ATOMS AND MOLECULES

INTRODUCTION

It was proposed by Indian philosopher, maharishi Kanad, that if we go on dividing matter, we will get **smaller and smaller particles** of matter. Finally, we will get the **smallest particle** of matter, which **cannot be divided** further. ***John Dalton*** called these particles by the name **atom,** which means '**indivisible'.** It was further proposed that the particles of matter **(atoms)** normally exists in a **combined form** and various combination of particles give u s **various kind** of matter. This combined form of atoms is called **molecules.**

All matter is made up of small particles called atoms and molecules. Different kind of atoms and molecules have different properties due to which different kind of matter also show different properties.

LAWS OF CHEMICAL COMBINATION

The laws of chemical combination are the **experimental laws** which led to the idea of **atoms being the smallest unit of matter.** The laws of chemical combination played a significant role in the development of Dalton's atomic theory of matter.

There are two important laws of chemical combination. These are :

(i) Law of conservation of mass

(ii) Law of constant proportions

(a) Law of Conservation of Mass or Matter :

This law was given by ***Lavoisier*** in 1774. According to the law of conservation of mass, matter can neither be created nor be destroyed in a chemical reaction.

The law of conservation of mass means that in a chemical reaction, the total mass of products in equal to the total mass of the reactants. There is **not change in mass** during a chemical reaction.

Suppose we carry out a chemical reaction between A and B and if the products formed are C and D then,

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

Suppose 'a' g of A and 'b' g ob B react to produce 'c' g of C and 'd' g of D. Then, according **to the law of conservation of mass,** we have,

$$a + b = c + d$$

Example :

We calcium Carbonate **($CaCO_3$)** is heated, a chemical reaction takes place to form Calcium Oxide **(CaO)** and Carbon Dioxide **(CO_2).** It has been found by experiments that if **100 grams** of calcium carbonate is decomposed completely, then **56 grams of** Calcium Oxide and **44 grams** of Carbon dioxide are formed.

$CaCO_3$ + Heat $\longrightarrow$ CaO + CO_2

(100 gm) 56g 44g

65g + 44g = 100g

Since the total mass of products (100g) is equal to the total mass of the reactants (100g), there is **no change in the mass** during this chemical reaction. The mass remains same of conserved.

Maharishi kanad told that if we keep dividing matter on and on, we will get the smallest particles called as paramanu.

(b) Law of constant Proportion / Law of Definite Proportions :

Proust, in **1779,** analysed the chemical composition (types of elements present and percentage of elements present) of a large number of compounds and came to the conclusion that the proportion of each element is a compound is constant (or fixed). According to the law of constant proportions : A chemical compound always consists of the same elements combined together in the same proportion by mass.

The chemical composition of a pure substance is not dependent on the source from which it is obtained.

Example :

Water is a compound of **hydrogen and oxygen.** It can be obtained from **various sources (like river, sea, well etc.)** or even **synthesized in the laboratory.** From whatever source we may get it, 9 parts by weight of water is always found to contain 1 part by weight of hydrogen and 8 parts by weight of oxygen. Thus, in **water,** this proportion of **hydrogen and oxygen** always **remains constant.**

The converse of Law of definite proportions that when same elements combine in the same proportion, the same compound will be formed, is not always true.

DALTON'S ATOMIC THEORY

Dalton put forward his **atomic theory** of matter in 1808. The various **postulates** (or assumptions) of **Dalton's atomic theory of matter** are as follows :

(i) Al the matter is made up of very small particles called **"atoms".**

(ii) Atoms **cannot be divided.**

(iii) Atoms can **neither be created nor be destroyed.**

(iv) Atoms are of **various kinds.** There are as many kinds of atoms as are elements.

(v) All the atoms of given element are **identical** in every respect, having the **same mass, size and chemical properties.**

(vi) Atoms of **different elements differ in mass, size and chemical properties.**

(vii) Chemical combination between **two** (or more) **elements** consist of the joining together of atoms of chemical elements to form **molecules of compounds.**

(viii) The **number and kind of atoms** in a given compound is **fixed.**

(ix) During chemical combination, atoms of different elements combine in **small whole numbers** to form compounds.

(x) Atoms of the same elements can combine in **more than one ratio** to form more than one compound.

Dalton's atomic theory provides a simple explanation for the laws of chemical combination and was the first modern attempt to describe the behaviour of matter in terms of atoms.

E.g. he postulate of **Dalton's atomic theory** that "*atoms can neither be created nor be destroyed"* was a result of the **law of conservation of mass** and the postulate of **Dalton's** atomic theory that *"the elements consist of atoms having fixed mass,* and that the number and kind of atoms in a given compound is fixed," came from the **law of constant proportions.**

EXERCISE

OBJECTIVE DPP - 7.1

1. Which postulate of Dalton's Atomic theory suggests the law of conservation of mass ?

(A) Atoms cannot be divided.

(B) All the meter is made up of very small particles called atoms.

(C) Elements consist of atoms combined in a fixed ratio.

(D) Atoms can neither be created nor be destroyed.

2. The elements present in baking soda are -

(A) sodium, carbon and oxygen (B) sodium, carbon and hydrogen

(C) sodium, carbon, hydrogen and oxygen (D) potassium, carbon and oxygen.

3. All samples of carbon dioxide contain carbon and oxygen in the mass ratio 3 : 8. This is in agreement with the law of

(A) conservation of mass (B) constant proportions

(C) (A) and (B) both (D) none of these

4. When 5 g of Calcium is burnt in 2 g of Oxygen then 7 g of Calcium oxide is produced. What mass of calcium oxide will be produced when 5 g of calcium reacts with 20 g of oxygen ?

(A) 7 g (B) 2 g (C) 25 g (D) 4 g

5. The law of conservation of mass was given by

(A) John Dalton (B) Proust (C) Lavoisier (D) None of these

6. If the mass of reactants is equal to the mass of products then which of the following statements is true ?

(A) Law of conservation of mass holds good.

(B) Mass can neither be created nor be destroyed.

(C) There is no change in mass during a chemical reaction.

(D) All the above

7. Hydrogen & Oxygen combine in the ratio of 1 : 8 by mass to form water. What mass of oxygen gas would be required to react completely with 3 g of hydrogen gas ?

(A) 24 g (B) 27 g (C) 21 g (D) 3 g

8. Which postulate of Dalton's atomic theory explains the law of constant proportion ?

(A) Atoms cannot be divided.

(B) All the matter is made up of very small particles called atoms.

(C) Elements consist of atoms combined in a fixed ratio.

(D) Atoms can neither be created nor be destroyed.

9. The term 'Paramanu' for the smallest particles of matter (padarth) was given by -

(A) Dalton (B) Maharishi Kanad (C) Proust (D) Lavoisier

10. When calcium carbonate is heated, it gives -

(A) CaO & CO (B) Ca & CO_2 (C) CaO & CO_2 (D) None of these

SUBJECTIVE DPP - 7.2

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1. "If 100 grams of pure water taken from different sources is decomposed by passing electricity, 11 grams of hydrogen and 89 grams of oxygen are always obtained." Which chemical law is illustrated by this statement ?

2. Dalton's atomic theory says that atoms are indivisible. In this statement still valid ? Give reasons for your answer.

3. Potassium chlorate decomposes on heating to form potassium chloride and oxygen. When 24.5 g of potassium chlorate is decomposed completely then 14.9 g potassium chloride is formed. Calculate the mass of oxygen formed. Which law of chemical combination have you used in solving this problem ?

4. In an experiment 1.288 g of copper oxide was obtained from 10.3 g of Cu. In another experiment 3.672 g of copper oxide gave on reduction 2.938 g of copper. Which law of chemical combination can be illustrated by this example ?

ATOMS AND MOLECULES

ATOMS

All the **matter** is made up of **atoms.** An atom in the **smallest particle** of an element that can **take part** in a **chemical reaction.** Atoms of most of the elements are **very reactive** and **do not exist in the free state** (as single atoms). They exist in **combination** with the atoms of the **same element or another element.**

Atoms are **very, very small** in size. The size of an atom is indicated by its **radius** which is called **"atomic radius"** (radius of an atom). Atomic radius is measured in **"nanometers"** (nm). **1 metre = 10^9 nanometers or 1 nm = 10^{-9} m.**

Atoms are so small that we cannot see them under the most powerful optical microscope.

Hydrogen atom is the smallest atom of all, having an atomic radius 0.037 nm.

(a) Symbols of Elements :

A symbol is a short hand notation of an element which can be represented by a sketch or letter etc.

Alton was the first to use symbols to represent elements is a short way but Dalton's symbols for elements were difficult to draw and inconvenient to use, so **Dalton's** symbols are only of historical importance. They are not used at all.

Element	Dalton's symbol
Hydrogen	
Carbon	

It was J.J. Berzelius who proposed the modern system of representing en element. The **symbol** of an element is the **"first letter"** or the **"first letter and another letter"** of the **English name** or the **Latin name** of the element.

Eg. The symbol of **Hydrogen** is H.

The symbol of **Oxygen** is O.

There are some elements whose **names begin** with the **same letter.** For example, the names of elements *Carbon, Calcium, Chlorine* and *Copper* and Copper all begin with the letter C. In such cases, one of the elements is given a "**one letter"** symbol but all other elements are given a **"first letter and another letter"** symbol of the **English or Latin name** of the element. This is to be noted that "another letter" may or may not be the "second letter" of the name. Thus,

The symbol of **Carbon** is C.

The symbol of **Calcium** is Ca.

The symbol of **Chlorine** is Cl.

The symbol of **Copper** is Cu (from its Latin name **Cuprum)**

It should be noted that in a **"two letter"** symbol, the **first letter** is the **"capital letter"** but the **second letter** is the **'small letter'**

Symbol of Derived from English Names	
English name of the Element	**Symbol**
Hydrogen	H
Helium	He
Lithium	Li
Boron	B
Carbon	C
Nitrogen	N
Oxygen	O
Fluorine	F
Neon	Ne
Magnesium	Mg
Aluminium	Al
Silicon	Si
Phosphorous	P
Sulphur	S
Chlorine	Cl
Argon	Ar
Calcium	Ca

Symbols Derived from Latin Names

English name of the Element	**Symbol**	**Latin Name of the Element**
Sodium	Na	Natrium
Potassium	K	Kalium

(b) Significance of The Symbol of an Element :

(i) Symbol represents name of the element.

(ii) Symbol represents one atom of the element.

(iii) Symbol also represents one mole of the element. That is, symbol also represent 6.023×10^{23} atoms of the element.

(iv) Symbol represent a definite mass of the element i.e. atomic mass of the element.

Example :

(i) Symbol H represents hydrogen element.

(ii) Symbol H also represents one atom of hydrogen element.

(iii) Symbol H also represents one mole of hydrogen atom.

(iv) Symbol H also represents one gram hydrogen atom.

(c) Atomic Mass of an Element :

Actual masses of the atoms of the elements are **very, very small.** For example, one atoms of **hydrogen** (H) has mass of **1.673×10^{-24} gram.** To avoid the inconvenience in using such small and complicated figures in our calculation, it was necessary to define atomic mass in such as way that we get simple figures for them. **Carbon -12 atom** is that atom of carbon which has 6 protons and 6 neutrons in its nucleus, so that its mass number is 12.

Carbon -12 atom has been assigned an atomic mass of exactly 12 atomic mass units, written as **12 u.**

Definition of atomic mass : Atomic mass express as to how many time an atom of a substance is heavier than $\frac{1}{12}$ th mass of the carbon - 12 atom.

Atomic Mass Unit (u) = One - twelfth the mass of a Carbon - 12 atom or 1u = 1.6605×10^{-24} g.

One atomic mass unit (1u) is defined as exactly one-twelfth the mass of an atom of Carbon-12. The **atomic mass** of an element is the **relative mass** of its atom as compared with the mass of a Carbon-12 atom taken as 12 units.

(d) How Do Atoms Exist ?

The atoms of only a few elements called **noble gases** (such as helium, neon, argon and krypton etc.) are **chemically uncreative** and exist in the **free state** (as single atoms). Atoms of most of the elements are **chemically very reactive and do not exist in the free state** (as single atoms).

Atoms usually exist in two ways :

(i) in the form of **molecules** and

(ii) in the form of **ions.**

When atoms form molecules or ins, they become **stable** (because in doing so they acquire the stable electron arrangements of noble gases).

MOLECULES

A molecule **is an electrically neutral group of two (or more) atoms chemically bonded together by means of attractive forces.**

OR

A molecule is the **smallest particle** of a substance (element or compound) which has the properties of that substance and can exist in the free state. Molecules can be formed either by the combination of atoms of the **"same element"** or of **"different elements"**/

Every compound is a molecule, but every molecule is not a compound.

There are two types of molecules : molecules of **elements** and molecules of **compounds.**

(a) Molecules of Elements :

The molecule of an element contains two (or more) similar atoms chemically bonded together. For example, a molecule of hydrogen element contains 2 hydrogen atoms combined together and it is written as $\mathbf{H_2}$ representing Hydrogen gas. Similarly, **Ozone gas** has 3 oxygen atoms combined together, so ozone exists in the form of $\mathbf{O_3}$**.** The noble gases like *helium, neon, argon and krypton* etc., exist as single atoms *He, Ne, Ar and Kr* respectively. So, their atoms and molecules are just the same.

Atomicity of phosphorus is 4 and sulphur is 8.

(b) Molecules of Compounds :

The molecule of compound contains two (or more) different types of atoms chemically bonded together. For example, the molecule of hydrogen chloride (HCl) contains one atom of hydrogen (H) chemically bonded with one atom of chlorine (Cl). Some more example of the molecules of compounds are : sulphur dioxide (SO_2), methane, (CH_4) and ammonia (NH_3).

(c) Atomicity :

The number of atoms present in one molecule of an element or compound is called it **atomicity.** For example, the atomicity of noble gases is 1, that of hydrogen, nitrogen, oxygen etc. is 2 each and of ozone is 3. Thus, **noble gases, hydrogen and ozone are** respectively **monatomic, diatomic, and triatomic** molecules.

A compound which consists of molecules and not ions, is called a molecular compound.

MOLECULAR MASS

The **molecular mass** of a substance may be defined as the relative mass of its molecule as compared to the mass of an atom of carbon (carbon - 12) taken as 12 units.

Molecular mass expresses as to how many times a molecular of a substance is heavier than $1/12^{th}$ of the mass of an atom of carbon (carbon -12).

Eg. A molecule of water is 18 times heaver than $1/12^{th}$ of the mass of carbon atom. Therefore, the molecular mass of water is **18u**. Similarly, the molecular mass of CO_2 is **44u.**

Calculation : The molecular mass is equal to sum of the atomic masses of all the atoms present in one molecule of the substance.

Eg. The molecular mass of **Sulphuric Acid (H_2SO_4)** can be calculated as follows :

Molecular mass of H_2SO_4 = Mass of 2 H atoms + Mass of 1 S atom + Mass of 4 O atoms

$$= (2 \times 1) + (1 \times 32) + (4 \times 16) = 2 + 32 + 64 = 94u.$$

Thus, the molecular mass of **Sulphuric acid is 98u.**

Atoms are the components of molecules and the molecules are the components of elements or compounds.

EXERCISE

OBJECTIVE DPP - 8.1

1. The number of atoms present in a molecule of element is called its -

(A) molecularity (B) atomicity (C) valency (D) reactivity

2. Which of the following is symbol of copper ?

(A) Ca (B) Cu (C) Co (D) None of these

3. The symbol of element oxygen is -

(A) O (B) O_2 (C) O_3 (D) None of these

4. 1 u is equal to

(A) 1.6605 g (B) 1.6605×10^{24} g (C) 1.6605×10^{-24} g (D) 1 g

5. The atoms of which one of the following element exist in free state ?

(A) Nitrogen (B) Helium (C) Hydrogen (D) Oxygen

6. Atoms can exist in the form of -

(A) molecules (B) Ions (C) Both A & B (D) None of these

7. A molecule of hydrogen is represented as -

(A) H (B) 2H (C) H_2 (D) All of these

8. The first scientist to use the symbols of elements was -

(A) Dalton (B) Berzilius (C) Kanad (D) Proust

9. Molecular mass of H_2SO_4 is -

(A) 89 U (B) 98 U (C) 49 U (D) 198 U

10. Molecular formula of sulphur is -

(A) S_4 (B) S_2 (C) S_8 (D) S_{18}

SUBJECTIVE DPP - 8.2

1. State whether the following statement is correct or not any why ?

The symbol of element cobalt is CO.

2. An element X has a valency of 4 whereas another element Y has a valency of 1. What will be the formula of the compound between X and Y ?

3. The valencies (or charges) of some of the ions are given below -

Ion	**Valency**	**Ion**	**Valency**
Sodium ion	+1	Bromide ion	-1
Ammonium ion	+1	Hydroxide ion	-1
Calcium ion	+2	Sulphate ion	-2
Lead ion	+2	Phosphate ion	-3

Using this information, write down the formulae of the following compounds -

(i) Sodium phosphate (B) Ammonium sulphate

(iii) Calcium hydroxide (D) Lead bromide

4. What is the difference between the molecule of an element and the molecule of a compound ? Give one example of each.

5. What is the significance of the symbol of an element ? Explain with the help of examples.

6. Write the relation between nanometer and metre.

ATOMS AND MOLECULES

IONS

An **ion** is a **positively or negatively charged** atom or group of atoms.

Every atom contains **equal number of electron (negatively charged) and protons** (positively charged). Both charges balance each other, hence atom is **electrically neutral.**

(a) Cation :

If an atom has **less electrons** than a **neutral atom,** then it gets **positively charged** and a positively charged ion is known as **cation.**

E.g. Sodium ion (Na^{+}), Magnesium ion (Mg^{2+}) etc.

A cation bears that much **units of positive charge as are the number of electrons lost** by the neutral atom to form that cation.

E.g. An aluminum atom loses 3 electrons to form aluminum ion, so **aluminum ion** bears 3 units of positive charge and it is represented as Al^{3+}.

All metal elements form cations.

(b) Anion :

If an atom has **more number of electrons than that of neutral atom,** then it gets negatively charged and a **negatively charged** iron is known as **union.**

E.g. Chloride ion (Cl^{-}), oxide ion (O^{2-}) etc.

All non-metal elements form anions (except hydrogen).

An anion bears that much **units of negative charge as are the number of electrons gained** by the neutral atom to form that anion.

E.g. A nitrogen atom gains 3 electrons to form nitride ion, so **nitride ion** bears 3 units of negative charge and it is represented as N^{3-}.

Size of a cation is always smaller and anion is always greater than that of the corresponding neutral atom.

MONOATOMIC IONS AND POLYATOMIC IONS

Monoatomic ions : Those ions which are formed form **single atoms** are called **monoatomic ions or simple ions.**

E.g. Na^+, Mg^{2+} etc.

Polyatomic ions : Those ions which are formed from **group of atoms** joined together are called **polyatomic ions or compound ions.**

E.g. Ammonium ion (NH_4^+), hydroxide ion (OH^-) etc. which are formed by the joining of two types of atoms, nitrogen and hydrogen in the first case and oxygen and hydrogen in the second.

IONIC COMPOUNDS

Those compounds which are **made up of ions (cations and anions)** and are held together by **strong electrostatic forces of attraction** are called **ionic compounds.**

The forces which **hold the ions together** in an ionic compound are known **as ionic bonds or electrovalent bonds.**

E.g. Calcium nitrate $Ca(NO_3)_2$ is an ionic compound, whose one molecule is made up of one calcium ion (Ca^{2+}) and two nitrate ions (NO_3), making the overall charge on calcium nitrate zero.

Overall charge on an ionic compound is always zero.

(a) Formula Unit of Ionic Compounds :

The **simplest combination of ions** that produces and **electrically neutral unit,** is called **a formula unit** of the **ionic compound.** Molecular formula of ionic compounds cannot be determined because they consist of large no. of ions. So ionic compounds are represented by formula unit.

Eg. Sodium chloride is an ionic compound which consists of **a large number of Na^+ and Cl^- ions** (but they should be equal in number). So, the **actual formula** of sodium chloride should be **$(Na^+)_n(Cl^-)_n$ or $(Na^+Cl^-)_n$,** where 'n' is a large number. **Nacl is the simplest formula** of sodium chloride and thus, the formula unit of sodium chloride is NaCl.

FORMULA MASS

The formula mass of an ionic compound is the relative mass of its formula unit as compared with the mass of a carbon atom (carbon - 12) taken as 12 units.

E.g. To find the formula mass of **potassium carbonate (K_2CO_3).**

Formula mass of K_2CO_3 = mass of 2 K atoms + Mass of 1 C atom + Mass of 3 O atoms

$= (2 \times 39) + (1 \times 12) + (3 \times 16)$

$= 78 + 12 + 48$

$= 138$ u .

Hence, the formula mass of K_2CO_3 is 138 u.

CHEMICAL FORMULA /MOLECULAR FORMULA

The **chemical formula** of a compound or an element represent the **composition** of a **molecule** of the compound or an element, in terms of the **symbols of elements and the number of atoms** of each element present in one molecule of the substances.

(a) Formulae of Elements :

The **chemical formula** of an element is a representation of the **composition of its molecule** in which **symbol** represents the **element** and **subscript** represents, how many **atoms** are present in one molecule.

E.g. One molecule of hydrogen element contains **Two atoms** of hydrogen, therefore, the formula of hydrogen is H_2. It should, however, be noted that **2H** represents **two separate atoms** of hydrogen, while $\mathbf{H_2}$ represents **one molecule** of hydrogen.

(b) Formulae of Compounds :

The **chemical formula** of a compound is representation of the **composition of its molecule** in which **symbol** represents, which **elements** are present and the **subscript** shows us how many **atoms of each element** are present in one molecule of a compound. **E.g.** One **molecule of water** contains **2 atoms of hydrogen** and **1 atom of oxygen.** Hence, the formula of water is H_2O.

(i) In the **chemical formula** of a compound, the elements present are **denoted by their symbols and the number of atoms** of each element are denoted by writing their number as **subscripts** to the symbols of the respective elements.

E.g. Water is a compound whose one molecule is made up of 2 atoms of hydrogen and 1 atom of oxygen and hence, its **chemical formula is $\mathbf{H_2O}$.**

(ii) While writing the formula of an ionic compound, the metal is written on the left hand side, while the non metal is written on the right hand side.

E.g. Magnesium oxide is written as MgO, Sodium chloride is written as NaCl etc.

The name of the metal remains as such, but that of the non-metal is changed to have the ending 'ide'.

(iii) Molecular compounds, formed by the combination between **two different non - metals,** are written in such a way that the less electronegative element is written on the left hand side, while the more electronegative element is written on the right hand side. In naming molecular compounds, the name of the **less negative non-metal is written as such** but the name of the **more electronegative element is changed** to have the **ending 'ide'.**

E.g. H_2S is named as hydrogen sulphide and HCI is named as hydrogen chloride.

(iv) When there are **more than one atoms** of an element present in the formula of the compound, then the **number of atoms are indicated by the use of appropriate prefixes (mono for 1, di for 2, tri for 3, tetra for 4 atoms etc. respectively)** in the name of the compound.

E.g. CO is named as **carbon monoxide,** CO_2 is named s **carbon dioxide** and CCl_4 is named as **carbon tetrachloride.**

(v) The **prefixes** are needed in naming those **binary compounds** in which the two **non-metals** form more than one compounds (by having different number of atoms).

E.g. Two non-metals, nitrogen and oxygen, combine to form different compounds like nitrogen monoxide (NO), nitrogen dioxide (NO_2), dinitrogen trioxide (N_2O_3) etc.

(vi) If **two non-metals** form only **one compound,** then **prefixes are not used** in naming such compounds.

E.g. Hydrogen and sulphur combine to form only one compound H_2S. So, **H_2S is named as hydrogen sulphide and not as hydrogen monosulphide.**

In a chemical formula higher electronegative element is written on the right side.

WRITTING THE FORKULA OF MOLECULAR COMPOUND

If we **know the valencies** of the **elements involved in a compound,** then we can write the **formula** of the compound by **balancing the valencies** of different elements. The steps to be followed for writing the formula of molecular compounds are :

(i) First, **write the symbols** of the elements constituting the compound.

(ii) Then, **below each symbol,** write its corresponding **valency.**

(iii) Finally, we **exchange the valencies of the** combining atoms, i.e. with first atom, we write the valency of the second atom and second atom, we write the valency of the first atom. The valencies are to be written **as subscripts** to the symbols.

(iv) If the valencies have any **common factor,** then the formula is **divided by that common factor.** This gives the required formula of the compound.

Writing the formula of carbon dioxide as an example : Following steps are used to write the formula of carbon dioxide

- **Carbon dioxide** is a compound composed of two elements, **carbon and oxygen**. So, we first write their symbols C and O respectively.

- The **valency of carbon is 4** and the **valency of oxygen is 2.** Now, these valencies are to be **written under** the corresponding symbols of elements.

Symbols : C O

Valencies : 4 2

- Now, the **valencies** of carbon and oxygen are to be **exchanged.** So, the **subscript** corresponding to **C is 2** and that corresponding to **O is 4.** Hence, the formula of the **compound becomes C_2O_4.**

- But, the valancies 2 and 4 have a **common factor 2.** So, on dividing the whole formula by 2, we get the simplest formula CO_2. Thus, the **formula of carbon dioxide is CO_2.**

VALLENCY OF IONS

The **valency of an ion is same as the charge** present on the ion.

if an ion has 1 unit of positive charge, its valency is +1 and it is known as a **monovalent cation.** If an ion has 2 units of negative charge, its valency is -2 and it is known as a **divalent anion.**

LIST OF COMMON ELECTROVALENT POSITIVE RADICALS

Monovalent Electropositive		Bivalent Electropositive		Trivalent Electropositive		Tetravalent Electropositive	
1. Hydrogen	H^+	1. Magnesium	Mg^{2+}	1. Aluminium	Al^{3+}	1. Stannic [Tin (IV)]	Sn^{4+}
2. Ammonium	NH_4^+	2. Calcium	Ca^{2+}	2. Ferric [Iron (III)]	Fe^{3+}	2. Plumbic [Lead (IV)]	Pb^{4+}
3. Sodium	Na^+	3. Zinc	Zn^{2+}	3. Chromium	Cr^{3+}		
4. Potassium	K^+	4. Plumbous [Lead (II)]	pb^{2+}				
5. Cuprous [(Copper (I)]	Cu^+	5. Cupric [(Cupper) (II)]	Cu^{2+}				
6. Argentous [Silver (I)]	Ag^+	6. Argentic [(Silver (II)]	Ag^{2+}				
7. Mercurous [Mercury (I)]	Hg^+	7. Stannous [Tin (II)]	Sn^{2+}				
		8. Famous [Iron (II)]	Fe^{2+}				
		9. Mercuric [Mercury (II)]	Hg^{2+}				
		10. Barium	Ba^{2+}				

LIST OF COMMON ELECTROVALENT NEGATIVE RADICALS

Monovalent Electropositive		Bivalent Electropositive		Trivalent Electropositive		Tetravalent Electropositive
1. Fluoride	F^-	1. Sulphate	SO_4^{2-}	1. Nitride	N^{3-}	1. Carbide C^{4-}
		2. Sulphite	SO_3^{2-}	2. Phosphide	P^{3-}	
2. Chloride	Cl^-	3. Sulphite	S^{2-}	3. Phosphite	PO_3^{2-}	
3. Bromide	Br^-	4. Thiosulphate	$S_2O_3^{2-}$	4. Phosphate	PO_4^{3-}	
4. Iodide	I^-	5. Zincate	ZnO_2^{2-}			
5. Hydride	H^-	6. Oxide	O^{2-}			
6. Hydroxide	OH^-	7. Peroxide	O_2^{2-}			
7. Nitrite	NO_2^-	8. Dichromate	$Cr_2O_7^{2-}$			
8. Nitrate	NO_3^-	9. Carbonate	CO_3^{2-}			
9. Bicarbonate or Hydrogen carbonate	HCO_3^-	10. Silicate	SiO_3^{2-}			
10. Bisulphite or Hydrogen sulphite	HSO_3^-					
11. Bisulphide or Hydrogen sulphide	HS^-					
12. Bisulphate or Hydrogen sulphate	HSI_4^-					
13. Acetate	CH_3COO^-					

Cation contains less no. of electrons and anion contains more no. of electrons than the no. of protons present in them.

WRITING THE FORMULA OF IONIC COMPOUNDS

Steps :

(i) First, write the **symbols of the ions** from which the ionic compound is made. As a convention, the **cation** is written on the **left side,** while the **anion** is written on the **right side.**

(ii) Them the respective **valencies** of the respective cation and anion are **written below their symbols.**

(iii) Then, the **valencies** of the cation and anion are **exchanged.** The **number of cations and anions** in the formula of the compound are **adjusted** in such a way that **total positive charge of cations become equal to the total negative charge of the anions** making the ionic compound **electrically neutral.**

(iv) The final **formula of the ionic compound is then written** but the **charges** present on the cation and the anion are **not shown.**

E.g. Two write the formula for aluminum sulphate

First, write the symbols of aluminum ion and sulphate ion and write their respective valencies below their symbols as shown :

Symbols : Al SO_4

Valencies : +3 -2

(Charges)

Now, we exchange the valencies. So, -2 gets associated with Al and +3 gets associated with SO_4, So, the final formula of the compound aluminum sulphate is $Al_2(SO_4)$ after removing the charges associated with aluminum ion and sulpahte ion.

Ionic compound is electrically neutral as it contains equal number of positive and negative charges.

GRAM ATOMIC MASS AND GRAM MOLECULAR MASS

(a) Gram Atomic Mass

The amount of a substance in grams which is numerically equal to the atomic mass of that substance, is known as gram atomic mass of that substance. If we want to write the gram atomic mass of a substance, we write its atomic mass, remove the atomic mass unit u, and add grams to the numerical value of the atomic mass.

$$\textbf{Number of gram atoms} = \frac{\text{Mass of the element in grams}}{\text{Atomic mass of the element in grams}}$$

E.g. Atomic mass of nitrogen, (N) = 14 u

So, gram atomic mass of nitrogen = 14 grams

(b) Molar Mass :

The **molar mass** of a substance is the **mass of 1 mole, i.e. 6.023×10^{23} particles,** of that substance. Its unit is gram per mole, **i.e. g/mol.** The molar mass of an element is its atomic mass expressed in g/mol and the molar mass of a compound is its molecular mass expressed in g/mol.

E.g. The atomic mass of sodium (Na) is 23 u, so the molar mass of the element sodium (Na) is 23 g/mol.

(c) Gram Molecular Mass:

The **amount of a substance** in grams which is numerically **equal to the molecular mass of that substance,** is known as **gram molecular mass** of that substance. If we want to write the gram molecular mass of a substance, we write its molecular mass, remove the molecular mass unit u, and add grams to the numerical value of the molecular mass.

E.g. gram molecular mass of oxygen gas (O_2) is 32 g.

$$\textbf{Number of gram molecules} = \frac{\text{Mass of the substnce in grams}}{\text{Molecular mass of the substance in grams}}$$

Gram molecular mass should not be confused with the mass of one molecule of the substance in grams. The mass of one molecule of a substance is known as its actual mass or molecular mass.

EXERCISE

OBJECTIVE DPP - 9.1

1. Which of the following represents a polyatomic ion ?

(A) Sulphide (B) Chloride (C) Sulphate (D) Nitride.

2. The formula mass of NaCl is -

(A) 56.5 u (B) 36.5 u (C) 58.5 u (D) 55.5 u

3. Which of the following set of ions is present in potassium sulphate (K_2SO_4) ?

(A) K^4, SO_4^{-2} (B) K^{+4}, SO^{-2} (C) K^{+2}, SO_4^- (D) K^+, SO_4^-

4. Two elements A (atm. wt. 75) and B (atm wt. 16) combine to yield a compound. The percentage by weight of A in the compound was found to be 75.08. The formula of the compound is -

(A) AB (B) AB_2 (C) A_2B (C) A_2B_3

5. In the molecular mass of a compound is 74.5 then the compound is -

(A) KCl (B) HCl (C) NaCl (D) LiCl

6. The overall charge on an ionic compound is equal to -

(A) the charge of the cation (B) zero

(C) the charge of the anion (D) none of these

7. Which one of the following is a trivalent anion ?

(A) Aluminum ion (B) Phosphide ion (C) Ferric ion (D) Calcium ion

8. In a chemical formula more electronegative element is written on the -

(A) right side (B) left side (C) either side (D) None of these

9. Which of the following is the formula of nitrate ion ?

(A) N_3^- (B) NO_3^- (C) NO^+ (D) NO_2^+

10. Symbol of ferric ion is -

(A) Fe^{++} (B) Fe^{+++} (C) Fe (D) F^-

SUBJECTIVE DPP - 9.2

1. The molecular formula of glucose is $C_6H_{12}O_6$. Calculate its molecular mass.

2. What do we call those particles which have -

(a) more electrons than the normal atoms ?

(b) less electrons than the normal atoms ?

3. Calculate the formula mass of Al_2O_3

4. Name of following compounds. Also write the symbols and formulae of the ions present in them.

(a) $CuSO_4$ (b) $(NH_4)_2SO_4$ (c) Na_2O

(d) Na_2CO_3 (e) $CaCl_2$

5. An element A forms an oxide A_2O_5. Then answer the following -

(a) What is the valency of element A ?

(b) What will be the formulae of chloride of A ?

ATOMS AND MOLECULES

MOLE CONCEPT

For the counting of articles, the unit dozen or unit gross is commonly used irrespective of their nature.

E.g. One dozen pencils = 12 pencils

One gross books = 144 books

In a similar way, for counting of **atoms, molecules, ions** etc. chemists use the unit **"mole".**

A mole is the amount of a substance that contains the same number of entities (i.e. atoms, molecules or ions) as there are atoms in 12 grams of the carbon $^{12}_{6}C$.

Mole i s a collection of 6.023×10^{23} particles (may it be atoms, molecules or ions) of a substance.

E.g. 1 mole of oxygen **atoms (O)** = 6.023×10^{23} atoms of oxygen.

1 mole of **oxygen molecules (O_2)** = 6.023×10^{23} molecules of oxygen.

The number, 6.023×10^{23}, which represents the number of particles in a mole, is known as Avogadro Number (N_A).

(a) Moles of Atoms :

(i) 1 mole atoms of any element occupy a mass which is equal to the **gram atomic mass** of that element.

(ii) The **symbol of an element** represents **6.023×10^{23} atoms (**1 mole of atoms) of that element.

E.g. Symbol **N** represents **1 mole** of nitrogen atoms and **2N** represents **2 moles** of nitrogen atoms.

The terms mole was introduced by Ostwald in 1896.

(b) Moles of Molecules :

(i) 1 mole molecules of any substance occupy a mass which is equal to the **gram molecular mass** of that substance.

E.g. 1 mole of water (H_2O) molecules weight equal to the gram molecular mass of water (H_2O), i.e. 18 grams.

(ii) The **formula of compound** represents **6.023×10^{23} molecules** (1 mole of molecules) of that compound.

E.g. Symbol H_2O represents 1 more of water molecules and 2 H_2O represents 2 moles of water molecules.

NOTE : The symbol H_2O does not represent 1 mole of H_2 molecules and 1 mole of O atoms. Instead, it represents 2 moles of hydrogen atoms and 1 mole of oxygen atoms.

The SI unit of the amount of a substance is Mole.

(c) Mole in Terms of Volume :

Volume occupied by **1 gram molecular mass** or **1 mole** of a gas under standard conditions of temperature and pressure (273 K and 1 atm) is called **gram molecular volume.** Its value is **22.4 litres** for each gas.

1 Mole = 1 Gram molecular mass

= 22.4 litre (at NTP)

= 6.023×10^{23} molecules

SOME IMPORTANT RELATIONS REGARDING MOLES OF ATOMS

1. Mass of 1 mole of atoms = Gram atomic mass
2. 1 mole of atoms = 6.023 × 10- atoms
3. Gram atomic mass = Mass of 6.023×10^{23} atoms

E.g. to calculate the number of moles in 16 grams of sulphur (Atomic mass of sulphur = 32 u).

Solution :

1 mole of atoms = Gram atomic mass.

So, 1 mole of sulphur atoms = Gram atomic mass of sulphur = 32 grams.

Now, 32 grams of sulphur contains = 1 mole of sulphur

So, 16 grams of sulphur will contain = (1/32) × 16

= **0.5 mole**

Thus, 16 grams of sulphur constitute 0.5 mole of sulphur.

Mole is the Latin word meaning heap or pile.

SOME USEFUL FORMULAE

(i) Number of moles of atoms = $\dfrac{\text{Mass of element in grams}}{\text{Gram atomic mass of the element}}$

(ii) Number of moles = $\dfrac{\text{No. of atoms of element}}{\text{Avogadro' no of atoms}} = \dfrac{N}{N_A}$

(iii) Number of moles of molecules = $\dfrac{\text{Mass of substance in grams}}{\text{Gram molecular mass of substance}}$

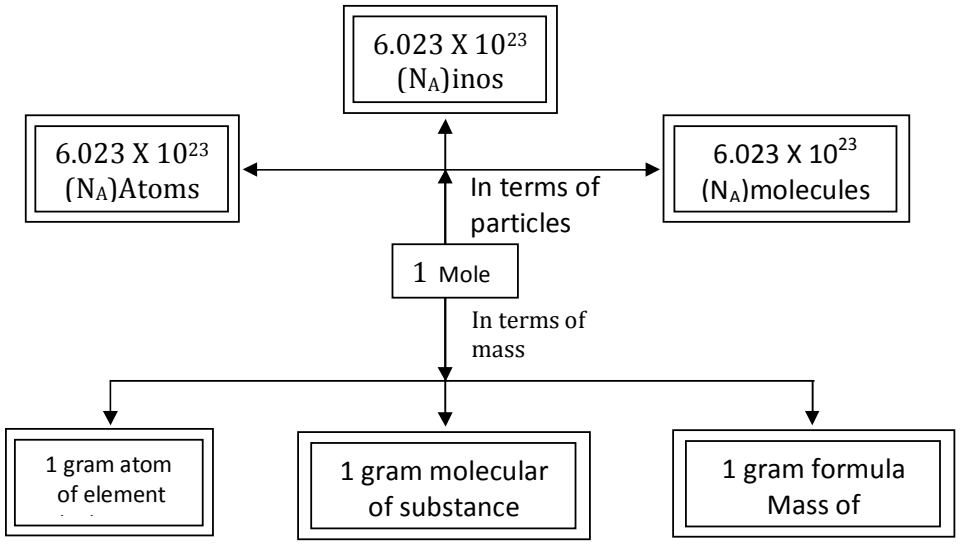
(iv) Number of moles of molecules = $\dfrac{\text{No. of molecules of element}}{\text{Avogadro' no. of molecules}} = \dfrac{N}{N_A}$

SOME USEFUL FORMULAE

(i) 1 mole of molecules = Gram molecular mass

(ii) 1 mole of molecules = 6.023×10^{23} molecules

(iii) Gram molecular mass = 6.023×10^{23} molecules



SOME USEFUL FORMULAE

Example : Calculate the mass of the following :

(i) 0.5 mole of O_2 gas (ii) 0.5 mole of O atoms

(iii) 3.011×10^{23} atoms of O (iv) 6.023×10^{23} molecules of O_2.

(Given : Gram atomic mass of oxygen = 16 g, gram molecular mass of oxygen (O_2) = 32 g).

Solution : (i) 0.5 mole of O_2 gas

No. of moles = $\dfrac{\text{Mass of } O_2 \text{ in grams}}{\text{Gram molecular mass}} = \dfrac{m}{M}$

$\therefore$ Mass of O_2 in grams (m) = No. of moles × M

= 0.5 × (32g) = 16g

(ii) 0.5 mole of oxygen (O) atoms

$$\textbf{No. of moles} = \frac{\textbf{Mass of oxygen (O) in grams}}{\textbf{Gram atomic mass}} = \frac{\textbf{m}}{\textbf{M}}$$

Mass of oxygen (O) in grams (m) = No. of moles × M

= 0.5 × (16g) = 8g.

(ii) **3.011×10^{23} atoms of oxygen (O)**

Step I : Calculation of no. of gram atoms of oxygen

$$\textbf{No . of gram atoms} = \frac{\textbf{No. of atoms of oxygen}}{\textbf{Avogadro no. of atoms}} = \frac{\textbf{N}}{\textbf{N}_\textbf{A}}$$

$$= \frac{3.011 \times 10^{23}}{6.022 \times 10^{23}} = 0.5 \text{ gram atoms}$$

Step II : Calculation of mass of oxygen (O) atoms

Mass of oxygen (O) atoms = Gram atomic mass of oxygen x No. of gram atoms of oxygen.

= 16 × 0.5 = **8g.**

(iv) 6.023×10^{23} molecules of oxygen (O_2) -

Step I : Calculation of no. of moles of oxygen.

$$\textbf{No. of moles} = \frac{\textbf{No. of molecules oxygen}}{\textbf{Avogadro no. of molecules}} = \frac{\textbf{N}}{\textbf{N}_\textbf{A}}$$

$$= \frac{6.023 \times 10^{23}}{6.023 \times 10^{23}} = 1 \text{mole}$$

Step II : Calculation of mass of oxygen (O_2) molecules.

Mass of oxygen (O_2) molecules = Gram molecular mass of oxygen x No. of moles of oxygen.

= 32 × 1 = 32 g

EXERCISE

OBJECTIVE DPP - 10.1

1. Which of the following has the smallest mass ?

(A) 4 g of He (B) 6.023×10^{23} atoms of He

(C) 1 atom of He (D) 1 mole atoms of He

2. The number of carbon atoms in 1 g of $CaCO_3$ is -

(A) 6.023×10^{23} (B) 6.023×10^{21} (C) 3.0125×10^{22} (D) 1.204×10^{23}

3. 6.023×10^{20} atoms of silver (Atomic mass = 108 u) weight -

(A) 108×10^3 g (B) 108 g (C) 0.108 g (D) 10.8 g

4. Which of the following has largest number of molecules ?

(A) 8 g of CH_4 (B) 4.4 g of CO_2

(C) 34.2 g of $C_{12}H_{22}O_{11}$ (D) 2 g of H_2

5. Which of the following contains one mole molecules of the substance ?

(A) 16 g Oxygen (B) 7 g Nitrogen (C) 2 g Hydrogen (D) 36 g Water.

6. The number of molecules in 16.0 g of oxygen is -

(A) 6.02×10^{23} (B) 6.02×10^{-23} (C) 3.01×10^{-23} (D) 3.01×10^{23}

7. The volume of one mole of a gas at normal temperature and pressure is -

(A) 11.2 litres (B) 22.4 litres (C) 100 litres (D) None of these

8. The number of gram atoms in 8 g of he are -

(A) 2 (B) 1.204×10^{24} (C) 3.1×10^{23} (D) None of these

9. The percentage of hydrogen in H_2O is -

(A) 8.88 (B) 11.12 (C) 20.60 (D) 80.0

10. The charge in coulombs of 1 gram ion of N^{3-} is (the charge on an electron is 1.602×10^{-19} C) -

(A) 2.894×10^5 C (B) 3.894×10^5 C (C) 2.894×10^6 C (D) None of these

11. The mass of oxygen contained in 1 kg of potassium nitrate (KNO_3) will be-

(A) 478.5 g (B) 485.5 g (C) 475.2 g (D) 488.2 g

12. 1 mole of a compound contains 1 mole of carbon and 2 moles of oxygen. The molecular weight of the compound is -

(A) 3 (B) 12 (C) 32 (D) 44

SUBJECTIVE DPP - 10.2

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1. Define the term mole.

2. What is the mass of 0.2 mole of oxygen atoms ?

3. Calculate the mass of 10.044×10^{25} molecules of oxygen.

4. If 1 g of oxygen element contains X atoms, what will be the number of atoms in 1 g of aluminum ? (Atomic mass : O = 16 u, Al = 27 u)

5. Calculate the number of aluminum ions present in 0.051 g of aluminum oxide (Al_2O_3). [Atomic mass : Al = 27 u ; O = 16 u]

6. What weight of oxygen gas will contain the same number of molecules as 56 g of nitrogen gas ?
(A) Atomic mass : O : = 16 u ; N = 14u)

7. Calculate the number of atoms and volume of 1g He gas at NTP.

8. What is the mass of 4.0×10^{-3} mol of glucose, ($C_6H_{12}O_6$) ? How many carbon atoms are there is 4.0×10^{-3} mole of glucose ?

9. How many molecules of water are present in one ml of water vapours at NTP ?

10. If one takes one second to count five wheat grains, calculate the time taken is counting one mole of wheat grains.

ANSWER KEY

(Objective Dpp 7.1)

Qus.	1	2	3	4	5	6	7	8	9	10
Ans.	D	C	B	A	C	D	A	C	B	C

2. The formula of baking soda is $NaHCO_3$.

(Subjective DPP - 7.2)

1. La of content proportion

3. Mass of oxygen = 9.6 gm, Law of conservation of mass.

(Objective Dpp 8.1)

Qus.	1	2	3	4	5	6	7	8	9	10
Ans.	B	B	A	C	B	C	C	A	B	C

(Subjective DPP - 8.2)

2. Formula of the compound = XY_4

3. (i) Na_3PO_4 (ii) $(NH_4)_2SO_4$ (iii) $Ca(OH)_2$ (iv) $PbBr_2$

6. 1nm = 10^{-9} m

(Objective Dpp 9.1)

Qus.	1	2	3	4	5	6	7	8	9	10
Ans.	C	B	C	D	A	B	B	A	B	

(Subjective Dpp 9.2)

1. 180 u **3.** 102 u

5. (a) Valency of A = + 5 (b) Formula of chloride of A = ACl_5

(Objective Dpp 10.1)

Qus.	1	2	3	4	5	6	7	8	9	10	11	12
Ans.	C	B	C	D	C	D	B	A	B	A	C	D

2. 3.2 g **3.** 5.33 kg **4.** $\frac{16X}{27}$ atoms **5.** 6.023×10^{20}

6. 64 g **7.** 1.5055×10^{23}, 5.6 L **8.** 0.72 g, 1.445×10^{22}

9. 0.0268×10^{21} molecules **10.** 1.2046×10^{23} sec