Atoms and Molecules

In this Chapter...

- Law of Constant Proportions/ Law of Definite Proportions
- Atoms
- Molecules
- Ions
- Valency
- Molecular Mass
- Mole Concept

In the present chapter, we shall discuss about the various laws (which explains how atoms combine to form molecule), symbols and formulae of atoms and molecules and various ways of expressing their masses.

Law of Constant Proportions/Law of Definite Proportions

According to this law, in a chemical substance (or compound), the elements are always present in definite proportions (or ratios) by mass.

e.g. In a compound such as water, the ratio of the mass of hydrogen to the mass of oxygen is always **1 : 8**, whatever the source of water.Thus, if 9g of water is decomposed, 1g of hydrogen and 8g of oxygen are always obtained.

Similarly, carbon dioxide ($\mathbf{CO_2}$) always contains carbon and oxygen in the ratio of 3 : 8. If a sample of $\mathbf{CO_2}$ contains 36 g of carbon then it is compulsory that the sample has 96 g oxygen.

This is calculated as $\frac{3}{8} = \frac{36}{x} \quad \therefore \quad x = \frac{36 \times 8}{3} = 96\ \text{g}$

Atoms

Atoms are the smallest particles of an element which may or may not have independent existence but take part in a chemical reaction. These are the building blocks of all matter.

e.g. Atoms of hydrogen, oxygen, nitrogen etc., are not capable of independent existence whereas atoms of helium, neon etc., are capable of existing independently.

Atoms are very small and their radius is measured in **nanometres.**

$$1/10^9\ \text{m} = 1\ \text{nm}$$

or

$$1\ \text{m} = 10^9\ \text{nm}$$

Hydrogen atom is the smallest atom and its radius is 0.1 nm.

Modern Day Symbols of Atoms of Different Elements

In chemistry, symbols are the representation of an element. It is simple to use the symbol of an element rather writing a whole word of an element.

Dalton was the scientist who introduced symbols for representing elements for the first time.

⊙ Hydrogen	◯ Carbon	○ Oxygen
⊗ Phosphorus	⊕ Sulphur	Ⓘ Iron
Ⓒ Copper	Ⓛ Lead	Ⓢ Silver
Ⓖ Gold	Ⓟ Platina	◌ Mercury

Symbols for some elements as proposed by Dalton

Dalton's symbol were difficult to draw, so JJ Berzelius introduced modern symbols for the elements.

Symbols for Some Elements

Elements	Symbols	Elements	Symbols	Elements	Symbols
Aluminium	Al	Copper	Cu	Nitrogen	N
Argon	Ar	Fluorine	F	Oxygen	O
Barium	Ba	Gold	Au	Phosphorus	P
Boron	B	Hydrogen	H	Potassium	K
Bromine	Br	Iodine	I	Silicon	Si
Calcium	Ca	Iron	Fe	Silver	Ag
Carbon	C	Lead	Pb	Sodium	Na
Chlorine	Cl	Magnesium	Mg	Sulphur	S
Chromium	Cr	Mercury	Hg	Uranium	U
Cobalt	Co	Neon	Ne	Zinc	Zn

Atomic Mass

According to Dalton's, each element has a characteristic atomic mass. But determining the mass of an individual atom was a relatively difficult task due to its very small size.

Hence, their relative atomic masses were determined using the laws of chemical combinations and the compounds formed.

Relative Atomic Mass

It is defined as the number of times a given atom is heavier than **1/12** th of mass of 1 atom of carbon-12 (C-12) or it is the average mass of the atom as compared to 1/12th the mass of one carbon-12 atom.

Atomic Mass Unit

It is defined as the mass unit equal to exactly **1/12** th of the mass of one atom of C-12 isotope. It is written as **'u'- unified mass**.

Atomic Masses of Few Elements

Element	Atomic Mass (u)	Element	Atomic Mass (u)
Hydrogen	1	Magnesium	24
Carbon	12	Sulphur	32
Nitrogen	14	Chlorine	35.5
Oxygen	16	Calcium	40
Sodium	23		

Molecules

A molecule is a group of two or more atoms that are chemically bonded together. Atoms of the same element or of different elements can join together to form molecules.

Molecules are of two types

1. Molecules of Elements

They contain same type of atoms of an element. Molecules of many elements are made up of only one atom of that element. e.g. noble gases like argon (Ar), helium (He) etc. The molecules of most of the non-metals are made up of more than one atom. e.g. a molecule of oxygen (O_2) consists of two atoms of oxygen and is known as **diatomic** molecule, ozone (O_3) consists of three atoms of oxygen is known as **triatomic** molecules.

Atomicity

Atomicity tells us the number of atoms present in a molecule.

On the basis of atomicity, molecules can be classified as

(i) Monoatomic molecules consist of only one atom.
e.g. He, Ne, Ar, Xe, Fe, Al etc.

(ii) Diatomic molecules consist of two atoms.
e.g. H_2, O_2, N_2, I_2, Br_2, Cl_2, HCl, NaCl etc.

(iii) Triatomic molecules consist of three atoms.
e.g. O_3, $\mathbf{CO_2}$, $\mathbf{NO_2}$ etc.

(iv) Tetra-atomic molecules consist of four atoms.
e.g. P_4, $\mathbf{H_2O_2}$ etc.

(v) Polyatomic molecules consist of more than four atoms.
e.g. $\mathbf{CH_4}$ (penta-atomic), S_8(octa-atomic) etc.

Atomicity of Some Elements (Non-metals)

Name	Atomicity	Name	Atomicity
Argon	Monoatomic	Chlorine	Diatomic
Helium	Monoatomic	Ozone	Triatomic
Oxygen	Diatomic	Phosphorus	Tetra-atomic
Hydrogen	Diatomic	Sulphur	Poly-atomic (octa-atomic)
Nitrogen	Diatomic		

2. Molecules of Compounds

Atoms of different elements join together in definite proportions to form molecules of compounds.

Molecules of Some Compounds

Compounds	Combining Elements	Ratio by Mass
Water ($\mathbf{H_2O}$)	Hydrogen and oxygen	1 : 8
Ammonia ($\mathbf{NH_3}$)	Nitrogen and hydrogen	14 : 3
Carbon dioxide ($\mathbf{CO_2}$)	Carbon and oxygen	3 : 8
Hydrogen sulphide ($\mathbf{H_2S}$)	Hydrogen and sulphur	1 : 16
Sulphuric acid ($\mathbf{H_2SO_4}$)	Hydrogen, sulphur and oxygen	1 : 16 : 32
Glucose ($\mathbf{C_6H_{12}O_6}$)	Carbon, hydrogen and oxygen	6 : 1 : 8
Baking powder ($\mathbf{NaHCO_3}$)	Sodium, hydrogen, carbon and oxygen	23 : 1 : 12 : 48
Common salt (NaCl)	Sodium, chlorine	23 : 35.5
Limestone ($\mathbf{CaCO_3}$) or calcium carbonate	Calcium, carbon and oxygen	40 : 12 : 48 or 10 : 3 : 12
Caustic soda (NaOH)	Sodium, oxygen and hydrogen	23 : 16 : 1

Compounds	Combining Elements	Ratio by Mass
Caustic potash (KOH)	Potassium, oxygen and hydrogen	39 : 16 : 1
Ethanol (C_2H_5OH)	Carbon, hydrogen and oxygen	24 : 6 : 16 or 12 : 3 : 8
Methanol (CH_3OH)	Carbon, hydrogen and oxygen	12 : 4 : 16 or 3 : 1 : 4
Ethyne (C_2H_2)	Carbon and hydrogen	24 : 2 or 12 : 1

Prediction of Number of Atoms from Mass Ratio

In order to predict the number of atoms from mass ratio, divide the given mass of each element by the atomic mass of the element and calculate the simplest ratio between the obtained moles, e.g. we know that mass ratio of nitrogen.

Ions

When atoms, groups of atoms or molecules lose or gain electron(s) they become charged. These charged species are known as **ions**. Atoms in solution generally exist in the form of ions. These can be negatively or positively charged, thus can be categorised into two groups.

(i) **Cations** The positively charged ions are known as cations. e.g. Na^+, K^+, Ca^{2+}, Al^{3+} etc. These are formed when elements loses electrons. Usually, metals form cations.

(ii) **Anions** The negatively charged ions are known as anions. e.g. Cl^-, Br^-, O^{2-}, N^{3-} etc. These are formed when elements gain electrons. Usually, non-metals form anions.

Polyatomic Ion

A group of atoms carrying charge and act as a single entity is known as a polyatomic ion. It carries a fixed charge. e.g. NO_3^- (nitrate ion), CO_3^{2-} (carbonate ion) and SO_4^{2-} (sulphate ion) etc.

Some Ionic Compounds

Ionic Compounds	Constituting Elements	Ratio by Mass
Calcium oxide	Calcium and oxygen	5:2
Magnesium sulphide	Magnesium and sulphur	3:4
Sodium chloride	Sodium and chlorine	23:35.5

Valency

The combining power (or capacity) of an element is called its valency. Valency can be used to find out how the atoms of an element will combine with the atom(s) of another element to form a chemical compound. The valency of an ion is equal to the charge on the ion.

Molecular Mass

The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance. It is therefore, the relative mass of a molecule expressed in atomic mass units (u). e.g. the relative molecular mass of water (H_2O) is 18 u, which can be calculated as,

atomic mass of hydrogen = **1** u

atomic mass of oxygen = **16** u

H_2O contains two hydrogen atoms and one oxygen atom.

Therefore, molecular mass of water is $= \mathbf{2 \times 1 + 1 \times 16 = 18}$ u

Formula Unit Mass

It is the sum of the atomic masses of all atoms present in a formula unit of a compound. Formula unit mass is calculated in the same manner as we calculate the molecular mass.

The difference is that, here the word formula unit is used for the substance whose constituent particles are ions,

e.g. Formula unit mass for sodium chloride (NaCl)

$= \mathbf{1 \times 23 + 1 \times 35.5 = 58.5}$ u

Mole Concept

The mole is the amount of a substance which contains as many particles (atoms/ions/molecules/formula units etc.) as in 12 g of C-12. Thus, one mole of any species (atoms, molecules, ions or particles) is that quantity in number having a mass equal to its atomic or molecular mass in grams.

The number of particles present in 1 mole of any substance is same and fixed, which is equal to $\mathbf{6.022 \times 10^{23}}$. This is a constant, known as **Avogadro constant** or **Avogadro number** ($\mathbf{N_A}$). Thus, mole is also defined as number of particles equal to the Avogadro constant, $\mathbf{N_A}$ ($\mathbf{6.022 \times 10^{23}}$).

1 mole = $\mathbf{6.022 \times 10^{23}}$ particles, in number.

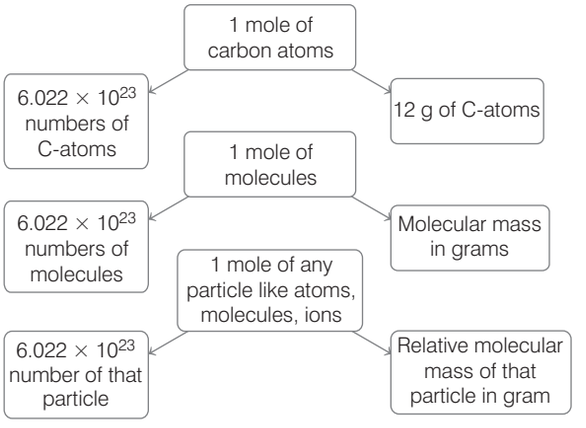
Molar Mass and Moles

The mass of 1 mole of a substance is equal to its relative atomic or molecular mass in gram. The atomic mass of an element gives us the mass of one atom of that element in atomic mass units (u). Number of moles can be calculated directly by using the formula.

(i) Number of moles $= \dfrac{\textbf{Given mass}}{\textbf{Molar mass}}$

(ii) Number of moles

$= \dfrac{\textbf{Given number of particles (atoms/molecules)}}{\textbf{Avogadro number}}$



Relationship between mole, Avogadro number and molecular mass

Chapter Practice

PART 1
Objective Questions

1. Who discovered law of constant proportions?
(a) Antoine L. Lavoisier (b) John Dalton
(c) Ernest Rutherford (d) Neils Bohr

2. Which postulate of Dalton's atomic theory can explain the law of definite proportions?
(a) Atoms are indivisible particles, which can neither be created nor be destroyed in a chemical reaction
(b) Atoms of different elements have different masses and chemical properties
(c) Atoms combine in the ratio of small whole numbers to form compounds
(d) The relative numbers and kinds of atoms are constant in a given compound

3. During an experiment hydrogen (H_2) and oxygen (O_2) gases reacted in an electric arc to produce water as follows: $2H + O_2 \xrightarrow{\text{Electricity}} 2H_2O$

The experiment is repeated three times and data tabulated as shown below:

Experiment number	Mass of H_2 reacted	Mass of O_2 reacted	Mass of H_2O produced
1	2 g	16 g	18 g
2	4g	32 g	36 g
3	–	–	9 g

During 3rd experiment, the researcher forgot to list masses of $\mathbf{H_2}$ and $\mathbf{O_2}$ used. So, if the law of constant proportion is correct then find mass of $\mathbf{O_2}$ used during 3rd experiment.
(a) 4 g (b) 8 g (c) 16 g (d) 32 g

4. Which of the following statement is not true about an atom? **(NCERT Exemplar)**
(a) Atoms are not able to exist independently
(b) Atoms are the basic units from which molecules and ions are formed
(c) Atoms are always neutral in nature
(d) Atoms aggregate in large numbers to form the matter that we can see, feel or touch

5. The chemical symbol for sodium is **(NCERT Exemplar)**
(a) So (b) Sd (c) NA (d) Na

6. Which of the following represent 1 amu ?
(a) Mass of hydrogen molecule
(b) $\frac{1}{12}$th of mass of C-12 atom
(c) Mass of O-12 atom
(d) Mass of C-12 atom

7. What is the atomic mass of magnesium?
(a) 24 (b) 32 (c) 16 (d) 35.5

8. The chemical symbol for nitrogen gas is? **(NCERT Exempler)**
(a) Ni (b) N_2 (c) N^+ (d) N

9. How many atoms are present in a H_2O_2 molecule?
(a) 3 (b) 1 (c) 4 (d) 5

10. A molecule of salt found to contain sodium and chlorine combined together in the ratio of **23 : 35.5** by mass. What is the formula of salt?
(a) Na_2Cl (b) $NaCl_2$ (c) Na_3Cl_2 (d) NaCl

11. What is the valency of CO_3^{2-} ?
(a) 1 (b) 3 (c) 2 (d) 4

12. What is the molecular mass of CO_2?
(a) 44 (b) 42
(c) 40 (d) 50

13. Match the formula units given in Column I with their masses given in Column II.

Column I	Column II
A. Calcium oxide	1. 56 u
B. Magnesium chloride	2. 95 u
C. Aluminium phosphide	3. 58 u
D. Calcium carbonate	4. 100 u
E. Aluminium oxide	5. 102 u

	A	B	C	D	E
(a)	3	1	2	5	4
(b)	4	3	5	1	2
(c)	1	2	3	4	5
(d)	2	5	1	3	4

14. Calculate the number of aluminium ions which are present in 0.0051 g of aluminium oxide.

(a) 6.022×10^{15} Al^{3+} ions (b) 6.022×10^{19} Al^{3+} ions

(c) 6.022×10^{14} Al^{3+} ions (d) 6.022×10^{23} Al^{3+} ions

15. The number of molecule of sulphur (S_8) present in 16 g of solid sulphur will be

(a) 3.76×10^{16} molecules (b) 3.76×10^{22} molecules

(c) 2.76×10^{14} molecules (d) 2.76×10^{22} molecules

• Assertion-Reasoning MCQs

Direction (Q. Nos. 16-20) Each of these questions contains two statements Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

(a) Both A and R are true and R is the correct explanation of A.

(b) Both A and R are true, but R is not the correct explanation of A.

(c) A is true, but R is false.

(d) A is false, but R is true.

16. **Assertion** Pure water obtained from different sources such as river, well, spring, sea, etc., always contains hydrogen and oxygen in the ratio of 1 : 8 by mass.

Reason A chemical compound always contains elements combined in a fixed proportions by mass.

17. **Assertion** Atomic mass has no unit but expressed in amu.

Reason It is the average mass of an atom taking care of relative abundance of its all isotopes.

18. **Assertion** Atomic mass of aluminium is 27.

Reason An atom of aluminium is 27 times heavier than 1/12th of the mass of carbon-12 atom.

19. **Assertion** Elements that are made up of only one kind of atoms are classified as pure substances.

Reason Hydrogen, oxygen and nitrogen are elements.

20. **Assertion** Molecular weight of SO_2 is double to that of O_2.

Reason One mole of SO_2 contains double the number of molecules present in one mole of O_2.

• Case Based MCQs

21. Read the following and answer the questions from (i) to (v) given below

In chemistry, symbols are the representation of an element. It is simple to use the symbol of an element rather writing a whole word of an element.

Dalton was the scientist who introduced symbols for representing elements for the first time but they were difficult to draw and inconvenient to use, so modern symbols were introduced. These symbols are defined as "a short hand representation of the name of an element."

In the beginning, the names of elements were derived from the name of the place where they were found for the first time. Now a days, it is the IUPAC (International Union of Pure and Applied Chemistry) who approves the names and symbols of the elements.

Element	Latin name of the element
P	Cuprum
Q	Kalium
R	Ferrum
S	Natrium
T	Argentum

(i) What is the name of element *P*?

(a) Carbon (b) Copper

(c) Chlorine (d) Chromium

(ii) The symbol of element *S* is .....

(a) Na (b) Nt (c) Nm (d) NA

(iii) Who discovered modern symbols of elements ?

(a) John Dalton (b) Amedeo Avogadro

(c) J J Berzelius (d) Joseph Stefan

(iv) Name the element *R*.

(a) Iron (b) Fluorine

(c) Phosphorus (d) Magnesium

(v) An element is used for making jewellery and is a good conductor of heat and electricity. Identify the Latin name of that element.

(a) Kalium (b) Cuprum

(c) Ferrum (d) Argentum

22. Read the following and answer the questions from (i) to (v) given below

The molecular mass of a substance is the sum of the atomic masses of all the atoms in a molecule of the substance. It is therefore, the relative mass of a molecule expressed in atomic mass units (u). Depending upon the number of atoms of same or different elements present in the molecule, it can be monoatomic, diatomic, triatomic, tetra-atomic or polyatomic molecule.

The formula unit mass is calculated in the same manner as the molecular mass calculated. It is a sum of the atomic masses of all atoms in a formula unit of compound.

The atomic masses of few elements are given below.

Element	Atomic mass (u)
Hydrogen	1
Carbon	12
Oxygen	16
Sodium	23
Calcium	40

(i) Which of the following is an example of polyatomic molecule ?
(a) H_2 (b) O_3 (c) S_8 (d) Cl_2

(ii) The relative molecular mass of H_2O is
(a) 23 u (b) 18 u (c) 10 u (d) 40 u

(iii) How many kinds of atoms are present in a molecule of copper carbonate ($CuCO_3$)?
(a) 3 (b) 4
(c) 5 (d) 6

(iv) What is the ratio by mass of the combining elements in the compound methanol.
(a) **1 : 3 : 4** (b) **4 : 3 : 1**
(c) **4 : 1 : 3** (d) **3 : 1 : 4**

(v) What is the formula unit mass of $CaCl_2$?
(a) 110 u (b) 94 u
(c) 111 u (d) 115 u

23. Read the following and answer the questions from (i) to (v) given below

Formula unit mass is the sum of atomic masses of all atoms present in a formula unit of a compound and it is calculated in the same manner as we calculate molecular mass. The mole is the base unit of amount of substance in the international system of units (SI). The definition of mole was adopted in November 2018 as one of the seven. SI base units reviving the previous definition that specified one mole as the amount of substance in 12 grams of carbon-12 (^{12}C), an isotope of carbon.

The mole is widely used in chemistry as a convenient way to express amounts of reactants and products of chemical reactions. October 23, in the US is recognized as mole day. It is an informal holiday in honor of the unit among chemists.

We can calculate number of moles present in a compound by calculating it's molecular mass.

(i) What is the formula unit mass of **HCl** ?
(a) 35.5 (b) 36.5
(c) 40 (d) 35

(ii) Formula unit is used for the substance whose constituent particles are .....
(a) Ions (b) molecules
(c) fixed (d) atoms

(iii) The number of particles present in 1 mole of any substance is equal to .....
(a) 6.022×10^{-23} (b) 6.022×10^{24}
(c) 6.022×10^{23} (d) 6.022×10^{20}

(iv) What is the mass of 1 mole of oxygen atoms?
(a) 32 g (b) 18 g
(c) 3.2 g (d) 16 g

(v) Calculate the number of moles for 84g of nitrogen atoms.
(a) 5 moles (b) 6 moles
(c) 7 moles (d) 8 moles

PART 2
Subjective Questions

• Short Answer Type Questions

1. (i) State the law of constant proportion.
(ii) In a compound, carbon and oxygen react in a ratio
3 : 8 by mass to form carbon dioxide. What mass of oxygen is required to react completely with 9 g carbon?

2. Copper oxide was prepared by two different methods. In one case, 1.75 g of the metal gave 2.19 g of oxide. In the second case, 1.14 g of the metal gave 1.43 g of the oxide. Show that the given data illustrate the law of constant proportions.

3. Initially $\frac{1}{16}$ of the mass of an atom of naturally occurring oxygen was taken as standard unit.
Give two reasons.

4. Define atomic mass unit. What is the atomic mass of nitrogen and sulphur?

5. Why is it not possible to see an atom with naked eyes ?

6. State three points of differences between an atom and a molecule.

7. Classify each of the following on the basis of their atomicity.
(i) F_2 (ii) NO_2
(iii) N_2O (iv) C_2H_6
(v) P_4 (vi) H_2O_2
(vii) P_4O_{10} (viii) O_3
(ix) HCl (x) CH_4
(xi) He (xii) Ag **(NCERT Exemplar)**

8. How many atoms are present in a
(i) H_2S molecule and (ii) PO_4^{3-} ion ?

9. What is a molecule? Name and explain two categories in which molecules are divided and give examples for each.

10. Nitrogen and hydrogen atoms combine in the ratio 14 : 3 by mass to form ammonia molecule. Find the formula of ammonia molecule by calculating the molar ratio.
[Given atomic mass of N = 14 u **and** H = 1 u]

11. A bicarbonate of sodium is found to contain sodium, hydrogen, carbon and oxygen combined together in the ratio of **23 : 1 : 12 : 48** by mass. Derive the formula of the bicarbonate and name it.

12. What do you mean by ions ? Explain the types of ions with examples.

13. Calculate the molecular mass of the following substances:
(i) Nitric acid, $\mathbf{HNO_3}$
(ii) Ethyne, $\mathbf{C_2H_2}$
(iii) Sulphur molecule, $\mathbf{S_8}$

14. Calculate the molecular mass of NH_3 and CH_3OH.

15. Calculate the formula unit masses of ZnO, $\mathbf{Na_2O}$, $\mathbf{K_2CO_3}$.
[Given, atomic mass of **Zn = 65** u, **Na = 23 u** , **K = 39 u , C = 12u** and **O = 16 u**] **(NCERT)**

16. (i) Define Avogadro's number. Write its value.
(ii) Calculate the mass of 0.2 mole of oxygen gas.

17. Which has more number of atoms, 100 g of sodium or 100 g of iron?
[Given, atomic mass of **Na = 23 u and Fe = 56 u]**

18. What is the mass of
(i) 1 mole of nitrogen atoms?
(ii) 4 moles of aluminium atoms
[Atomic mass of aluminium = **27**] ?
(iii) 10 moles of sodium sulphite ($\mathbf{Na_2SO_3}$) ? **(NCERT)**

19. Calculate the number of aluminium ion present in 2 g of aluminium oxide.

20. The mass of one steel rod is 4.11 g. Find the mass of one mole of these steel screws. Compare this value with the mass of the earth ($\mathbf{5.98 \times 10^{24}}$ kg). Which one of the two is heavier and by how many times? **(NCERT Exemplar)**

21. Convert into mole
(i) 12 g of oxygen gas
(ii) 20 g of water
(iii) 22 g of carbon dioxide **(NCERT)**

22. Which would weigh more, 2 moles of $CaCO_3$ or 10 moles of $\mathbf{H_2O}$?

23. The mass of a single atom of M is 3.05×10^{-22} g. What is its atomic mass? What would this element be? Check periodic table for possible answer.

24. Calcium chloride when dissolved in water dissociates into its ions according to the following equation,

$$CaCl_2(aq) \longrightarrow Ca^{2+}(aq) + 2Cl^-(aq)$$

Calculate the number of ions obtained from $CaCl_2$ when 222 g of it is dissolved in water. **(NCERT Exemplar)**

25. (i) Calculate the number of atoms of hydrogen present in one dozen molecule of hydrogen gas. Convert the given number of hydrogen in terms of number of moles.
(ii) If hydrogen combines with oxygen in the ratio of 1 : 8 by mass to form water, how many moles of oxygen would be required for the given amount of hydrogen gas? [Atomic mass of H = 1.0 u and O = 16.0 u]

26. What is the mass of
(i) 0.2 mole of oxygen atoms ?
(ii) 0.5 mole of water molecules ?

27. Compute the difference in masses of one mole each of aluminium atoms and one mole of its ions (Mass of an electron is $\mathbf{9.1 \times 10^{-28}}$ g). Which one is heavier? **(NCERT Exemplar)**

28. Cinnabar (HgS) is a prominent ore of mercury. How many grams of mercury are present in 225 g of pure HgS? Molar mass of Hg and S are 200.6 g mol^{-1} and 32 g mol^{-1} respectively. **(NCERT Exemplar)**

29. Calculate the number of moles present in
(i) $\mathbf{3.011 \times 10^{23}}$ number of oxygen atoms
(ii) **60 g** of calcium
[Given that atomic mass of Ca = **40u** and Avogadro's number = $\mathbf{6.022 \times 10^{23}}$]

30. Find the number of copper atom present in 10 g of 22 carat gold.

31. Which has more number of atoms ?
100 g of N_2 or 100 g of $\mathbf{NH_3}$ **(NCERT Exemplar)**

32. (i) Find the mass of one molecule of water.
(ii) If 16.26 mg of a sample of an element X contains $\mathbf{1.66 \times 10^{20}}$ atoms. What is the atomic mass of the element X ?

• Long Answer Type Questions

33. (i) How do we express number of particles in terms of moles?
(ii) Calculate the number of moles of sodium in a sample containing $\mathbf{10^{20}}$ atoms of sodium.
(iii) How do we express mass of a substance in terms of moles?

(iv) Calculate the number of moles in
(a) 56 g of He (b) 23 g of Na

34. 'SO_2 is an air pollutant released during burning of fossil fuels and from automobile exhaust'.
(i) Write the names of elements present in this gas.
(ii) What are the valencies of sulphur in SO_2 and SO_3?
(iii) Find out the number of molecules in 5 moles of SO_2.
(iv) Calculate the number of moles in 320 g of SO_2 gas.
(v) Calculate the molar mass of 10 moles of sodium sulphite.
[Given, atomic masses of S = 32 u, O = 16 u, Na = 23 u and $\mathbf{N_A} = 6.022 \times 10^{23}$ per mol]

35. (i) Calculate the number of moles in 112 g of iron.
(ii) Calculate the mass of 0.5 mole of sugar ($C_{12}H_{22}O_{11}$).
(iii) Define the term molecular mass.
(*iv*) Determine the molecular mass of $ZnSO_4$
[Atomic mass of Zn = 65 u, S = 32 u and O = 16 u].
(v) Calculate the number of molecules of carbon dioxide, CO_2 present in 4.4 g of CO_2.
[Atomic mass of C = 12 u, O = 16 u and $\mathbf{N_A} = 6.022 \times 10^{23}\ mol^{-1}$]

36. (i) Which has more number of atoms?
(a) 10 g of nitrogen (N_2)
(b) 10 g of ammonia (NH_3)
(ii) Calculate the total number of moles in 0.585 g of sodium chloride.
[Atomic mass of N = **14** u, H = **1** u, Cl = 35.5 u, Na = **23** u]

37. Fill in the missing data in the following table.

Species Property	**H_2O**	**CO_2**	**Na atom**	**$MgCl_2$**
Number of moles	2	—	—	0.5
Number of particles	—	$\mathbf{3.011 \times 10^{23}}$	—	—
Mass	36 g	—	115 g	—

(NCERT Exemplar)

• Case Based Questions

38. Read the following and answer the questions from (i) to (v) given below

Atoms of different elements join together in definite proportions to form molecules of compounds. In chemistry, mass ratio is also called as "percent composition by mass" which is defined as the proportion of a particular molecule that consists of each of that molecule's constituent elements.

One of the fundamental laws of chemistry deals with the fact that we cannot create or destroy matter.

When a reaction is run, the number of atoms of each specific type must be the same on both sides of the equation. For some materials, it turns out that one element can combine with a second element in more than ratio. Carrying out mass ratio calculations helped establish.

The law of constant composition which was put forth by Joseph Proust in 1800. A given compound always has the same proportion by mass of its constituent elements.

Compound	**Combining elements**	**Ratio by mass**
Water (**H_2O**)	Hydrogen and oxygen	**1 : 8**
Ammonia (**NH_3**)	Nitrogen and hydrogen	**14 : 3**
Carbon dioxide (**CO_2**)	Carbon and oxygen	**3 : 8**
Common Salt (NaCl)	Sodium, chlorine	23 : 35.5

(i) How many types of atoms are present in a molecule of water (H_2O)?
(ii) What is the ratio by mass of H_2SO_4?
(iii) An oxide of nitrogen is found to contain nitrogen and oxygen combined together in the ratio of **7 : 16** by mass. Derive the formula of the oxide and name it.
(iv) What are the combining elements of carbon monoxide?
(v) Give an example of monoatomic and polyatomic molecule.

39. Ion is any atom or group of atoms that bears one or more positive or negative electrical charges. Atoms in solution generally exists in the form of ions. Valency can be used to find out how the atoms of an element will combine with the atom(s) of another element to form a chemical compound.

Valency	**Polyatomic Ions**	**Symbol**
1	Ammonium; Nitrate	NH_4^+; NO_3^-
2	Carbonate; Sulphite	CO_3^{2-}; SO_3^{2-}
3	Phosphate	PO_4^{3-}

(i) What do you mean by ionic compounds? Explain with example.
(ii) How cation is different from anion?
(iii) Given symbol and valency of hydroxide ion.
(iv) What is the role of valency in the combination of atoms?
(v) What are polyatomic ions? Give examples.

EXPLANATIONS

Objective Questions

1. (*a*) Antione L. Lavoisier established law of constant proportions.

2. (*d*) 'The relative number and kinds of atoms are constant in a given compound'. This postulate explains law of definite proportions.

3. (*b*) The ratio of the mass of hydrogen to the mass of oxygen is always 1 : 8. Thus, if 9 g of water ($\mathbf{H_2O}$) is produced, then 1 g of hydrogen ($\mathbf{H_2}$) and 8 g of oxygen ($\mathbf{O_2}$) gases are used during 3rd experiment.

4. (*d*) Statement (d) is not true.

The correct statement is as: The molecules and ions aggregate together in large number to form the matter. We cannot see the individual molecules/ions with our eyes, only we can see the various substances which are a big collection of molecules/ions.

5. (*d*) The chemical symbol for sodium is derived from its Latin name '*Natrium*'. In a 'two letter' symbol, the first letter is the 'capital letter' but the second letter is the 'small letter'. Therefore, its symbol is 'Na'.

6. (*b*) 1 amu = $\frac{\mathbf{1}}{\mathbf{12}}$th of mass of C-12 atom.

7. (*a*) The atomic mass of magnesium is 24 u.

8. (*b*) Nitrogen molecule is diatomic molecule, therefore, it exists as N_2 molecule.

9. (*c*) In H_2O_2 molecule, four atoms [i.e. 2 atoms of H + 2 atoms of O] are present.

10. (*d*)

Element	Mass ratio (x)	Atomic mass (y)	Mole Ratio $\left(\frac{x}{y}\right)$	Simplest Ratio
Na	23	23	$\frac{23}{23} = 1$	1
Cl	35.5	35.5	$\frac{35.5}{35.5} = 1$	1

Thus, the formula of salt is NaCl.

11. (c) The valency of CO_3^{2-} is 2 because valency of an ion is equal to charge on the ion and CO_3^{2-} contains (-2) charge.

12. (a) The molecular mass of CO_2 is

= [(Atomic mass of C) + (2 × atomic mass of O)]

$= 12 + 2 \times 16 = 44$ u

13. (*c*) A→(1), B→(2), C→(3), D→(4), E→(5)

A. Calcium oxide, CaO

$40 + 16 = 56$ u.

B. Magnesium chloride, $MgCl_2$

$24 + 2 \times 35.5 = 95$ u

C. Aluminium phosphide, AlP

$27 + 31 = 58$ u

D. Calcium carbonate, $CaCO_3$

$40 + 12 + 3 \times 16 = 100$ u

E. Aluminium oxide, Al_2O_3

$2 \times 27 + 3 \times 16 = 102$ u

14. (*b*) Molar mass of 1 mole of aluminium oxide (Al_2O_3)

$= 2 \times 27 + 3 \times 16 = 54 + 48 = 102$ g

$\because$ 102 g of Al_2O_3 contains

$2 \times 6.022 \times 10^{23}$ Al^{3+} ions.

$\therefore$ 0.0051 g of Al_2O_3 will contain

$$= \frac{2 \times 6.022 \times 10^{23}}{102} \times 0.0051 \text{ } Al^{3+} \text{ ions}$$

$$= 6.022 \times 10^{19} \text{ } Al^{3+} \text{ ions}$$

15. (*b*) Molar mass of 1 mole of $S_8 = 8 \times 32 = 256$ g

256 g of S_8 contains = 6.022×10^{23} molecules

$\therefore$ 16 g of S_8 contains = $\frac{6.022 \times 10^{23}}{256} \times 16$

$= 3.76 \times 10^{22}$ molecules

16. (*a*) Both A and R are true and R is the correct explanation of A.

The law of constant proportion states that in a chemical substance, the elements are always present in definite proportion by mass. So, pure water obtained from different sources such as river, well, spning, etc. contain H and O in the ratio 1 : 8.

17. (*a*) Both A and R ture and R is the correct explanation of A.

$$\text{Atomic mass} = \frac{\text{Average mass of an atom}}{\frac{1}{12} \times \text{mass of an atom } {}^{12}C}$$

$$\text{Average mass of an atom} = \frac{(RA)_1 \times z_1 + (RA)_2 \times z_2}{(RA)_1 + (RA)_2}$$

Here, **RA** = relative abundance and **z** = mass number.

As atomic mass is a ratio, so it is a unitless quantity.

18. (*a*) Both A and R are true and R is the correct explanation of A. Atomic mass of aluminium is 27. It shows how many times an atom of that element is heavier than 1/12th of the mass of C-12 atom.

19. (*b*) Both A and R are true but R is not the correct explanation of A. Pure substances are defined as substances that are made up of only one type of atoms or molecules. Thus, elements and compounds are examples of pure substances.

20. (*c*) A is true but R is false. The correct R is as follows :

1 mole of SO_2 and 1 mole of O_2, both contains same number of molecules, known as Avogadro number of molecules.

21. (i) (*b*) The name of element *P* is copper because it's Latin name is Cuprum.

(ii) (*a*) The symbol of element *S* is Na because it's Latin name is 'Natrium'. So, the first letter should be capital and second letter should be small.

(iii) (*c*) JJ Berzelius discovered modern symbols of elements because Dalton's symbol for elements were difficult to draw and inconvenient to use.

(iv) (*a*) The name of element *R* is iron which has the symbol 'Fe' according to it's Latin name.

(v) (*d*) The Latin name of the element is Argentum which is now known as silver (Ag). This element is very ductile and malleable, so is used for making jewellery and has the highest conductor of heat and electricity of all metals.

22. (i) (*c*) S_8 has more than 4 atoms. Therefore, it is an example of polyatomic molecule (octa-atomic).

(ii) (*b*) The relative molecular mass of water (H_2O) is
$= \mathbf{2 \times 1 + 1 \times 16 = 18}$ u.

(iii) (*a*) Copper carbonate ($CuCO_3$) contains three type of atoms, i.e. one copper atom, one carbon atom and three oxygen atoms.

(iv) (*d*) Methanol (CH_3OH) $\rightarrow$ C : H : O = **12 : 4 : 16 = 3 : 1 : 4**.

(v) (*c*) The formula unit mass of $\mathbf{CaCl_2}$
$=$ [(Atomic mass of Ca) + (**2** $\times$ Atomic mass of Cl)
$= [\mathbf{40 + (2 \times 35.5)}] = \mathbf{111}$ u

23. (i) (*b*) The formula unit mass of HCl is $\mathbf{1 + 1} \times 35.5 = 36.5$ u

(ii) (*a*) The formula unit word is used for the substances whose constituent particles are ions. e.g. NaCl.

(iii) (*c*) The number of particles (atoms/ions/molecules) present in 1 mole of any substance is equal to Avogadro number whose value is 6.022×10^{23}.

(iv) (*d*) Mass of 1 mole of oxygen atoms
$= 1 \times$ molar mass of oxygen atoms (g)
$= \mathbf{1 \times 16 = 16}$ g

(v) (*b*) 14g of N-atom = **1** mole of N-atom
$\therefore$ 84g of N-atom $= \dfrac{\mathbf{1}}{\mathbf{14}} \times \mathbf{84} = \mathbf{6}$ moles

Subjective Questions

1. (i) Law of constant proportion states that, "a pure chemical compound always consists of the same elements that are combined together in a fixed (or definite) proportion by mass".

(ii) Carbon : Oxygen (by mass) = **3 : 8** , i.e. **3** g of carbon requires **8** g of oxygen to form carbon dioxide.
$\therefore$ **9** g of carbon require **(3 × 8)24** g of oxygen to form carbon dioxide.

2. ***Case* I** Mass of copper = **1.75** g
and mass of copper oxide = 2.19 g
So, mass of oxygen = Mass of copper oxide − Mass of copper
$= \mathbf{2.19 - 1.75 = 0.44}$ g
Now, in first sample of copper oxide compound.
Mass of copper : Mass of oxygen = 1.75 : 0.44 $= \dfrac{\mathbf{1.75}}{\mathbf{0.44}} : 1$
$= \mathbf{3.98 : 1} \approx 4 : 1$

***Case* II** Mass of copper = 1.14 g
and, mass of copper oxide = 1.43 g
So, mass of oxygen = Mass of copper oxide − Mass of copper
$= \mathbf{1.43 - 1.14 = 0.29}$ g
Now, in second sample of copper oxide compound.
Mass of copper : Mass of oxygen = 1.14 : 0.29
$= \dfrac{\mathbf{1.14}}{\mathbf{0.29}} : 1 = \mathbf{3.93 : 1} \approx 4 : 1$

3. The reasons are

(i) Oxygen reacted with a large number of elements and formed compounds.

(ii) This unit gave masses of most of the elements as whole numbers.

4. It is defined as the mass unit equal to exactly $\dfrac{\mathbf{1}}{\mathbf{12}}$th of the mass of one atom of C-12 isotope.

The atomic mass of nitrogen in 14 u and sulphur is 32 u.

5. Atoms are very small, they are smaller than anything we can imagine. More than millions of atoms when stacked would make a layer barely as thick as the sheet of paper. These are very small in radii and measured in terms of nanometers (1nm = $\mathbf{10^{-9}}$m). Hence, it is not possible to see an atom with naked eyes.

6.

	Atom	**Molecule**
(i)	An atom is the smallest particle of an element that can take part in a chemical reaction.	A molecule is the smallest particle of an element or compound which has the properties of that element or compound.
(ii)	An atom may or may not exist independently.	A molecule is capable of independent existence.
(iii)	Examples : Hydrogen (H), oxygen (O).	Examples: Hydrogen molecule ($\mathbf{H_2}$), oxygen molecule ($\mathbf{O_2}$), water molecule ($\mathbf{H_2O}$).

7. Monoatomic : Ag, He
Diatomic : HCl, F_2
Triatomic : $\mathbf{NO_2}$, N_2O, $\mathbf{O_3}$
Tetra-atomic : P_4, H_2O_2
Polyatomic : C_2H_6, P_4O_{10}, CH_4

8. (i) In H_2S molecule, three atoms
[i.e. 2 atoms of H + 1 atom of S] are present.

(ii) In PO_4^{3-} ion, five atoms
[i.e. 1 atom of P + 4 atoms of O] are present.

9. The smallest particle of an element or compound which is capable of independent existence and shows all the properties of that substance is called as molecule. In general, molecule is a group of two or more atoms that are chemically bonded together.

Molecules can be divided into two categories:

(i) **Molecules of Elements** They contain same type of atoms, i.e. either made up of only one atom of that element. e.g. noble gases like argon (Ar), helium (He) etc. or made up of more than one atom of an element.
e.g. Non-metals like oxygen forms a molecule of O_2 that consists of two atoms of oxygen and is known as diatomic molecule.

(ii) **Molecules of Compounds** Atoms of different elements join together in definite proportions to form molecules of compounds.

e.g. Water (H_2O) contains hydrogen and oxygen as combining elements and it's ratio by mass is **1 : 8**.

10. Number of nitrogen atom present in the molecule

$$= \frac{\textbf{Proportion by mass}}{\textbf{Atomic mass}} = \frac{\textbf{14}}{\textbf{14}} = \textbf{1}$$

Number of hydrogen atom present in the molecule

$$= \frac{\text{Proportion by mass}}{\textbf{Atomic mass}} = \frac{\textbf{3}}{\textbf{1}} = \textbf{3}$$

This means number of nitrogen and hydrogen atoms combine in ratio = **1 : 3**

Thus, the formula of molecule of ammonia is NH_3.

11.

Element	Mass ratio (x)	Atomic mass (y)	Mole ratio $\left(\frac{x}{y}\right)$	Simplest ratio
Na	23	23	$\frac{23}{23} = 1$	1
H	1	1	$\frac{1}{1} = 1$	1
C	12	12	$\frac{12}{12} = 1$	1
O	48	16	$\frac{48}{16} = 3$	3

Therefore, bicarbonate of sodium contains one sodium, one-carbon, one hydrogen and three oxygen atoms. Hence, the formula is $NaHCO_3$, i.e. sodium bicarbonate which is also known as "Baking powder".

12. When atoms, groups of atoms or molecules lose or gain electron(s), they become charged. These charged species are known as ions.

Ions are categorised into two groups:

(i) **Cations** They are positively charged ions. e.g. Na^+, K^+, Ca^{2+}, Al^{3+} etc. These are formed when elements loses electrons. Usually, metals form cations.

(ii) **Anions** They are negatively charged ions. e.g. Cl^-, Br^-, O^{2-}, N^{3-} etc. These are formed when elements gain electrons. Usually, non-metals form anions.

13. The molecular mass of :

(i) Nitric acid, HNO_3

= (Atomic mass of H) + (Atomic mass of N) + (3 × Atomic mass of O)

= **1 + 14 + (3 × 16) = 15 + 48 = 63** g/mol

(ii) Ethyne, C_2H_2

= (2 × Atomic mass of C) + (2 × Atomic mass of H)

= **(2 × 12) + (2 × 1) = 26** g/mol

(iii) Sulphur molecule, S_8

= **8** × Atomic mass of S

= **8 × 32 = 256** g/mol

14. Molecular mass of NH_3 (ammonia) = (Atomic mass of nitrogen × **1**) + (Atomic mass of hydrogen × **3**)

= **(14 × 1) + (1 × 3) = 14 + 3 = 17** u

Molecular mass of CH_3OH (methanol or methyl alcohol) = (Atomic mass of carbon × **1**) + (Atomic mass of hydrogen × **3**) + (Atomic mass of oxygen × **1**) + (Atomic mass of hydrogen × **1**)

= **(12 × 1) + (1 × 3) + (16 × 1) + (1 × 1)**

= **12 + 3 + 16 + 1 = 32** u

15. (i) Formula unit mass of ZnO (zinc oxide)

= **65 + 16 = 81** u

(ii) Formula unit mass of Na_2O (sodium oxide)

= **(23 × 2) + (16 × 1) = 46 + 16 = 62** u

(iii) Formula unit mass of K_2CO_3 (potassium carbonate)

= **(39 × 2) + (12 × 1) + (16 × 3) = 78 + 12 + 48 = 138 u**

16. (i) Avogadro's number is the number of particle (atom, molecules or ions) constituted in 1 mole of a substance.

Value of Avogadro's number (N_A) = $\mathbf{6.022 \times 10^{23}}$

(ii) 1 mole of oxygen gas (O_2) consists = **32** g

∴ 0.2 mole of oxygen gas (O_2) consists

= 0.2 × **32** g = **6.4 g**

17. 23 g atomic unit or 23 g (1 mol) Na = $\mathbf{6.022 \times 10^{23}}$ atoms

∴ 100 g sodium contains = $\frac{\mathbf{6.022 \times 10^{23}}}{\mathbf{23}} \times \mathbf{100}$

= $\mathbf{2.617 \times 10^{24}}$ atoms

Again, 56 g atomic unit or 56 g (1 mol) iron = $\mathbf{6.022 \times 10^{23}}$ atoms

∴100 g iron contains = $\frac{\mathbf{6.022 \times 10^{23}}}{\mathbf{56}} \times \mathbf{100} = \mathbf{1.075 \times 10^{24}}$ atoms

Therefore, 100 g of Na has more atoms than 100 g of iron.

18. (i) Atomic mass of N = **14 u**

∴ Mass of 1 mole of N-atoms = **14** g

(ii) Mass of 1 mole of Al-atoms = **27** g

∴ Mass of 4 moles of Al-atoms = **27 × 4 = 108** g

(iii) Mass of 1 mole of $\mathbf{Na_2SO_3}$

= **(23 × 2) + 32 + (16 × 3) = 46 + 32 + 48 = 126** g

Mass of 10 moles of $\mathbf{Na_2SO_3}$ = **126 × 10 = 1260** g

19. 1 mole of $\mathbf{Al_2O_3} = \mathbf{2 \times 27 + 3 \times 16 = 102}$ g mol^{-1}

∵ **102** g of $\mathbf{Al_2O_3}$ contains $\mathbf{2 \times 6.022 \times 10^{23}}$ $\mathbf{Al^{3+}}$ ions

∴ 1g of $\mathbf{Al_2O_3}$ will contain $\frac{\mathbf{2 \times 6.022 \times 10^{23}}}{\mathbf{102\ g}}$ Al^{3+} ions

and 2 g of $\mathbf{Al_2O_3}$ **will contain** $\frac{\mathbf{2 \times 6.022 \times 10^{23}}}{\mathbf{102\ g}} \times \mathbf{2}$

= $\frac{4 \times 6.022 \times 10^{23}}{102\ \text{g}} = \mathbf{2.36 \times 10^{22}}$ $\mathbf{Al^{3+}}$ ions

20. Given that, mass of one steel rod = 4.11 g

Mass of earth = $\mathbf{5.98 \times 10^{24}}$ kg = $\mathbf{5.98 \times 10^{27}}$ g

We know that,

1 mole = 6.022×10^{23} atoms/molecules/ions

Mass of 1 mole of rod $= 6.022 \times 10^{23} \times 4.11\,g = 2.48 \times 10^{24}\,g$

$$\frac{\text{Mass of 1 mole screw}}{\text{Mass of earth}} = \frac{2.48 \times 10^{24}\ g}{5.98 \times 10^{27}\ g} = \frac{\mathbf{1}}{\mathbf{2410}}$$

$\therefore$ Ratio of 1 mole of rod and mass of earth = **1 : 2410**

$\therefore$ Earth is heavier than rod by 2410 times.

21. (i) 12 g of oxygen gas (O_2)

Molar mass of oxygen (O_2) $= 16 \times 2 = 32$ g / mol

$$\text{Number of moles} = \frac{\text{Given mass}}{\text{Molar mass}} = \frac{12\ g}{32\ g/mol} = 0.375\ \text{mol}$$

(ii) 20 g of water (H_2O)

Molar mass of water (H_2O) $= \mathbf{2 + 16 = 18}$ g/mole

$$\text{Number of mol} = \frac{\text{Given mass}}{\text{Molar mass}} = \frac{20\ g}{18\ g/mol} = 1.11\ \text{mol}$$

(iii) 22 g of carbon dioxide (CO_2)

Molar mass of carbon dioxide (CO_2) $= 12 + 32 = 44$ g/mol

$$\text{Number of mol} = \frac{\text{Given mass}}{\text{Molar mass}} = \frac{22\ g}{44\ g/mol} = 0.5\ \text{mol}$$

22. $\because$ Mass of 1 mole of $CaCO_3 = \mathbf{40 + 12 + (16 \times 3)} = \mathbf{100}$ g

$\therefore$ Mass of 2 moles of $CaCO_3 = \mathbf{100 \times 2 = 200}$ g

Now, mass of 1 mole of $H_2O = 2 + 16 = 18$ g

$\therefore$ Mass of 10 moles of $\mathbf{H_2O = 18 \times 10 = 180}$ g

Therefore, mass of 2 moles of $CaCO_3$ is more, i.e. 200 g.

23. 1 mole = atomic mass of element $= 6.022 \times \mathbf{10^{23}}$ atoms

$\because$ Mass of 1 atom $= 3.05 \times \mathbf{10^{-22}}$ g

$\therefore$ Mass of $6.022 \times \mathbf{10^{23}}$ atoms

$= 3.05 \times \mathbf{10^{-22}} \times 6.022 \times \mathbf{10^{23}} = 183.671$ g

This is nearly the atomic mass of tungsten ($W^{183.8}$).

24. Molar mass of $CaCl_2 = 40 + 2 \times 35.5 = 40 + 71 = 111\ g\ mol^{-1}$

$CaCl_2$ ionises in water as:

$$\underset{[111\ g]}{\underset{1\ mol}{CaCl_2\,(aq)}} \longrightarrow \underbrace{\underset{1\ mol}{Ca^{2+}\,(aq)} + \underset{2\ mol}{2Cl^-\,(aq)}}_{3\ mol}$$

$\because$ 111 g of $CaCl_2$ produces ions = **3** mol

$= \mathbf{3 \times 6.022 \times 10^{23}}$ ions

$\therefore$ 222 g of $CaCl_2$ produces ions

$$= \frac{\mathbf{3 \times 6.022 \times 10^{23}}}{\mathbf{111}} \times \mathbf{222} = \mathbf{36.132 \times 10^{23}}$$

$$= \mathbf{3.6132 \times 10^{24}\ ions}$$

25. (*i*) 1 molecule of hydrogen gas contains 2 atoms of hydrogen

$\because$ 1 dozen of H_2 molecules = **24** atoms of H

$= \mathbf{12}$ molecules of $\mathbf{H_2}$

$\mathbf{6.022 \times 10^{23}}$ molecules of $H_2 = \mathbf{1}$ mole

$$\therefore \text{ 12 molecules of } \mathbf{H_2} = \frac{\mathbf{12}}{\mathbf{6.022 \times 10^{23}}} = \mathbf{1.99 \times 10^{-23}} \text{moles}$$

(*ii*) Hydrogen : Oxygen (by mass) $= \mathbf{1 : 8 = 2\ g : 16}$ g

$\because$ 1 mole of H_2 combines with $\frac{\mathbf{1}}{\mathbf{2}}$ mole of oxygen

$\frac{\mathbf{12}}{\mathbf{6.022 \times 10^{23}}}$ moles H_2 combines with

$\frac{\mathbf{6}}{\mathbf{6.022 \times 10^{23}}}$ moles oxygen

or, the required ratio of H_2 and O_2 is 2 : 1.

26. (i) Mass of 1 mole O-atoms = **16** g

Mass of 0.2 mole O-atoms $= 16 \times 0.2 = 3.2$ g

(ii) Mass of 1 mole of H_2O molecules = **18** g

Mass of 0.5 mole of H_2O molecules $= 18 \times 0.5 = 9.0$ g

27. 1 mole of Al atom = $\mathbf{6.022 \times 10^3}$ Al atoms

Ionisation of Al atom occurs as $Al \longrightarrow Al^{3+} + 3\,\mathbf{e}^-$

Therefore, Al^{3+} ion is formed from Al atom by loss of 3 electrons. Difference in mass of 1 mole of Al atoms and 1 mole of Al^{3+} ions

$= (\mathbf{3 \times 6.022 \times 10^{23}}) \times$ (mass of electrons)

$= (\mathbf{3 \times 6.022 \times 10^{23}}) \times (9.1 \times 10^{-28}\ g)$

(as mass of an electron $= 9.1 \times 10^{-28}$ g)

$= 164.4 \times 10^{-5}\ g = 1.644 \times 10^{-3}$ g

1 mole of Al atoms is heavier than 1 mole of $\mathbf{Al^{3+}}$ ions.

It is because 1 mole of Al atoms has $\mathbf{13 \times 6.022 \times 10^{23}}$ electrons and 1 mole of Al^{3+} ions has $\mathbf{10 \times 6.022 \times 10^{23}}$ electrons.

28. Given that, molar mass of Hg $= 200.6\ g\ mol^{-1}$

and that of S $= 32\ g\ mol^{-1}$

Molar mass of HgS = Molar mass of the Hg + Molar mass of the S

Molar mass of HgS $= 200.6 + 32 = 232.6\ g\ mol^{-1}$

$\because$ 232.6 g of HgS contains Hg = 200.6

(as molar mass of Hg $= 200.6\ g\ mol^{-1}$)

$$\therefore \text{ 225 g of HgS will contains Hg} = \frac{200.6 \times 225}{232.6} = 194.05\ g$$

29. (i) $\text{Number of moles} = \dfrac{\text{Given number of atoms}}{\text{Avogadro's number}}$

$$\text{Number of moles of oxygen atoms} = \frac{\mathbf{3.011 \times 10^{23}}}{\mathbf{6.022 \times 10^{23}}} = \mathbf{0.5}\ \text{moles}$$

(ii) $\text{Number of moles 60 g of calcium} = \dfrac{\text{Given mass}}{\text{Molar mass}} = \dfrac{60}{40}$

$= 1.5$ moles

[$\because$ Atomic mass of Ca = **40** u]

30. [22 carat gold means 22 out of 24 parts is gold and rest is copper]

$$\text{Mass of copper} = \frac{\mathbf{2}}{\mathbf{24}} \times \mathbf{10}\ g$$

$$\text{Number of moles of Cu} = \frac{\text{Given mass}}{\text{Molecular mass}} = \frac{\mathbf{2}}{\mathbf{24}} \times \frac{\mathbf{10}}{\mathbf{63.5}}$$

$$\text{Number of atoms of Cu} = \text{Number of moles} \times \mathbf{N_A}$$

$$= \frac{\mathbf{2}}{\mathbf{24}} \times \frac{\mathbf{10}}{\mathbf{63.5}} \times \mathbf{6.022 \times 10^{23}}$$

$$= \mathbf{7.9 \times 10^{21}}\ \text{atoms}$$

31. Molar mass of 1 mole of $N_2 = 2 \times 14 = 28$ g

$\because$ 28 g of N_2 has number of molecules $= \mathbf{6.022 \times 10^{23}}$

$\therefore$ 100 g of N_2 has number of molecules $= \dfrac{\mathbf{6.022 \times 10^{23} \times 100}}{\mathbf{28}}$

$= \mathbf{2.1 \times 10^{24}}$

Atoms in 100 g of $N_2 = 2.1 \times 10^{24} \times 2 = \mathbf{4.2 \times 10^{24}}$ atoms.

Similarly, molar mass of 1 mole of $NH_3 = \mathbf{14 + 3 \times 1 = 17}$ g

$\because$ 17g NH_3 has number of molecules $= \mathbf{6.022 \times 10^{23}}$

$\therefore$ 100 g NH_3 has number of molecules

$$= \frac{\mathbf{6.022 \times 10^{23} \times 100}}{\mathbf{17}} = \mathbf{3 \cdot 54 \times 10^{24}}$$

Atoms in 100 g of $\mathbf{NH_3} = 3.54 \times 10^{24} \times 4 = \mathbf{1.416 \times 10^{25}}$

Thus, 100 g of NH_3 has more number of atoms.

32. (i) Molar mass of water $(H_2O) = \mathbf{2 \times 1 + 16} = \mathbf{18}$ g/mol

$\because$ 1 mol $= \mathbf{6.022 \times 10^{23}}$ molecules $= \mathbf{18}$ g of water

$\therefore$ 1 molecule weigh $\dfrac{\mathbf{18}}{\mathbf{6.022 \times 10^{23}}} = \mathbf{2.99 \times 10^{-23}}$ g

(ii) Mole of element X contains $= 6.022 \times \mathbf{10^{23}}$ atoms

$\because$ $\mathbf{1.66 \times 10^{20}}$ atoms weigh 16.26 mg $= \mathbf{16.26 \times 10^{-3}}$ g

$\therefore$ $\mathbf{6.022 \times 10^{23}}$ atoms will weigh

$$= \frac{\mathbf{16.26 \times 10^{-3}}}{\mathbf{1.66 \times 10^{20}}} \times \mathbf{6.022 \times 10^{23}} = \mathbf{58.9}\ \text{g} \approx 59\ \text{g}$$

Therefore, atomic mass of element X is 59 u

33. (i) Number of moles $= \dfrac{\textbf{Given number of particles}}{\textbf{Avogadro's number}}$

(ii) Number of moles $= \dfrac{\textbf{Number of atoms of sodium}}{\textbf{Avogadro's number of particles}}$

$$= \frac{1.0 \times 10^{20}\ \text{atoms}}{6.022 \times 10^{23}\ \text{atoms}} = 1.66 \times \mathbf{10^{-4}}\ \text{mol}$$

(iii) $\textbf{Number of moles} = \dfrac{\textbf{Given mass}}{\textbf{Gram atomic mass}}$

(iv) (*a*) $\textbf{Number of moles} = \dfrac{\textbf{Mass of He}}{\textbf{Gram atomic mass of He}}$

$$= \frac{\mathbf{56}}{\mathbf{4}} = \mathbf{14}\ \text{mol}$$

(*b*) Number of moles $= \dfrac{\textbf{Mass of Na}}{\textbf{Gram atomic mass of Na}}$

$$= \frac{\mathbf{23}}{\mathbf{23}} = \mathbf{1}\ \text{mol}$$

34. (i) Sulphur and oxygen

(ii) Valency of sulphur in $SO_2 = \mathbf{4}$

Valency of sulphur in $SO_3 = 6$

(iii) $\mathbf{5} \times$ Avogadro's number $= \mathbf{5} \times 6.022 \times \mathbf{10^{23}}$

$= \mathbf{3.011 \times 10^{24}}$ molecules

(iv) $\mathbf{m} = \mathbf{320}$ g, Molar mass (M) of $\mathbf{SO_2} = \mathbf{32 + 2 \times 16}$

$= \mathbf{64}$ g/mol

$$\Rightarrow \mathbf{n} = \frac{\mathbf{m}}{\mathbf{M}} = \frac{\mathbf{320}}{\mathbf{64}} = \mathbf{5}\ \text{moles}$$

(*v*) Molar mass of 10 moles of Na_2SO_3

$= \mathbf{10\,[23 \times 2 + 32 + 16 \times 3] = 1260}$ g

35. (i) 1 mole of iron (Fe) = 56 g (molar mass)

$\because$ 56 g of Fe = **1** mol

$\therefore$ 112 g of Fe $= \dfrac{\mathbf{1}}{\mathbf{56}} \times \mathbf{112}$ mol $= \mathbf{2}$ mol

(ii) Molar mass of $C_{12}H_{22}O_{11}$ (sugar)

$= \mathbf{12 \times 12 + 22 \times 1 + 11 \times 16}$

$= \mathbf{342}$ g/mol

or 1 mole of sugar = **342** g of sugar

$\therefore$ 0.5 mole of sugar $= \mathbf{342 \times 0.5 = 171}$ g

(iii) **Molecular mass** It is the sum of the atomic masses of all the atoms present in a molecule of the substance.

(iv) $ZnSO_4 = \mathbf{65 + 32 + 4 \times 16 = 161}$ u

(v) Molar mass of 1 mole of $CO_2 = \mathbf{12 + 2 \times 16 = 44}$ g

$\because$ 44 g of CO_2 contains $\mathbf{6.022 \times 10^{23}}$ molecules

$\therefore$ 4.4 g of CO_2 contains $\dfrac{\mathbf{6.022 \times 10^{23}}}{\mathbf{44}} \times \mathbf{4.4}$

$= \mathbf{6.022 \times 10^{22}}$ molecules

36. (i) (a) Molecular mass of nitrogen $= \mathbf{2 \times 14 = 28}$ u

Mass of 1 mole of nitrogen = **28** g

Number of molecules in 28 g of nitrogen $= \mathbf{6.022 \times 10^{23}}$

Number of molecules in 1 g of nitrogen $= \dfrac{\mathbf{6.022 \times 10^{23}}}{\mathbf{28}}$

Number of molecules in 10 g of nitrogen

$$= \frac{\mathbf{6.022 \times 10^{23}}}{\mathbf{28}} \times \mathbf{10} = \mathbf{2.15 \times 10^{23}}$$

Number of atoms in 10 g of nitrogen $(\mathbf{N_2})$

$= \mathbf{2 \times 2.15 \times 10^{23}}$

$= \mathbf{4.30 \times 10^{23}}$

(*b*) Molecular mass of ammonia $= \mathbf{14 + 3 \times 1 = 17}$ u

Mass of 1 mole of ammonia = **17** g

Number of molecules in 17 g of ammonia $= 6.022 \times \mathbf{10^{23}}$

Number of molecules in 1g of ammonia $= \dfrac{6.022 \times \mathbf{10^{23}}}{\mathbf{17}}$

Number of molecules in 10 g of ammonia

$$= \frac{6.022 \times \mathbf{10^{23}}}{\mathbf{17}} \times \mathbf{10} = 3.54 \times \mathbf{10^{23}}$$

Number of atoms in 10 g of ammonia $(\mathbf{NH_3})$

$= \mathbf{4 \times 3.54 \times 10^{23} = 1.46 \times 10^{24}}$

10 g of NH_3 contains more number of atoms.

(ii) Molecular mass of sodium chloride (NaCl) $= \mathbf{23 + 35.5}$

$= \mathbf{58.5\ u}$

58.5 g of sodium chloride (NaCl) = **1** mol

1 g of sodium chloride (NaCl) $= \dfrac{\mathbf{1}}{\mathbf{58.5}}$ mol

0.585 g of sodium chloride (NaCl)

$$= \frac{\mathbf{1}}{\mathbf{58.5}} \times \mathbf{0.585}\ \text{mol} = \mathbf{0.01}\ \text{mol}$$

37. **For H_2O**

Given, number of moles = **2** and mass = **36** g

$\therefore$ Number of particles = number of moles $\times$ $\mathbf{6.022 \times 10^{23}}$

$$= \mathbf{2 \times 6.022 \times 10^{23} = 1.2044 \times 10^{24}}$$

$$\left[\because \quad \text{Number of moles} = \frac{\text{Number of particles}}{\text{Avogadro's number}}\right]$$

For CO_2

Given, number of particles = $\mathbf{3.011 \times 10^{23}}$

$\therefore$ Number of moles of CO_2

$$= \frac{\text{Number of particles}}{6.022 \times 10^{23}}$$

$$= \frac{3.011 \times 10^{23}}{6.022 \times \mathbf{10^{23}}} = \mathbf{0.5}\ \text{mol}$$

Mass of CO_2 = moles $\times$ molar mass = $0.5 \times 44 = 22$ g

($\because$ Molar mass of $CO_2 = \mathbf{12 + 2 \times 16 = 44}$)

For Na atom

Given, mass = **115** g

$$\text{Number of moles} = \frac{\text{Mass}}{\text{Molar mass}} = \frac{\mathbf{115}}{\mathbf{23}} = \mathbf{5}\ \text{mol}$$

$\therefore$ Number of particles = $\mathbf{5 \times 6.022 \times 10^{23} = 3.011 \times 10^{24}}$

For $MgCl_2$

Given, number of moles = **0.5** mole

$\therefore$ Number of particles = $\mathbf{0.5 \times 6.022 \times 10^{23} = 3.011 \times 10^{23}}$

Mass = number of moles $\times$ molar mass

(Molar mass of $MgCl_2 = \mathbf{24 + 2 \times 35.5 = 24 + 71 = 95}$ g mol^{-1}

$$= \mathbf{0.5 \times 95 = 47.5}\ \text{g}$$

Thus, the completed table is as :

Species Property	**H_2O**	**CO_2**	**Na atom**	**$MgCl_2$**
Number of moles	2	0.5	5.0	0.5
Number of particles	$\mathbf{1.2044 \times 10^{24}}$	$\mathbf{3.011 \times 10^{23}}$	$\mathbf{3.011 \times 10^{24}}$	$\mathbf{3.011 \times 10^{23}}$
Mass	36g	22g	115g	47.59g

38. (i) H_2O contains two type of atoms, i.e. two hydrogen atoms and one oxygen atom.

(ii) $H_2SO_4 \rightarrow$ H : S : O = $\mathbf{2 \times 1 : 32 : 4 \times 16 = 2 : 32 : 64}$

The ratio by mass of H_2SO_4 = **1 : 16 : 32**

(iii)

Element	**Mass ratio (x)**	**Atomic mass (y)**	**Mole ratio $\left(\frac{x}{y}\right)$**	**Simplest ratio**
N	7	14	$\frac{7}{14} = \frac{1}{2}$	$\frac{1}{2} \times 2 = 1$
O	16	16	$\frac{16}{16} = 1$	$1 \times 2 = 2$

Thus, the oxide of nitrogen contains one nitrogen atom and two oxygen atoms. So, the formula of the oxide is NO_2 which is also known as nitrogen dioxide.

(iv) The combining elements of carbon monoxide (CO) is carbon and oxygen.

(v) Monoatomic molecules consists of only one atom, e.g. Xe, Al and polyatomic molecules are those molecules which consist of more than four atoms.

e.g. $\mathbf{PCl_5}$ (Hexa-atomic), $\mathbf{CH_3—CH_3}$ (octa-atomic).

39. (i) The compounds which are made up of ions are called as ionic compounds. e.g. sodium chloride or common salt (NaCl) consists of a positively charged sodium ion (Na^+ cation) and negatively charged chloride ion (Cl^- anion).

(ii) Cations are positively charged ions which are formed when elements loses electrons. e.g. K^+.

Anions are negatively charged ions which are formed when elements gain electrons. e.g. Br^-.

(iii) The symbol of hydroxide ion is OH^- and valency is 1.

(iv) Valency helps in making pair of electrons needed by one and pair of electrons to be loosed to attain nearest noble gas configuration or to fulfill the octet.

The elements which have same valency can combine with each other to form a compound. e.g. Ca^{2+} and CO_3^{2-} both have same valency, i.e. 2 so they combine together and form $CaCO_3$.

(v) A group of atoms carrying a charge and behaving like one entity is known as polyatomic ion. e.g. oxygen atom and by hydrogen atom combine to form hydroxide ion ($\mathbf{OH^-}$) and one C-atom and three O-atoms combine to form carbonate ion ($\mathbf{CO_3^{2-}}$).

Chapter Test

Multiple Choice Questions

1. Atoms combine in the ratio of small ..... to form compounds.

(a) integers (b) whole numbers
(c) fraction (d) proportions

2. What is the atomicity of I_2 and Na_2SO_4?

(a) 1, 3 (b) 2, 7
(c) 2, 5 (d) 1, 5

3. ..... form cations.

(a) Molecules (b) Non-metals
(c) Metalloids (d) Metals

4. Calculate the molecular mass of $Al_2(SO_4)_3$.

(a) 342 u (b) 242 u
(c) 249.5 u (d) 288 u

5. Which of the following correctly represents 360 g of water?

(i) 2 moles of H_2O
(ii) 20 moles of water
(iii) 6.022×10^{23} molecules of water
(iv) 1.2044×10^{25} molecules of water

(a) Only (i) (b) (i) and (iv)
(c) (ii) and (iii) (d) (ii) and (iv)

Assertion-Reasoning MCQs

Direction (Q. Nos. 6-7) Each of these questions contains two statements Assertion (A) and Reason (R). Each of these questions also has four alternative choices, any one of which is the correct answer. You have to select one of the codes (a), (b), (c) and (d) given below.

(a) Both A and R are true and R is the correct explanation of A.
(b) Both A and R are true, but R is not the correct explanation of A.
(c) A is true, but R is false.
(d) A is false, but R is true.

6. **Assertion** SI unit of atomic mass and molecular mass is u.
Reason It is equal to the mass of 6.023×10^{23} atoms.

7. **Assertion** Atomicity of O_3 is 3.
Reason 1 mole of an element contains 6.023×10^{23} atoms.

8. **Assertion** Molecular weight of N_2 is half to that of MgS.
Reason One mole of N_2 contains half the number of molecules present in one mole of MgS.

Short Answer Type Questions

9. Hydrogen and 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 ? [**Ans.** 24 g]

10. How did Berzelius assign symbols to the elements ? What is the chemical symbol of chlorine?

11. Write one example of each.
(i) Tetra-atomic molecule
(ii) Diatomic molecule

12. Find the mass of each one of the following:
(i) 1 mole of water (H_2O)
(ii) 1 mole of ethanol (C_2H_5OH)
(iii) 1 mole of glucose ($C_6H_{12}O_6$)
[Atomic mass of H = 1u, O = 16 u and C = 12 u]
[**Ans.** (i) 18 g, (ii) 46 g, (iii) 180 g]

13. Calculate
(i) the mass of 1.0505×10^{23} molecules of carbon dioxide (CO_2).
(ii) the number of molecules in 0.25 mole of NH_3.
(iii) the formula unit mass of Na_2SO_3.
[Atomic mass of Na = 23 u, S = 32 u, O = 16u, H = 1 u and $N_A = 6.022 \times 10^{23}\ mol^{-1}$]
[**Ans.** (i) 7.676 g, (ii) 1.5055×10^{23} molecules, (iii) 1264]

Long Answer Type Questions

14. (i) Explain, why the number of atoms in one mole of hydrogen gas is double the number of atoms in one mole of helium gas?
(ii) Explain atomic mass unit.
(iii) How many atoms are present in
(a) MnO_2 molecule
(b) CO molecule?

15. (i) One mole of carbon atoms weighs 12 g. Find the mass of 1 atom of carbon in grams.
[Avogadro's number = 6.022×10^{23} per mole]
[**Ans.** 1.99×10^{-23} g]

(ii) Calculate the mass of the following:
(a) 0.5 mole of N_2 gas
(b) 0.2 mole of O-atoms
(c) 4 moles of aluminium atom
[Given, N = 14 u, O = 16 u, Al = 27 u,
Avogadro's number = 6.022×10^{23} per mole]
[**Ans.** (a) 14 g, (b) 3.2 g (c) 108 g]

Answers

Multiple Choice Questions

1. *(b)* ***2.*** *(b)* ***3.*** *(d)* ***4.*** *(a)* ***5.*** *(d)*

Assertion-Reasoning MCQs

6. *(c)* ***7.*** *(b)* ***8.*** *(c)*