	– 3 Charge	Formula
Name of ion		**Name of ion**		**Name of ion**	
Hydrogen carbonate or bicarbonate ion	HCO_3^-	Carbonate ion	CO_3^{2-}	Phosphate ion	PO_4^{3-}
		Manganate ion	MnO_4^{2-}	Arsenate ion	AsO_4^{3-}
Hydrogen sulphate or (bisulphate ion)	HSO_4^-	Thiosulphate ion	$S_2O_3^{2-}$	Arsenite ion	AsO_3^{3-}
		Silicate ion	SiO_3^{2-}		

Hydroxide ion	OH^-	Sulphate ion	SO_4^{2-}	Phosphite ion	PO_3^{3-}
Nitrate ion	NO_3^-	Sulphite ion	SO_3^{2-}		
Chlorate ion	ClO_3^-	Chromate ion	CrO_4^{2-}	Borate ion	BO_3^{3-}
Nitrite ion	NO_2^-	Dichromate ion	$Cr_2O_7^{2-}$	Ferricyanide ion	$[Fe(CN)_6]^{3-}$
Permanganate ion	MnO_4^-	Hydrogen phosphate ion	HPO_4^{2-}		
Acetate ion	CH_3COO^-	Oxalate ion	$C_2O_4^{2-}$		
Cyanide ion	CN^-				
Hypophosphite ion	$H_2PO_2^-$				– 4 Charge
Meta aluminate ion	AlO_2^-			Carbide ion	C^{4-}
	+1 Charge			Ferrocyanide ion	$[Fe(CN)_6]^{4-}$
Ammonium ion	NH_4^+				

❖ Tests of Chemical Reaction :

A chemical reaction must satisfy the following :

(i) There must be either evolution or absorption of heat, i.e., a chemical reaction must be accompanied with change in temperature.

(ii) The reaction must occur between fixed quantities of the reactants.

(iii) There must not be either gain or loss of matter, i.e., a chemical reaction should follow the law of conservation of mass.

(iv) The products obtained as a result of chemical reaction must have properties different from those of the reactants.

➤ CHEMICAL EQUATIONS

All chemical reactions are represented by chemical equations. A chemical equation is a shorthand representation of a chemical reaction using the symbols and formulae of substance involved in the chemical reaction.

The symbols and formulae of the substances (elements or compounds) are arranged to show the reactants and products of a chemical reaction.

Examples :

1. When potassium nitrate is heated, it gives potassium nitrite and oxygen. This reaction may be represented in the form of a chemical equation as follows.

$$\underset{\text{potassium nitrate}}{KNO_3} \rightarrow \underset{\text{potassium nitrite}}{KNO_2} + \underset{\text{oxygen}}{O_2}$$

2. Zinc and dilute sulphuric acid react to form zinc sulphate and hydrogen. This reaction is represented by a chemical equation as

$$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$$

❖ Rules for writing chemical equation :

Certain rules have to be followed while writing a chemical equation.

1. The reactants taking part in the reaction are written in terms of their symbols or molecular formulae on the left-hand side of the equation.
2. A plus (+) sign is added between the formulae of the reactants.
3. The products of reaction are written in terms of their symbols or molecular formulae on the right-hand side of the equation.
4. A plus (+) sign is added between the formulae of the products.
5. In between the reactants and the products an arrow sign (→) is inserted to show which way the reaction is occurring.

$$A + B \longrightarrow C + D$$

In this chemical equation, A and B are the reactants, and C and D are the products. The arrow indicates that the reaction proceeds towards the formation of C and D.

Balancing of Chemical Equation :

Observe the following two chemical equations :

$Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$ .....(i)

$Na + H_2O \longrightarrow NaOH + H_2$ .....(ii)

In equation (i), the number of atoms of Zn, H, S and O are equal on both sides, i.e., the equation is balanced

Balanced Equations :
The equations in which atoms of various elements on the reactants' and the products side are equal.

Equation (ii) is not balanced because the number of hydrogen atoms in not equal on both sides. It is called a skeleton chemical equation.

Reason of Balancing Equations :

The number of atoms of elements on both sides of a chemical equation should be equal in accordance with the law of conservation of mass.

Balancing :

The process of making atoms of various elements equal in an equation on either side is called balancing.

Steps in Balancing of Chemical Equations :

A number of steps are involved in balancing a chemical equation, e.g.,

$$Na + H_2O \rightarrow NaOH + H_2$$

Step-1 : Examine the number of atoms of different elements present in unbalanced equations.

	Number of atoms in reactants	Number of atoms in products
Na	1	1
H	2	3
O	1	1

Step-2 : Pick an element to balance the equation. In the above equation Na and O are balanced, Hydrogen is not.

Step : To balance Hydrogen on both sides we need to multiply H_2O by 2 which makes Hydrogen atoms equal to 4 on the reactants' side. To make Hydrogen 4 on the products' side, multiply NaOH by 2. Now oxygen has become 2 on both side. But Sodium atoms has become two on the products' side. Multiply Na by 2 on the reactants side so that they become equal on both side. The steps are as follows :

(i) $Na + 2\ H_2O \rightarrow NaOH + H_2$

(ii) $Na + 2\ H_2O \rightarrow 2NaOH + H_2$

(iii) $2\ Na + 2\ H_2O \rightarrow 2NaOH + H_2$

The equation is now balanced.

Example : $Fe + H_2O \longrightarrow Fe_3O_4 + H_2$

Step-1 :

Element	Number of atoms in reactants	Number of atoms in products
Fe	1	3
H	2	2
O	1	4

Step-2 :Pick up the compound which has the maximum number of atoms whether a reactant or a product, and in that compound select the elements which has the highest number of atoms, e.g., we select Fe_3O_4 in the above equation :

To balance oxygen atoms,

	In reactants	In products
Initial	1 (in H_2O)	4 (in Fe_3O_4)
To balance	1×4	4×1

To equalise the number of atoms, we put the coefficient on the left side of the formula.

A coefficient is a small whole number, like coefficients used in algebraic equations.

You must keep in mind that we can put coefficients but we cannot change the subscripts in the formula, i.e., to balance Oxygen atoms, we can put the coefficient 4 as $4\ H_2O$ and not H_2O_4 or $(H_2O)_4$. Now the partly balanced equation becomes as follows :

$$Fe(s) + 4\ H_2O(g) \longrightarrow Fe_3O_4(s) + H_2(g)$$

(Partly balanced)

Step-3 : Pick up the second element to balance this partly balanced equation. Let us try to balance hydrogen atoms.

In partly balanced equation. Atoms of Hydrogen.

	In reactants	In products

Initial	8 (in 8 H_2O)	2 (in H_4)
To balance	8×1	2×4

To equalise the number of Hydrogen atoms, we use 4 as the coefficient of H_2 in the products.

$$Fe(s) + 4\,H_2O(g) \longrightarrow Fe_3O_4(s) + 4\,H_2$$

Step-4 : Pick up third element to be balanced. The element which is left to be balanced is Fe.

	In reactants	In products
Initial	1 (in Fe)	3 (in Fe_3O_4)
To balance	1×3	3×1

To equalise, we use 3 as coefficient of Fe in reactants.

$$3Fe + 4H_2O \longrightarrow Fe_3O_4 + 4H_2$$

Atoms	In reactants	In products
Fe	3	3
H	8	8
O	4	4

The equation is balanced because atoms of all the elements are equal on both sides.

This method of balancing equation is known as hit and trial method.

◈ Balancing of Ionic Equations :

In these equations, charge balancing of atoms on both sides of the equation, e.g.,

Initial $Cu^{2+}(aq.) + H_2S \longrightarrow CuS\,(s) + H^+\,(aq)$

Balanced $Cu^{2+}\,(aq.) + H_2S \longrightarrow CuS\,(s) + 2H^+\,(aq)$

We have balanced the charges. It was + 2 on LHS and we have made + 2 on RHS. Number of Hydrogen atoms, Cu and Sulphur atoms are also balanced on both sides.

Compound	Formula	Ions involved
Sodium chloride	NaCl	Na^+ and Cl^-
Magnesium chloride	$MgCl_2$	Mg^{2+} and Cl^-
Magnesium oxide	MgO	Mg^{2+} and O^{2-}
Calcium chloride	$CaCl_2$	Ca^{2+} and Cl^-
Calcium oxide	CaO	Ca^{2+} and O^{2-}
Ammonium chloride	NH_4Cl	NH_4^+ and Cl-
Barium chloride	$BaCl_2$	Ba^{2+} and Cr
Potassium nitrate	KNO_3	K^+ and NO_3^-
Ammonium sulphate	$(NH_4)_2SO_4$	NH_4^+ and SO_4^{2-}
Cupric sulphate	$CuSO_4$	Cu^{2+} and SO_4^{2+}
Cupric chloride	$CuCl_2$	Cu^{2+} and Cl^-

◈ Electrovalency :

When an element forms electrovalent bond, its valency is known as electrovalency.

The number of electrovalent or ionic bonds an atom can form is called its electrovalency. The electrovalency of an element is, therefore, equal to the number of electrons lost or gained by the atom to form an ion.

Elements which lose electrons show positive electrovalency and those which gain electrons show negative electrovalency. For example, in the formation of sodium chloride (Na^+Cl^-), the electrovalency of sodium (Na) is +1, while that of chlorine (Cl) is – 1.

Elements which lose or gain one, two, three, ... , etc., electrons are said to be monovalent (orunivalent), divalent (or bivalent), trivalent, ... , etc., respectively.

Monovalent elements : Na, CI, F

Divalent elements : Mg, Ca, Ba, O

Trivalent elements : Al, B

◈ Characteristics of electrovalent or ionic compounds :

1. Electrovalent compounds are made up of positively and negatively charged ions. For example, sodium chloride (NaCl) is made up of Na^+ and Cl^- ions arranged in a definite order in three dimensions to form crystals.

2. Electrovalent compounds have high melting and boiling points. This is due to the presence of strong electrostatic forces of attraction between the positive and negative ions. A large amount of heat energy is required to break this force of attraction. Hence, the melting and boiling points of electrovalent compounds are high.

3. Electrovalent compounds are usually soluble in water but insoluble in organic solvents such as benzene, acetone, carbon disulphide and carbon tetrachloride.
4. Electrovalent compounds conduct electricity in molten state and in their aqueous solutions.

In solid electrovalent compounds the ions are held together in fixed positions and cannot move. Hence, such compounds in the solid state do not conduct electricity.

When an electrovalent compound is dissolved in water or is melted, the crystal structure breaks down. The ions now become free to move and can, therefore, conduct electricity.

That the ionic compounds in molten state or in solution become conductors of electricity can be shown by the some specific activity.

➢ THE COVALENT BOND

The chemical bond farmed when two atoms share electrons between them is known as a covalent bond.

The sharing of electrons between the two atoms takes place in such a way that both the atoms acquire the stable electronic configurations of their nearest noble gases.

There are three types of covalent bonds :

1. Single covalent bond
2. Double covalent bond
3. Triple covalent bond

◈ Single covalent bond :

A single covalent bond is formed when one pair of electrons is shared between two atoms.

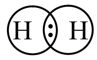
EXAMPLES :

1. Formation of a hydrogen molecule (H_2) :

A molecule of hydrogen consists of two hydrogen atoms. Each hydrogen atom has one electron. When two atoms of hydrogen combine, one electron of each takes part in sharing. Thus, two electrons (one pair of electrons) are shared between the two atoms.

$$H^{\bullet} + {}^{\bullet}H \rightarrow H : H$$

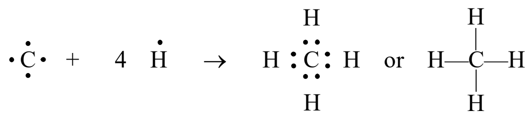
The shared electron pair always exists between the two atoms. The two dots between the two H atoms represent the pair of shared electrons. One pair of shared electrons gives a single bond. Such a bond is represented by a short line between the two atoms. Thus, a hydrogen molecule may be represented as in figure.

$H : H$ or $H - H$ 

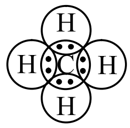
Once the bond is formed, the both atoms have a stable configuration of the noble gas helium.

2. Formation of a methane molecule (CH_4) :

A carbon atom has four electrons in its outermost shell (valence shell). It shares its valence electrons with those of four H atoms. Thus, an atom of carbon forms four single covalent bonds with four H atoms.



Pictorially, a methane molecule may be represented as in Figure.



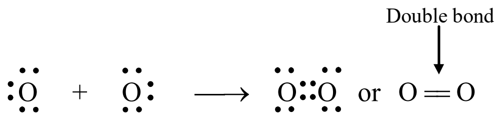
◈ Double covalent bond :

A double covalent bond is formed when two pairs of electrons are shared between the two combining atoms. A sharing of two pairs of electrons is shown by marking two short lines between the symbols of the two atoms.

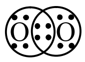
EXAMPLES :

1. Formation of an oxygen molecule (O_2) :

An atom of oxygen contains six electrons in its valence shell. It requires two more electrons to attain a stable eight-electron configuration (octet). This is achieved when each of the two oxygen atoms shares its two electrons with the other, resulting in the formation of a stable oxygen molecule.

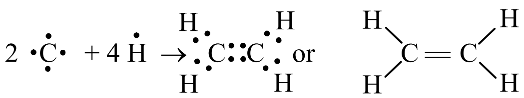


Pictorially, the oxygen molecule may be represented as in figure.



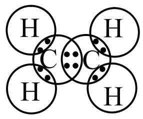
2. **Formation of an ethylene molecule (C_2H_4) :**

In the formation of an ethylene molecule (C_2H_4), each of the two C atoms combines with two H atoms to form two single covalent bonds. The remaining two electrons of each C atom form a double bond between the two C atoms.



(Ethylene molecule)

Pictorially, a molecule of ethylene (C_2H_4) may be represented a in figure.



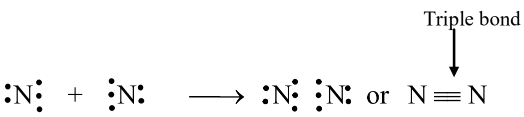
◈ Triple covalent bond :

A triple covalent bond is formed when three pairs of electrons (six electrons) are shared between the two combining atoms. A triple bond is shown by marking three short lines between the two symbols of the atoms.

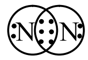
EXAMPLES :

1. **Formation of a nitrogen molecule (N_2) :**

An atom of nitrogen has five electrons in its valence shell. It requires three more electrons to attain the stable octet. This is achieved when two nitrogen atoms combine together by sharing three electrons each to form a nitrogen molecule.



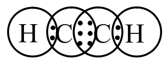
Pictorially, a nitrogen molecule can be represented as in figure.



2. **Formation of an acetylene molecule (C_2H_2) :**

In an acetylene molecule, two C atoms combine with two H atoms. Each C atom shares three of its valence electrons with the other C atom. One electron of each C atom is shared with one electron of a H atom.

Thus, in a molecule of acetylene, there is a triple covalent bond between the two C atoms and each C atom is joined to one H atom by a single covalent bond. Pictorially, a molecule of acetylene may be represented as in figure.



◈ Characteristics of covalent compounds :

1. Covalent compounds are made up of neutral molecules. Hence, the forces of attraction between the molecules are weaker than those found in ionic compounds. Therefore, covalent compounds are usually volatile liquids or gases.
2. The melting and the boiling points of covalent compounds are generally low. Since covalent compounds are made up of neutral molecules, the forces of attraction between the molecules are very weak. So, a comparatively small amount of heat energy is required to break these weak intermolecular forces of attraction. Hence, they have low melting and boiling points.
3. Covalent compounds are insoluble in water but soluble in organic solvents.
4. Covalent compounds do not conduct electricity. This is because they are made up of neutral molecules, not ions, and do not produce ions in the molten state or in aqueous solutions.

➤ BONDING IN METALS

As you know, metals are hard solids and they are made up of atoms. It has been established that the atoms in a metal are very closely packed together.

The force that holds the atoms closely together in a metal is known as the metallic bond.

Metal atoms lose one, two or three electrons to form positively charged ions, called cations.

The electrons thus lost move freely in the metal, i.e., these electrons become mobile, but the cations do not leave their positions. So in a metal lattice it is assumed that the metal ions are immersed in a sea of electrons. Due to the presence of mobile electrons, metals are good conductors of heat and electricity.

POINT TO REMEMER

- A chemical bond is the force of attraction which holds together the atoms in a molecule.
- An electrovalent bond is formed as a result of complete transfer of electron(s) from one atom to another.
- Atoms which can lose electrons and form positive ions are said to be electropositive.
- Atoms which can gain electrons and form negative ions are said to be electronegative.
- The total number of electrons lost or gained by an atom to attain the stable configuration of the nearest noble gas is known as the valency of the atom.
- The number of electrovalent bonds by an atom can form is called its electrovalency.
- Covalent bonds are formed by the mutual sharing of electrons between the combining atoms.
- Compounds containing covalent bonds are called covalent compounds.
- The. total number of electrons shared by a given atom in the formation of covalent bonds to attain the stable configuration of its nearest noble gas is known as its covalency.
- The force that holds the atoms closely together in a metal is known as the metallic bond.