Atoms and Molecules

Recap Notes

- **Laws of chemical combination** : Lavoisier and Joseph L. Proust established the two laws of chemical combination :
  - **Law of conservation of mass :** It states that mass can neither be created nor destroyed in a chemical reaction. In other words, in any chemical reaction, the total mass of the reactants is equal to the total mass of the products.

    $$\underset{\text{Carbon (12 g)}}{C} + \underset{\text{Oxygen (32 g)}}{O_2} \longrightarrow \underset{\text{Carbon dioxide (44 g)}}{CO_2}$$

  - **Law of constant proportions :** It is also known as the law of definite proportions. It states that in a chemical substance, the elements are always present in definite proportions by mass.In water, the ratio of the mass of hydrogen to the mass of oxygen is always 1 : 8.
  - **Dalton's atomic theory :** This theory was based on the laws of chemical combination. According to this theory, all matter, whether an element, a compound or a mixture is composed of small particles called atoms.
  - The postulates of Dalton's atomic theory are stated as follows :
    - All matter is made of very tiny particles called atoms.
    - Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.
    - Atoms of a given element are identical in mass and chemical properties.
    - Atoms of different elements have different masses and chemical properties.
    - Atoms combine in the ratio of small whole numbers to form compounds.
    - The relative number and kinds of atoms are constant in a given compound.
- **Atom :**
  - The building blocks of all matter are atoms.
  - The smallest unit of an element, which may or may not exist independently, but always takes part in a chemical reaction, is called an atom.
  - The size of an atom is indicated by its radius which is called atomic radius. It is measured in 'nanometres'. One nanometre is one billionth part of a metre.

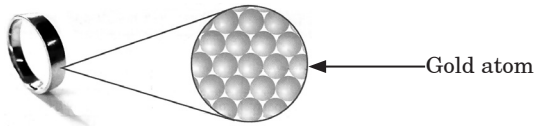
    1 nanometre (nm) = 10^{-9} metre (m) or 1 metre (m) = 10^{9} nanometre (nm)
- **Modern day symbols of atoms of different elements :**
  - IUPAC (International Union of Pure and Applied Chemistry) approves names of the different elements.
    - Many of the symbols are the first one or two letters of the element's name in English.
    - The first letter of a symbol is always written as a capital letter and the second letter as a small letter.
    - Symbols of some elements are formed from the first letter of the name and a letter, appearing later in the name.
    - Other symbols have been taken from the names of elements in Latin, German or Greek.

- **Atomic mass :** Atoms are extremely small particles. The actual masses of the atoms are so small that it is difficult to determine the actual masses of individual atoms. It was found convenient to compare the masses of atoms of different elements with some reference atom. The masses thus obtained are called relative atomic masses. It has no units.
- IUPAC recommended the use of an isotope of carbon with mass number 12 as the standard reference for measuring atomic masses. It is called carbon–twelve (C–12) and is represented as ^{12}C.
- Atomic mass is defined as the number of times one atom of an element is heavier than $\frac{1}{12}$th of the mass of an atom of carbon –12 isotope.

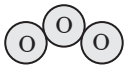
  Atomic mass = $\frac{\text{Mass of one atom of an element}}{\frac{1}{12^{\text{th}}}\text{ mass of one atom of carbon} - 12}$
- The atomic mass of an element is now defined as the average relative mass of its atoms as compared with the mass of an atom of carbon–12 isotope taken as 12 units.
- Atomic mass of an element is expressed in amu or u or it is written without units because it is the relative mass of the atom of that element.
- Atomic mass unit (amu) may be defined as $\frac{1}{12}$th of the mass of an atom of carbon–12 isotope on the atomic scale.

  1 amu = $\frac{1}{12}$th of mass of C–12 isotope
- Atomic mass expressed in grams is called gram atomic mass of that element. It is the quantity in grams which is numerically equal to the atomic mass of an element on a.m.u. scale.
- The amount of an element having mass equal to gram atomic mass is called one gram atom (or g atom) of the element.

- **Existence of atoms :**
  - Atoms of most elements are not able to exist independently.
  - Atoms form molecules and ions. These molecules or ions aggregate in large numbers to form the matter that we can see, feel or touch.

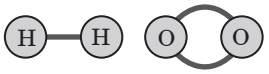


- **Molecules :**
  - A molecule is a group of two or more atoms that are chemically bonded together, that is, tightly held together by attractive forces.
  - A molecule can be defined as the smallest particle of an element or a compound that is capable of an independent existence and shows all the properties of that substance.



An ozone molecule (O_3)

  - Atoms of the same element or of different elements can join together to form molecule.
  - **Molecules of elements :** The molecules of an element are constituted by the same type of atoms.
  - Metals and some other elements, such as carbon, do not have a simple structure but consist of a very large and indefinite number of atoms bonded together.

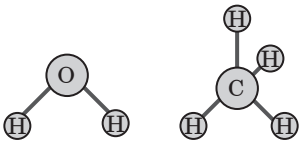


Hydrogen molecule Oxygen molecule

  - The number of atoms constituting a molecule is known as its atomicity. On the basis of their atomicities, elements are classified as monatomic, diatomic, triatomic, tetratomic, etc.

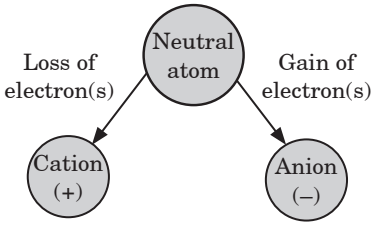
Monatomic element	Diatomic molecule	Tetratomic molecule
Krypton (Kr)	Nitrogen (N_2)	Phosphorus (P_4)

  - **Molecules of compounds :** Atoms of different elements join together in definite proportions to form molecules of compounds.

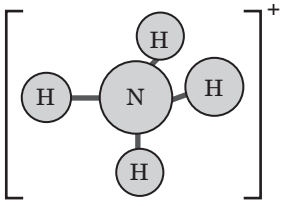


Water molecule Methane molecule

- **Ions :**
  - Compounds composed of metals and non-metals contain charged species. The charged species are known as ions.



  - An ion is a charged particle and can be negatively or positively charged.
    - A negatively charged ion is called an anion and the positively charged ion is called a cation.
    - Ions may consist of a single charged atom or a group of atoms that have a net charge on them.
    - A group of atoms carrying a charge is known as a polyatomic ion.
  - A radical is an atom or a group of atoms carrying positive or negative charge that behaves as a single unit in a chemical reaction. For example, NH_4^+



Ammonium ion

- **Writing chemical formulae :**
The chemical formula of a compound is a symbolic representation of its composition.
  - The chemical formulae of a compound can be written by the following methods :
    - Mass ratio method
    - Valency method
  - **Writing formula using mass ratio method :** The ratio of number of atoms in a molecule of a compound can be calculated, if the ratio of their masses and the atomic masses of the elements, constituting the molecule of the compound are known.
    - Collect the mass ratio of each element.
    - Find the atomic ratio of each element.
      Atomic ratio of an element =
      $$\frac{\text{Mass ratio of the element}}{\text{Relative atomic mass of the element}}$$
    - Change the atomic ratio into whole number to get a simple ratio.
      For example, if a sample of carbon dioxide contains carbon and oxygen in the mass ratio of 3 : 8, then

[Relative atomic mass : C = 12, O = 16]

Element	Mass ratio	Atomic ratio	Simple ratio
C	3	$\frac{3}{12} = \frac{1}{4}$	$\frac{1}{4} \times 4 = 1$
O	8	$\frac{8}{16} = \frac{1}{2}$	$\frac{1}{2} \times 4 = 2$

The formula of carbon dioxide = CO_2

  - **Formulae of simple compounds :** In case of simple molecular compounds, which are made up of two different elements (also called binary compounds), the symbols of two elements are written side by side and their respective valencies are written below their symbols.

Symbol H O
Valency 1 2
Formula : H_2O

  - In case of simple ionic compounds, made up of monatomic ions, the symbol of the metal atom (forming the cation) is written first followed by the symbol of the non-metal atom (forming the anion) and their respective valencies are written below their symbols.

Symbol Al O
Charge 3+ 2–
Formula : Al_2O_3

  - In case of ionic compounds containing polyatomic ions, the formula of the polyatomic ion is written in brackets and the valencies are written below.

Symbol Al (SO_4)
Charge 3+ 2–
Formula : $Al_2(SO_4)_3$

  - Then we must cross-over the valencies of the combining atoms or the charges.

- **Molecular mass and mole concept :**
  - **Molecular mass :** Molecular mass of a substance is the average relative mass of its molecules as compared with that of an atom of C–12 isotope taken as 12. In other words, molecular mass of a substance represents the number of times the molecule of that substance is heavier than 1/12th of the mass of an atom of C–12 isotope.

    Molecular mass =
    $$\frac{\text{Mass of one molecule of a substance}}{\frac{1}{12^{\text{th}}}\text{ mass of one atom of carbon}-12}$$

- 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).
- Like atomic mass, molecular mass of a substance (element or compound) is also expressed in amu or u or it is written without units because it is the relative mass of one molecule of the substance.
- **Formula unit mass :** The term formula unit is used for those substances whose constituent particles are ions.
- The formula unit mass of a substance is a sum of the atomic masses of all atoms in a formula unit of a compound.
  - Formula unit mass is calculated in the same manner as we calculate the molecular mass.
- **Mole concept :** It is more convenient to refer to the quantity of a substance in terms of the number of its molecules or atoms, rather than its mass. So, a new unit mole was introduced.
  - 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 (atoms, molecules or ions) present in 1 mole of any substance is fixed, with a value of 6.022×10^{23}. This is an experimentally obtained value. This number is called the Avogadro constant or Avogadro number (represented by N_0), named in honour of the Italian scientist, Amedeo Avogadro.
  1 mole (of anything) = 6.022×10^{23} (in number).
- Mass of 1 mole of a particular substance is also fixed.
- The mass of 1 mole of a substance is equal to its relative atomic or molecular mass in grams. The atomic mass of an element gives us the mass of one atom of that element in atomic mass units (u).
  1 mole = 6.022×10^{23} number = Relative mass in grams

Thus, a mole is the chemist's counting unit.
No. of moles = n, Given mass = m, Molar mass = M, Given number of particles = N, Avogadro number of particles = N_0

$$n = \frac{m}{M};\ n = \frac{N}{N_0};\ m = M \times n;\ m = M \times \frac{N}{N_0};$$

$$N = \frac{m}{M} \times N_0;\ N = n \times N_0;$$

- Avogadro's law states that equal volumes of all gases under the same conditions of temperature and pressure contain the same number of particles.
- The volume occupied by one mole of a gas is called its molar volume.
- **Mole concept for ionic compounds:** A mole of an ionic compound is that amount of the substance which has mass equal to gram formula unit mass, *i.e.,* formula unit mass of the ionic compound expressed in grams.
- A mole is defined as that amount of the substance which contains Avogadro's number of formula units.
  1 mole = Gram formula unit mass
  = 6.022×10^{23} formula units
- **Percentage composition :** Percentage composition is the percentage by mass of each element in a compound.
  % of an element in a compound

$$= \frac{\text{Mass of that element}}{\text{Mass of the compound}} \times 100$$

Practice Time

OBJECTIVE TYPE QUESTIONS

Multiple Choice Questions (MCQs)

1. If 12 g of carbon burns completely in 40 g oxygen in a closed container, the product has
(a) 44 g of carbon dioxide
(b) 8 g of oxygen
(c) both (a) and (b)
(d) none of these.

2. Elements belonging to different groups of the periodic table are given below. If the element *X* forms a chloride whose formula is 'XCl_2' then element '*X*' belongs to the group whose representative element is
(a) Al (b) Na
(c) Mg (d) Si

3. Identify the incorrect statement.
(a) The building blocks of all matter are atoms.
(b) Atoms are very small. They cannot be seen by the naked eye.
(c) The size of an atom is expressed in metres.
(d) An atom of hydrogen has the radius of the order of 10^{-10} m.

4. The number of atoms in 0.1 mole of a triatomic gas is
(a) 6.026×10^{22} (b) 1.806×10^{23}
(c) 3.6×10^{23} (d) 1.8×10^{22}

5. Which of the following statements is not true about an atom?
(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.

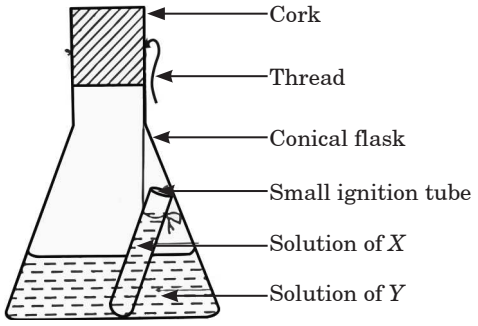
6. Match List-I with List-II and mark the correct option.

List-I	List-II
(P) 0.25 mole oxygen	1. 6.022×10^{23} molecules
(Q) 18 g water	2. 1.505×10^{23} molecules
(R) 46 g Na atom	3. 6.022×10^{23} atoms
(S) 1 mole C atom	4. 12.044×10^{23} atoms

(a) P-1, Q-2, R-3, S-4 (b) P-2, Q-1, R-4, S-3
(c) P-4, Q-1, R-3, S-2 (d) P-1, Q-4, R-3, S-2

7. Which one of the following pair of gases contains the same number of moles?
(a) 16 g of O_2 and 14 g of N_2
(b) 8 g of O_2 and 22 g of CO_2
(c) 28 g of N_2 and 22 g of CO_2
(d) 32 g of O_2 and 32 g of N_2

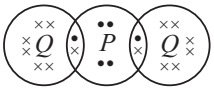
8. Observe the given experimental set-up in which an ignition tube containing solution of *X*, is dipped in a conical flask containing solution of *Y*. Tilt and swirl the flask, so that both the solutions get mixed.



According to the law of conservation of mass, what could be solutions *X* and *Y*?

X	*Y*
(a) Copper sulphate	Sodium carbonate
(b) Barium chloride	Sodium sulphate
(c) Lead nitrate	Sodium chloride
(d) All of these	

9. A compound, PQ_2 has the following arrangement of electrons :
The elements P and Q are respectively



(a) N, Cl (b) Cl, S
(c) O, F (d) Na, F

10. In a science project, Aditya has to make a chart, illustrating various elements and their atomicity.
Aditya decided to show elements of different atomicity by different shapes.

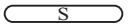
Monoatomic → 
Diatomic → 
Triatomic → 
Tetratomic → 
Polyatomic → 

Pick the element which is shown incorrectly.

(a) 

(b) 

(c) 

(d) 

11. The mass of a molecule of water is
(a) 3×10^{-26} kg (b) 3×10^{-25} kg
(c) 1.5×10^{-26} kg (d) 2.5×10^{-26} kg

12. 52 g of He contains
(a) $4 \times 6.022 \times 10^{23}$ atoms
(b) 13 atoms
(c) $13 \times 6.022 \times 10^{23}$ atoms
(d) 4 atoms

13. How many grams of H_2SO_4 are present in 0.25 mole of H_2SO_4?
(a) 2.45 (b) 24.5
(c) 0.245 (d) 25.4

14. Identify the correct statements.
(i) In a compound such as water, the ratio of the mass of hydrogen to the mass of oxygen is always 8 : 1.
(ii) If 9 g of water is decomposed, 1 g of hydrogen and 8 g of oxygen are always obtained.
(iii) In ammonia, nitrogen and hydrogen are always present in the ratio 3 : 14 by mass.
(iv) Many compounds are composed of two or more elements and each such compound has the same elements in the same proportions.
(a) (i) and (iii) (b) (i), (ii) and (iii)
(c) (ii) and (iv) (d) All of these

15. A sample of pure water, irrespective of its source contains 11.1% hydrogen and 88.9% oxygen. The data supports
(a) law of constant proportions
(b) law of conservation of mass
(c) law of reciprocal proportions
(d) law of multiple proportions.

16. How many atoms in total are present in $CoCl_3 \cdot 6H_2O$?
(a) 17 (b) 22
(c) 8 (d) 18

17. Match the columns by choosing the correct option.

Column I	**Column II**
(A) 52 g of He	(i) 2 moles
(B) 8 g of O_2	(ii) 1 mole
(C) 2 g of H_2	(iii) 0.25 mole
(D) 56 g of N_2	(iv) 13 moles

(a) (A)-(i), (B)-(iv), (C)-(iii), (D)-(ii)
(b) (A)-(iii), (B)-(ii), (C)-(i), (D)-(iv)
(c) (A)-(iv), (B)-(iii), (C)-(ii), (D)-(i)
(d) (A)-(iii), (B)-(i), (C)-(iv), (D)-(ii)

18. Which of the following pair of elements represents a mole ratio of 1 : 1?
(a) 10 g of calcium and 12 g of magnesium
(b) 12 g of magnesium and 6 g of carbon
(c) 12 g of carbon and 20 g of calcium
(d) 20 g of sodium and 20 g of calcium

19. Which of the following has the smallest mass?
(a) 4 g of He
(b) 6.022×10^{23} atoms of He
(c) 1 atom of He
(d) 1 mole atoms of He

20. Which of the following molecules are diatomic?
(i) Nitrogen (ii) Neon (iii) Oxygen
(iv) Sulphur (v) Phosphorus (vi) Ozone
(vii) Fluorine (viii) Hydrogen (ix) Fullerene
(a) (ii), (iv), (v) and (vi)
(b) (iv), (v) and (ix)
(c) (ii) and (vi)
(d) (i), (iii), (vii) and (viii)

21. If three gases *X, Y* and *Z* are arranged in increasing order of their relative molecular mass and the mass of each gas is 10 g at S.T.P state, which gas will contain the least number of molecules and which will contain the most?

(a) *X* least and *Y* maximum
(b) *X* maximum and *Z* least
(c) *Y* maximum and *Z* least
(d) *Y* least and *Z* maximum

22. Which of the following would weigh the highest?

(a) 0.2 mole of sucrose ($C_{12}H_{22}O_{11}$)
(b) 2 moles of CO_2
(c) 2 moles of $CaCO_3$
(d) 10 moles of H_2O

23. Match the columns by choosing the correct option.

Column I (Molecule)	**Column II (Mass ratio of elements)**
(A) Water (H : O)	(i) 14 : 3
(B) Ammonia (N : H)	(ii) 1 : 8
(C) Carbon dioxide (C : O)	(iii) 1 : 1
(D) Sulphur dioxide (S : O)	(iv) 3 : 8

(a) (A) - (ii), (B) - (i), (C) - (iv), (D) - (iii)
(b) (A) - (iii), (B) - (ii), (C) - (i), (D) - (iv)
(c) (A) - (i), (B) - (iv), (C) - (iii), (D) - (ii)
(d) (A) - (iv), (B) - (iii), (C) - (ii), (D) - (i)

24. Arrange the following in the order of increasing mass. (Atomic mass of O = 16 u, Cu = 63 u, N = 14 u)

I. one atom of oxygen
II. one atom of nitrogen
III. 1×10^{-10} mole of oxygen gas
IV. 1×10^{-10} mole of copper

(a) II < I < III < IV (b) I < II < III < IV
(c) III < II < IV < I (d) IV < II < III < I

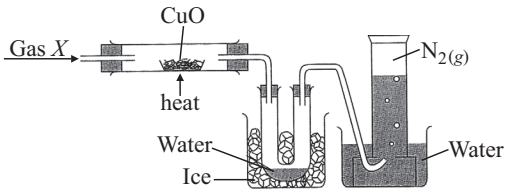
25. The total number of electrons present in 16 g of methane gas is

(a) 96.352×10^{23} (b) 48.176×10^{23}
(c) 60.22×10^{23} (d) 30.110×10^{23}

26. The formula of chloride of a metal *M* is MCl_3, then the formula of the phosphate of metal *M* will be

(a) MPO_4 (b) M_2PO_4
(c) M_3PO_4 (d) $M_2(PO_4)_3$

27. The given figure shows the set-up to study the reaction between gas *X* and copper (II) oxide:



Which of the following statements is/are correct? (Given : Atomic mass of N = 14 u, H = 1 u, O = 16 u, C = 12 u)

I. Gas *X* is a compound of two elements, nitrogen and hydrogen.
II. The number of atoms present in 0.5 mole of N_2 is 6.023×10^{23}.
III. 1 mole of H_2O contains 1 mole of oxygen molecules and 2 moles of hydrogen atoms.

(a) I and II only (b) I and III only
(c) II only (d) III only

28. Which of the following has highest 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

29. 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) multiple proportions
(d) gaseous volumes.

30. Two gaseous samples were analysed. One contained 1.2 g of carbon and 3.2 g of oxygen. The other contained 27.3% carbon and 72.7% oxygen. The experimental data are in accordance with

(a) law of conservation of mass
(b) law of definite proportions
(c) law of reciprocal proportions
(d) law of multiple proportions.

31. Which of the following weighs most?

(a) 2 g atoms of nitrogen
(b) 25 g iron
(c) 2×10^{23} atoms of carbon
(d) 1 mole of SO_2

32. 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) (i) (b) (i) and (iv)
(c) (ii) and (iii) (d) (ii) and (iv)

33. Arrange the following in the increasing order of mass in grams :
(i) One atom of silver
(ii) Two grams atom of nitrogen
(iii) One mole of calcium
(iv) Two grams of sodium
[At. masses : Ag = 108 u, N = 14 u, Ca = 40 u, Na = 23 u]
(a) (i) < (ii) < (iii) < (iv) (b) (iv) < (iii) < (ii) < (i)
(c) (i) < (iv) < (ii) < (iii) (d) (iii) < (ii) < (i) < (iv)

34. 3.42 g of sucrose are dissolved in 18 g of water in a beaker. The number of oxygen atoms in the solution are
(a) 6.68×10^{23} (b) 6.09×10^{22}
(c) 6.022×10^{23} (d) 6.022×10^{21}

35. It was found that 0.10 mole of MSO_4 combines with 9.0 g of water to form the hydrate salt $MSO_4.nH_2O$. What is the value of n?
(a) 2 (b) 3
(c) 4 (d) 5

36. The molecular mass of X is 106. X among the following is
(a) $CaCO_3$ (b) SO_3
(c) Na_2CO_3 (d) NaCl

Case Based MCQs

Case I : Read the passage given below and answer the following questions from 37 to 39.

The knowledge of valencies of various radicals helps us to write the formulae of chemical compounds. The total positive charge on positive ions (cations) is equal to the total negative charge on negative ions (anions) in a molecule. Therefore, in writing the formula of a compound, the positive and negative ions are adjusted in such a way that the total number of positive charges of positive ions (cations) becomes equal to the total number of negative charges of negative ions (anions).
There is another simple method for writing the formulae of ionic compounds. In this method, the valencies (or positive or negative charges) of the ions can be 'crossed over' to give subscripts. The purpose of crossing over of charges is to find the number of ions required to equalise the number of positive and negative charges.

37. Element X has two valencies 5 and 3 and Y has valency 2. The elements X and Y are most likely to be respectively
(a) copper and sulphur
(b) sulphur and iron
(c) phosphorus and fluorine
(d) nitrogen and iron.

38. The formula of the sulphate of an element X is $X_2(SO_4)_3$. The formula of nitride of element X will be
(a) X_2N (b) XN_2
(c) XN (d) X_2N_3

39. The formula of a compound is X_3Y. The valencies of elements X and Y will be respectively
(a) 1 and 3 (b) 3 and 1
(c) 2 and 3 (d) 3 and 2

Case II : Read the passage given below and answer the following questions from 40 to 43.

A mole of an atom is a collection of atoms whose total mass is the number of grams equal to the atomic mass. Since equal number of moles of different elements contain an equal number of atoms it becomes convenient to express the amounts of the elements in terms of moles. A mole represents a definite number of particles *viz*, atoms, molecules, ions or electrons. This definite number is called Avogadro number or Avogadro constant which is equal to 6.022×10^{23}. Hence a mole represents 6.022×10^{23} particles of the substance. One mole of substance represents one gram-formula of the substance. One mole of a gas at standard temperature and pressure occupies 22.4 litres.

40. How many grams of sodium must be taken to get 1 mole of the element ?
(a) 23 g (b) 35.5 g
(c) 63.5 g (d) 46 g

41. What is the mass in grams of a single atom of chlorine? (Atomic mass of chlorine = 35.5)

(a) 6.54×10^{23} g (b) 5.9×10^{-23} g

(c) 0.0025 g (d) 35.5 g

42. How many number of moles are there in 5.75 g of sodium ?

(Atomic mass of sodium = 23)

(a) 0.25 (b) 0.5

(c) 1 (d) 2.5

43. What is the mass in grams of 2.42 mol of zinc? (Atomic mass of Zn = 65.41)

(a) 200 g (b) 25 g

(c) 85 g (d) 158 g

Case III : Read the passage given below and answer the following questions from 44 to 46.

The molecular mass of a substance is the relative mass of its molecule as compared with the mass of a carbon–12 atom taken as 12 units. The molecular mass of a substance indicates the number of times one molecule of a substance is heavier than $\frac{1}{12}$ of C-12 atom. It is equal to the sum of atomic masses of all the atoms present in a molecule. Depending on the number of atoms of same or different elements present in the molecule, it can be monoatomic, diatomic, triatomic, tetratomic or a polyatomic molecule.

44. Which is an example of a polyatomic molecule?

(a) S_8 (b) HNO_3

(c) C_2H_5OH (d) All of these

45. Total number of atoms in 44 g of CO_2 is

(a) 6.02×10^{23} (b) 6.02×10^{24}

(c) 1.806×10^{24} (d) 18.06×10^{22}

46. Carbon dioxide, hydrogen sulphide, calcium chloride and sodium oxide are examples of

(a) triatomic molecules

(b) triatomic and tetratomic molecules

(c) diatomic and triatomic molecules

(d) tetratomic molecules.

Case IV : Read the passage given below and answer the following questions from 47 to 50.

According to Dalton's atomic theory, all matter whether an element, a compound or a mixture is composed of small particles called atoms which can neither be created nor destroyed during a chemical reaction. Dalton's theory provides a simple explanation for the laws of chemical combination. He used his theory to explain law of conservation of masses, law of constant proportions and law of multiple proportions, based on various postulates of the theory. Dalton was the first scientist to use the symbols for the elements in a very specific sense. When he used a symbol for an element he also meant a definite quantity of that element, that is one atom of that element.

47. Which postulate of Dalton's atomic theory is the result of the law of conservation of mass?

(a) Atoms can neither be created nor destroyed.

(b) Each element is composed of extremely small particles called atoms.

(c) All the atoms of a given element are identical.

(d) During chemical combination, atoms of different elements combine in simple ratios.

48. Which postulate of Dalton's atomic theory explains law of definite proportions?

(a) Atoms of an element do not change during a chemical reaction.

(b) An element consists of atoms having fixed mass and the number and kind of atoms in a given compound is fixed.

(c) Different elements have different kind of atoms.

(d) Atoms are of various kinds.

49. "If 100 g of calcium carbonate (whether in the form of marble or chalk) is decomposed, 56 g of calcium oxide and 44 g of carbon dioxide are formed." Which law of chemical combination is illustrated by this statement?

(a) Law of constant proportions

(b) Law of conservation of mass

(c) Law of multiple proportions

(d) Law of conservation of energy

50. When 5 g calcium is burnt in 2 g oxygen, 7 g of calcium oxide is produced. When 5 g of calcium is burnt in 20 g of oxygen, then also 7 g of calcium oxide is produced. Which law of chemical combination is being followed?

(a) Law of conservation of mass

(b) Law of multiple proportions

(c) Law of constant proportions

(d) No law is being followed.

Assertion & Reasoning Based MCQs

For question numbers 51-60, a statement of assertion followed by a statement of reason is given. Choose the correct answer out of the following choices.

(a) Both assertion and reason are true, and reason is correct explanation of the assertion.

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

(c) Assertion is true, but reason is false.

(d) Assertion is false, but reason is true.

51. Assertion : Both 44 g CO_2 and 16 g CH_4 have same number of carbon atoms.

Reason : Both contain 1 g atom of carbon which contains 6.023×10^{23} carbon atoms.

52. Assertion : The molecular mass and formula unit mass of a substance is the sum of atomic masses of all the atoms in the molecular formula or formula unit of a compound respectively.

Reason : The only difference between the molecular mass and formula unit mass is that, former is for molecular compounds (covalent compounds) and latter is for ionic compounds. However, their numerical value is the same.

53. Assertion : 1 amu equals to 1.66×10^{-24} g.

Reason : 1.66×10^{-24} g equals to $\frac{1}{12}$th of mass of a C–12 atom.

54. Assertion : When 10 g of $CaCO_3$ is decomposed, 5.6 g of residue is left and 4.4 g of CO_2 escapes.

Reason : Law of conservation of mass is followed.

55. Assertion : Law of conservation of mass holds good for nuclear reactions.

Reason : It states that mass can neither be created nor destroyed in a chemical reaction.

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

Reason : A chemical compound always contains same elements combined in same fixed proportion by mass.

57. Assertion : The balancing of chemical equations is based on law of conservation of mass.

Reason : Total mass of reactants is equal to total mass of products.

58. 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.

59. Assertion : One atomic mass unit (amu) is mass of an atom equal to exactly one-twelfth the mass of a carbon–12 atom.

Reason : Carbon–12 isotope was selected as standard.

60. 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.

SUBJECTIVE TYPE QUESTIONS

Very Short Answer Type Questions (VSA)

1. How many H atoms are in 0.80 moles of hexane, C_6H_{14}?

2. Formula of the carbonate of a metal M is M_2CO_3. Write the formula of its chloride.

3. Define law of conservation of mass.

4. Define the atomicity of a molecule of an element?

5. Calculate formula mass of sodium carbonate.

6. Calculate the mass of 1.12 moles of sulphur trioxide molecules.

7. Write the formulae for the following :

(a) Calcium phosphate

(b) Magnesium hydroxide

8. Give one example of (i) a polyatomic cation, (ii) a polyatomic anion.

9. What are the valencies of metal and non-metal in the following compounds?

(a) Fe_2O_3

(b) $BaCl_2$

10. Write the chemical formulae of the sulphates of the following cations : K^+, Ba^{2+}, Al^{3+}

Short Answer Type Questions (SA-I)

11. Why does the atomic mass of an element not represent the actual mass of its atom?

12. 8.4 g of sodium bicarbonate on reaction with 20 g of acetic acid liberated 4.4 g of carbon dioxide gas into the atmosphere. What is the mass of the residue left?

13. How many ions are there in 80 g of magnesium oxide?

14. Carbon and oxygen react with each other in the ratio 3 : 8 by mass. What weight of carbon should be used to react completely with 40 g of oxygen?

15. Calculate the number of moles in 12.044×10^{23} helium atoms.

16. How many particles are represented by 0.25 mole of an element?

17. What are the postulates of Dalton's atomic theory. Give at least four points.

18. (a) Define atomic mass unit.

(b) What is meant by saying that "the atomic mass of oxygen is 16"?

19. How many moles are present in 11.5 g of sodium?

20. A piece of copper weighs 0.635 g. How many atoms of copper does it contain?

Short Answer Type Questions (SA-II)

21. An element *X* shows a variable valency of 3 and 5. What are the formulae of the oxide formed by it?

22. Convert into mole.

(a) 12 g of oxygen gas

(b) 20 g of water

(c) 22 g of carbon dioxide

23. What is Avogadro number? How many atoms of each element are present in 6.3 g of nitric acid (HNO_3)?

24. 4.9 g of sulphuric acid contains 0.1 g of hydrogen, 1.6 g of sulphur and rest oxygen. Calculate the mass percentage composition of all the elements of sulphuric acid.

25. Calculate the formula unit masses of ZnO, Na_2O, K_2CO_3. Given atomic masses of Zn = 65 u, Na = 23 u, K = 39 u, C = 12 u and O = 16 u.

26. What mass of silver nitrate will react with 5.85 g of sodium chloride to produce 14.35 g of silver chloride and 8.5 g of sodium nitrate if the law of conservation of mass is true?

27. Calculate the number of aluminium ions present in 0.051 g of aluminium oxide.
(Hint : The mass of an ion is the same as that of an atom of the same element. Atomic mass of Al = 27 u)

28. 10^{22} atoms of an element '*X*' are found to have a mass of 930 mg. Calculate the molar mass of the element '*X*'.

29. A 0.24 g sample of compound of oxygen and boron was found by analysis to contain 0.096 g of boron and 0.144 g of oxygen. Calculate the percentage composition of the compound by weight.

30. The molecular formula of ferric sulphate is $Fe_2(SO_4)_3$. (Atomic mass : Fe = 56 u, S = 32 u, O = 16 u)

(a) Calculate the molar mass of $Fe_2(SO_4)_3$.

(b) How many moles of each element are there in 40 g of ferric sulphate?

31. Calculate the number of atoms of each element present in 122.5 g of $KClO_3$.

32. (a) An element shows variable valencies 4 and 6. Write the formulae of its two oxides.

(b) An element forms an oxide A_2O_5.

(i) What is the valency of the element *A*?

(ii) What will be the formula of the chloride of the element?

33. What is the mass of

(a) 1 mole of nitrogen atoms?

(b) 4 moles of aluminium atoms (atomic mass of aluminium = 27)?

(c) 10 moles of sodium sulphite (Na_2SO_3)?

34. Which amongst the following has more number of atoms?

(i) 11.5 g of sodium or

(ii) 15 g of calcium [Na = 23; Ca = 40]

35. A flask *P* contains 0.5 mole of oxygen gas. Another flask *Q* contains 0.4 mole of ozone gas. Which of the two flasks contains greater number of oxygen atoms?

Long Answer Type Question (LA)

36. Calculate the number of moles of phosphorus (P) atoms in 100 g of phosphorus. If phosphorus is considered to contain P_4 molecules, then how many moles of P_4 molecules are there?

37. Weight of copper oxide obtained by heating 4.32 g of metallic copper with nitric acid was 5.40 g. In another experiment, 2.30 g of copper oxide on reduction yielded 1.84 g of copper. Show that these findings are in accordance with the law of constant proportions.

38. A sample of ammonia (NH_3) weighs 2.00 g. What mass of sulphur dioxide (SO_2) contains the same number of molecules as are in 2.00 g of ammonia?

39. 25.4 g of iodine and 14.2 g of chlorine are made to react completely to yield a mixture of ICl and ICl_3. Calculate the ratio of the moles of ICl and ICl_3.

40. (i) What is the mass of one atom of hydrogen? (atomic mass of hydrogen = 1 u) (ii) How many NH_4^+ ions are present in 1.5 moles of $(NH_4)_3PO_4$?

ANSWERS

OBJECTIVE TYPE QUESTIONS

1. (c) : $C + O_2 \longrightarrow CO_2$

1 mole 1 mole 1 mole

12 g 32 g 44 g

Remaining oxygen = (40 – 32)g = 8 g

2. (c) : Mg has valency of +2. So, it will form $MgCl_2$ while Al, Na and Si will form chlorides $AlCl_3$, NaCl and $SiCl_4$ respectively.

3. (c) : The size of an atom is expressed in nanometres.

1 nm = 10^{-9} m

4. (b) : 1 mole of triatomic gas contains

$3 \times 6.022 \times 10^{23}$ atoms

0.1 mole of triatomic gas contains

$3 \times 6.022 \times 10^{23} \times 0.1 = 1.806 \times 10^{23}$ atoms

5. (a) : Atoms of inert gases exist in monoatomic or independent form.

6. (b)

7. (a) : 16 g O_2 has number of moles $= \frac{16}{32} = \frac{1}{2}$

14 g N_2 has number of moles $= \frac{14}{28} = \frac{1}{2}$

No. of moles are same, so no. of molecules are also same.

8. (d)

9. (c) :

	K	*L*	*M*	Valency
N (at. no. 7):	2	5	–	3
Cl (at. no. 17) :	2	8	7	1

Thus, N and Cl will form compound, NCl_3.

	K	*L*	*M*	Valency
Cl (at. no. 17) :	2	8	7	1
S (at. no. 16) :	2	8	6	2

Thus, S and Cl will form compound, SCl_2.

	K	*L*	*M*	Valency
O (at. no. 8) :	2	6	–	2
F (at. no. 9) :	2	7	–	1

Thus, O and F will form compound, OF_2.

	K	*L*	*M*	Valency
Na (at. no. = 11):	2	8	1	1
F (at. no. = 9) :	2	7	–	1

Thus, Na and F will form compound, NaF.

10. (c) : Phosphorus (P) is a tetratomic element (written as P_4). Hence, it should indicated as $\boxed{P}$.

11. (a) : 6.022×10^{23} molecules have mass = 18 g

1 molecule of water has mass $= \dfrac{18}{6.022 \times 10^{23}}$

$= 3 \times 10^{-23}$ g $= 3 \times 10^{-26}$ kg

12. (c) : No. of atoms = No. of moles × Avogadro's number

$= \dfrac{52}{4} \times 6.022 \times 10^{23}$ atoms

$= 13 \times 6.022 \times 10^{23}$ atoms

13. (b) : Mass = Number of moles × Molar mass

$= 0.25 \times 98 = 24.5$ g

14. (c) : In a compound such as water, the ratio of the mass of hydrogen to the mass of oxygen is always 1 : 8. In ammonia, nitrogen and hydrogen are always present in the ratio 14 : 3 by mass.

15. (a) : Water obtained from any source contains hydrogen and oxygen in the same proportion by mass. Hence, the data supports the law of constant proportions.

16. (b) : Atom of Co present = 1
Atoms of H present = 12
Atoms of O present = 6
Atoms of Cl present = 3
Total no. of atoms = 22

17. (c) : (A) 4 g of He = 1 mole

$\therefore$ 52 g of He $= \dfrac{1}{4} \times 52 = 13$ moles

(B) 32 g of O_2 = 1 mole

$\therefore$ 8 g of $O_2 = \dfrac{1}{32} \times 8 = 0.25$ mole

(C) 2 g H_2 = 1 mole

(D) 28 g of N_2 = 1 mole

$\therefore$ 56 g of $N_2 = \dfrac{1}{28} \times 56 = 2$ moles

18. (b) : 1 mole of Ca = 40 g
1 mole of Na = 23 g
1 mole of Mg = 24 g

($\therefore$ 12 g Mg $= \dfrac{1}{2}$ moles)

1 mole of C = 12 g

($\therefore$ 6 g C $= \dfrac{1}{2}$ moles)

Hence, mole ratio of Mg and C = 1 : 1

19. (c) : 4 g of He = 6.022×10^{23} atoms of He

= 1 mole atoms of He

$\therefore$ Mass of 1 He atom $= \dfrac{4}{6.022 \times 10^{23}} = 0.664 \times 10^{-23}$ g

$= 6.64 \times 10^{-24}$ g

$\therefore$ 1 atom of He has the smallest mass.

20. (d) : (i) Nitrogen – N_2 (ii) Neon – Ne
(iii) Oxygen – O_2 (iv) Sulphur – S_8
(v) Phosphorus – P_4 (vi) Ozone – O_3
(vii) Fluorine – F_2 (viii) Hydrogen – H_2
(ix) Fullerene – C_{60}

21. (b) : Suppose molecular mass of *X*, *Y* and *Z* are *M*, *M* + 1 and *M* + 2 respectively.
Number of moles in *X*, *Y*, *Z* are

$$\frac{10}{M}, \frac{10}{M+1}, \frac{10}{M+2}$$

$$\frac{10}{M} > \frac{10}{M+1} > \frac{10}{M+2}$$

Number of molecules = Number of moles × N_A
X has the maximum number of molecules and *Z* has the least number of molecules.

22. (c) : Weight = Number of moles × Molar mass
0.2 mole of sucrose ($C_{12}H_{22}O_{11}$) = 0.2 × 342 = 68.4 g
2 moles of CO_2 = 2 × 44 = 88 g
2 moles of $CaCO_3$ = 2 × 100 = 200 g
10 moles of H_2O = 10 × 18 = 180 g

23. (a) :

Molecule	**Ratio by mass of elements**		
H_2O	2 : 16	=	1 : 8
NH_3	14 : 3	=	14 : 3
CO_2	12 : 32	=	3 : 8
SO_2	32 : 32	=	1 : 1

24. (a) : (I) Mass of one atom of oxygen $= \dfrac{16}{6.023 \times 10^{23}}$

$= 2.65 \times 10^{-23}$ g

(II) Mass of one atom of nitrogen $= \dfrac{14}{6.023 \times 10^{23}}$

$= 2.32 \times 10^{-23}$ g

(III) Mass of 1×10^{-10} mole of oxygen gas

$= 32 \times 1 \times 10^{-10}$ g $= 3.2 \times 10^{-9}$ g

(IV) Mass of 1×10^{-10} mole of copper

$= 63 \times 1 \times 10^{-10}$ g $= 6.3 \times 10^{-9}$ g

So, the correct order is II < I < III < IV.

25. (c) : Total no. of electrons in 16 g *i.e.*, 1 mole of $CH_4 = 10 \times 6.022 \times 10^{23}$ electrons
$= 60.22 \times 10^{23}$ electrons

26. (a) : Valency of *M* is 3.

Symbol	*M*		PO_4
Valency	3		3
Dividing by common factor	1		1

$\therefore$ The formula of phosphate of metal *M* will be MPO_4.

27. (a) : Gas ***X*** combines with CuO to give N_2 and H_2O. Thus, it contains nitrogen and hydrogen. 1 mole of H_2O contains 1 mole of oxygen atoms and 2 moles of hydrogen atoms.

28. (d) : Number of particles in 8 g of CH_4

$$= \frac{6.022 \times 10^{23}}{16} \times 8 = 3.011 \times 10^{23}$$

No. of particles in 4.4 g of CO_2

$$= \frac{6.022 \times 10^{23}}{44} \times 4.4 = 0.6022 \times 10^{23}$$

No. of particles in 34.2 g of $C_{12}H_{22}O_{11}$

$$= \frac{6.022 \times 10^{23}}{342} \times 34.2 = 0.6022 \times 10^{23}$$

No. of particles in 2 g of H_2

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

29. (b) : Law of constant proportions states that a chemical compound is always made up of the same elements combined together in the same fixed proportion by mass.

30. (b) : Percentage of carbon in sample 1

$$= \frac{1.2}{1.2+3.2} \times 100 = 27.3\%$$

Percentage of oxygen in sample 1

$$= \frac{3.2}{1.2+3.2} \times 100 = 72.7\%$$

The two samples have same percentage composition which is in accordance with the law of definite proportions.

31. (d) : (a) 2 gram atom of nitrogen $= 2 \times 14 = 28$ g
(b) 25 g of iron
(c) 6.022×10^{23} atoms of carbon weigh = 12 g
$\therefore$ 2×10^{23} atoms of carbon will weigh

$$= \frac{12}{6.022 \times 10^{23}} \times 2 \times 10^{23} \approx 4 \text{ g}$$

(d) 1 mole of $SO_2 = 64$ g

32. (d) : (i) 1 mole of water = 18 g
2 moles of water $= 2 \times 18$ g $= 36$ g
(ii) 20 moles of water $= 18 \times 20 = 360$ g
(iii) 6.022×10^{23} molecules of water = 1 mole = 18 g
(iv) 1 mole of water $= 6.022 \times 10^{23}$ molecules
6.022×10^{23} molecules = 1 mole

$$1.2044 \times 10^{25} \text{ molecules} = \frac{1}{6.022 \times 10^{23}} \times 1.2044 \times 10^{25}$$
$= 20$ moles

$= 20 \times 18 = 360$ g

33. (c) : (i) 6.022×10^{23} atoms of silver weigh = 108 g

$$\therefore \text{ 1 atom of silver weighs} = \frac{108}{6.022 \times 10^{23}} = 1.79 \times 10^{-22} \text{ g}$$

(ii) 1 g atom of N = 14 g
2 g atom of N $= 2 \times 14 = 28$ g
(iii) Mass of 1 mole of calcium = 40 g
(iv) Mass of sodium = 2 g
Hence, increasing order of mass in gram is :
(i) < (iv) < (ii) < (iii).

34. (a) : Number of moles of sucrose $= \frac{3.42}{342} = 0.01$ mol

1 mol of sucrose $(C_{12}H_{22}O_{11}) = 11 \times N_A$ atoms of O
0.01 mol of $C_{12}H_{22}O_{11} = 0.01 \times 11 \times N_A$
$= 0.11 \times N_A$ atoms of O

Number of moles of water $= \frac{18}{18} = 1$ mol

1 mol of water contains $= 1 \times N_A$ atoms of O
Total number of oxygen atoms $= 0.11\ N_A + 1.0\ N_A$
$= 1.11\ N_A$
Number of oxygen atoms in solution $= 1.11\ N_A$
$= 1.11 \times 6.022 \times 10^{23} = 6.68 \times 10^{23}$

35. (d) : 18 g of $H_2O = 1$ mole
$\therefore$ 9 g of $H_2O = 0.5$ mole
0.1 mole of MSO_4 combines with 0.5 mole of H_2O
$\therefore$ 1 mole of MSO_4 will combine with

$$= \frac{0.5}{0.1} \times 1 \text{ mole of } H_2O = 5 \text{ moles of } H_2O$$

36. (c) : Mass of $CaCO_3 = 40 + 12 + 3 \times 16 = 100$ g/mol
Mass of $SO_3 = 32 + 16 \times 3 = 80$ g/mol
Mass of $Na_2CO_3 = 2 \times 23 + 12 + 16 \times 3 = 46 + 12 + 48$
$= 106$ g/mol
Mass of NaCl $= 23 + 35.5 = 58.5$ g/mol

37. (d) : N has valencies 3 and 5; Fe has valency 2.

38. (c) : According to the given formula of sulphate, ***X*** is trivalent and nitride, N^{3-} is also trivalent. So formula of nitride of ***X*** will be ***X***N.

39. (a) : According to the given formula, valency of ***X*** is 1 and valency of ***Y*** is 3.

40. (a) : 1 mole of atom = gram atomic mass of atom
$\therefore$ 1 mole of sodium = 23 g of sodium

41. (b) : Mass of 6.023×10^{23} atoms of chlorine = 35.5 g

Mass of 1 atom of chlorine $= \frac{35.5}{6.023 \times 10^{23}}$

$= 5.9 \times 10^{-23}$ g

42. (a) : No. of moles $= \frac{\text{Given mass in grams}}{\text{Molar mass}} = \frac{5.75}{23} = 0.25$

43. (d) : Mass in grams = No. of moles × molar mass
$= 2.42 \times 65.41 = 158.2 \text{ g} \approx 158 \text{ g}$

44. (d) : All of these are polyatomic molecules.

45. (c) : Total no. of atoms in 44 g *i.e.*, 1 mole of CO_2
$= 3 \times 6.022 \times 10^{23} = 1.806 \times 10^{24}$

46. (a) : Carbon dioxide (CO_2), hydrogen sulphide (H_2S), calcium chloride ($CaCl_2$) and sodium oxide (Na_2O) are the examples of triatomic molecules because all these contains 3 atoms in their molecules.

47. (a) : Since an atom cannot be created or destroyed, the number of various types of atoms in the products of a chemical reaction is the same as the number of all the atoms in the reactants.

48. (b) : According to Dalton's atomic theory every element has atoms having same mass and that, atoms of different elements combine to form compounds and the number and kind of atoms of each element in a compound is fixed. Since number of atoms, kind of atoms and the mass of atoms of each element in a given compound are fixed, a compound will always have the same elements combined in the same proportion by mass.

49. (b) : According to law of conservation of mass, total mass of reactants = total mass of products. Total mass of $CaCO_3$ = 100 g (mass of reactant).
Total mass of products = mass of CaO + mass of CO_2
= 56 g + 44 g = 100 g
$\therefore$ Total mass of reactants = Total mass of products

50. (c) : A pure chemical compound always contains the same elements combined together in the same proportion by mass.

51. (a) : 44 g of CO_2 = 1 mole = 1 g atom of C
16 g of CH_4 = 1 mole = 1 g atom of C
1 g atom of C = 12 g of C
12 g of C contains 6.023×10^{23} carbon atoms.

52. (b)

53. (b) : $\frac{1}{12}$ th of the mass of 1 atom of C–12 is 1.66×10^{-24} g and atomic mass unit (1 amu) = 1.66×10^{-24} g.

54. (a)

55. (d) : Law of conservation of mass does not hold good for nuclear reactions due to mass defect.

56. (a)

57. (a) : According to law of conservation of mass, in a chemical reaction total mass of the products is equal to the total mass of the reactants.

58. (c) : Both, 1 mole of SO_2 and 1 mole of O_2 contain same number of molecules *i.e.*, Avogadro's number of molecules.

59. (a) : For universally accepted atomic mass unit in 1961, C–12 was selected as standard. However,the new symbol used is 'u'(unified mass) in place of amu.

60. (a)

SUBJECTIVE TYPE QUESTIONS

1. Number of hexane molecules
= Number of moles × 6.022×10^{23}
= $0.8 \times 6.022 \times 10^{23} = 4.81 \times 10^{23}$
One hexane molecule contains 14 H atoms
Hence, total number of H atoms in 0.8 moles
$= 4.8 \times 10^{23} \times 14$
$= 67.2 \times 10^{23} = 6.72 \times 10^{24}$ atoms

2. In *M*Cl valency of *M* is 1.

3. Law of conservation of mass states that mass can neither be created nor be destroyed in a chemical reaction.

4. The number of atoms present in one molecule of an element is called its atomicity.

5. The formula of sodium carbonate is Na_2CO_3.
$\therefore$ Formula mass of sodium carbonate
$= 23 \times 2 + 12 + 3 \times 16 = 46 + 12 + 48 = 106$

6. Relative molecular mass of $SO_3 = 1(32) + 3(16) = 80$
Molar mass of SO_3 = 80 g/mol
Mass of 1.12 moles of SO_3
= Number of moles × Molar mass
= 1.12 mol × 80 g/mol = 89.6 g

7. (a) Calcium phosphate

Symbol	Ca	PO_4
Charge	$2+$	$3-$

Formula: $Ca_3(PO_4)_2$

(b) Magnesium hydroxide

Symbol	Mg	OH
Charge	$2+$	$1-$

Formula: $Mg(OH)_2$

8. (i) NH_4^+, (ii) SO_4^{2-}

9.

		Metal	Non-metal
(a)	Fe_2O_3	Fe(3)	O(2)
(b)	$BaCl_2$	Ba(2)	Cl(1)

10. K_2SO_4, $BaSO_4$, $Al_2(SO_4)_3$

11. Atomic mass of an element is the mass of its atom on the atomic scale, on the other hand, the actual mass of an atom is obtained by dividing the atomic mass by Avogadro's number.

12. Total mass of reactants = 8.4 g + 20 g = 28.4 g
Total mass of reactants = Total mass of products
$28.4 = 4.4 + x$ (mass of residue left)
$28.4 - 4.4 = x \Rightarrow x = 24$ g

13. Number of moles of magnesium oxide

$$= \frac{\text{Mass of magnesium oxide}}{\text{Molar mass of magnesium oxide}} = \frac{80}{40} = 2$$

$MgO \longrightarrow Mg^{2+} + O^{2-}$

From the equation, we can see that 1 mol of MgO contains 1 mol of Mg^{2+} ions and 1 mol of O^{2-} ions. 2.0 mol of MgO will contain 2.0 mol of Mg^{2+} ions and 2.0 mol of O^{2-} ions. Hence, 2.0 mol of MgO contains 4.0 mol of ions.
Number of ions = $4 \times 6.022 \times 10^{23} = 2.4088 \times 10^{24}$

14. Ratio by mass C : O
3 8
? 40

$$\text{Mass of carbon required} = \frac{3 \times 40}{8} = 15\,\text{g}$$

15. Given : $N = 12.044 \times 10^{23}$ (of Helium)
$N_0 = 6.022 \times 10^{23}$, $n = ?$
We know that,

$$\text{No. of moles } (n) = \frac{\text{No. of particles } (N)}{\text{Avogadro's number } (N_0)} \quad \text{or} \quad n = \frac{N}{N_0}$$

$$\therefore \quad n = \frac{12.044 \times 10^{23}}{6.022 \times 10^{23}} = 2$$

Thus, number of moles in 12.044×10^{23} helium atoms is 2.

16. 1 mole of an element contains 6.022×10^{23} particles
0.25 mole of an element contains = $6.022 \times 10^{23} \times 0.25$
$= 1.5 \times 10^{23}$ particles

17. The postulates of Dalton's atomic theory may be stated as follows :
(i) All matter is made of very tiny particles called atoms.
(ii) Atoms are indivisible particles, which cannot be created or destroyed in a chemical reaction.
(iii) Atoms of a given element are identical in mass and chemical properties.
(iv) Atoms of different elements have different masses and chemical properties.
(v) Atoms combine in the ratio of simple whole number to form compounds.
(vi) The relative number and kinds of atoms are constant in a given compound.

18. (a) The atomic mass unit is defined as $\frac{1}{12}$ th of the mass of one atom of a carbon (C–12) isotope.
(b) It means that one atom of oxygen is 16 times heavier than $\frac{1}{12}$ th of the mass of a ^{12}C atom.

19. No. of moles in 11.5 g of sodium = $\frac{\text{Given mass (in g)}}{\text{Molar mass}}$

$$= \frac{11.5}{23} = 0.5$$

20. Gram atomic mass of copper = 63.5 g

$$\text{Number of moles in 0.635 g of copper} = \frac{0.635}{63.5} = 0.01 \text{ moles}$$

Number of copper atoms in one mole = 6.022×10^{23}
Number of copper atoms in 0.01 moles
$= 0.01 \times 6.022 \times 10^{23} = 6.022 \times 10^{21}$

21. (i) Formula of oxide when X has valency = 3

Symbol	X	O
Valency	3	2

Formula = X_2O_3

(ii) Formula of the oxide when X has valency = 5

Symbol	X	O
Valency	5	2

Formula = X_2O_5

22. (a) Molar mass of $O_2 = 2 \times 16 = 32$ g
$\therefore$ Number of moles in 12 g of O_2

$$= \frac{\text{Given mass}}{\text{Molar mass}} = \frac{12}{32} = 0.375 \text{ mole}$$

(b) Molar mass of $H_2O = 2 \times 1 + 16 = 18$ g

$$\therefore \text{ Number of moles in 20 g of } H_2O = \frac{20}{18} = 1.11 \text{ moles}$$

(c) Molar mass of $CO_2 = 12 + 16 \times 2 = 12 + 32 = 44$ g

$$\therefore \text{ Number of moles in 22 g of } CO_2 = \frac{22}{44} = 0.5 \text{ mole}$$

23. The number of particles (atoms, molecules or ions) present in 1 mole of any substance is fixed and is called Avogadro number (N_A). Its value is 6.022×10^{23}.

Molar mass of nitric acid (HNO_3) = $1 + 14 + 3 \times 16$
$= 63 \text{ g mol}^{-1}$

63 g of HNO_3 contains = $1 \times 6.022 \times 10^{23}$ atoms of H

$\therefore$ 6.3 g of HNO_3 contains = $\frac{1 \times 6.022 \times 10^{23}}{63} \times 6.3$
$= 6.022 \times 10^{22}$ atoms of H

63 g of HNO_3 contains = $1 \times 6022 \times 10^{23}$ atoms of N

$\therefore$ 6.3 g of HNO_3 contains = $\frac{1 \times 6.022 \times 10^{23}}{63} \times 6.3$
$= 6.022 \times 10^{22}$ atoms of N

63 g of HNO_3 contains = $3 \times 6.022 \times 10^{23}$ atoms of O

$\therefore$ 6.3 g of HNO_3 contains = $\frac{3 \times 6.022 \times 10^{23} \times 6.3}{63}$
$= 1.8066 \times 10^{23}$ atoms of O

24. Mass of sulphuric acid (W) = 4.9 g
Mass of hydrogen (w_1) = 0.1 g
Mass of sulphur (w_2) = 1.6 g

$\therefore$ Mass percentage of hydrogen $= \frac{w_1}{W} \times 100 = \frac{0.1}{4.9} \times 100$
$= 2.04\%$

Mass percentage of sulphur $= \frac{w_2}{W} \times 100 = \frac{1.6}{4.9} \times 100 = 32.65\%$

$\therefore$ Mass percentage of oxygen = $100 - (2.04 + 32.65)$
$= 65.31\%$

25. Formula unit mass of ZnO = atomic mass of Zn + atomic mass of O = (65 + 16) u = 81 u

Formula unit mass of Na_2O = 2 × atomic mass of Na + atomic mass of O = (2 × 23 + 16) u = 62 u

Formula unit mass of K_2CO_3 = 2 × atomic mass of K + atomic mass of C + 3 × atomic mass of O = (2 × 39 + 12 + 3 × 16) u = (78 + 12 + 48) u = 138 u

26. The reaction is

Silver nitrate + Sodium chloride → Silver chloride + Sodium nitrate

If law of conservation of mass is true,

Total mass of reactants = Total mass of products

i.e., Mass of $AgNO_3$ + Mass of NaCl = Mass of AgCl + Mass of $NaNO_3$

We have : Mass of NaCl = 5.85 g, Mass of AgCl = 14.35 g, Mass of $NaNO_3$ = 8.5 g

Substituting these values in the above equation, we get

Mass of $AgNO_3$ + 5.85 g = 14.35 g + 8.5 g

Mass of $AgNO_3$ = (14.35 + 8.5) – 5.85 g
= 22.85 – 5.85 = 17.0 g.

27. Molar mass of Al_2O_3 = $2 \times 27 + 3 \times 16$
$= 54 + 48 = 102$ g

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

$\therefore$ 0.051 g of Al_2O_3 contains = $\frac{2 \times 6.022 \times 10^{23}}{102} \times 0.051$
$= 6.022 \times 10^{20}$ Al^{3+} ions

28. Molar mass of an element is the mass of Avogadro's number of atoms.

10^{22} atoms of the element have mass
$= 930 \text{ mg} = \frac{930}{1000} \text{ g} = 0.930 \text{ g}$

$\therefore$ 6.022×10^{23} atoms will have mass
$= \frac{0.930}{10^{22}} \times 6.022 \times 10^{23} \text{ g} = 56.0 \text{ g}$

$\therefore$ Molar mass of the element = 56 g mol^{-1}

Alternatively, $n = \frac{N}{N_0}$

Also, $n = \frac{m}{M}$

or $M = \frac{m}{n} = m \times \frac{N_0}{N} = 0.930 \text{ g} \times \frac{6.022 \times 10^{23} \text{ atoms mol}^{-1}}{10^{22} \text{ atoms}}$
$= 56.0 \text{ g mol}^{-1}$

29. We know that, % of any element in a compound
$= \frac{\text{Mass of element}}{\text{Mass of compound}} \times 100$

% of boron = $\frac{0.096}{0.24} \times 100 = 40\%$

% of oxygen = $\frac{0.144}{0.24} \times 100 = 60\%$

30. (a) The molar mass of $Fe_2(SO_4)_3$
$= 2 \times 56 + 3 \times 32 + 12 \times 16 = 400$

(b) No. of moles = $\frac{\text{Given mass}}{\text{Molar mass}} = \frac{40}{400} = 0.1$

1 mole of ferric sulphate contains 2 moles of iron

0.1 mole of ferric sulphate contains = 2×0.1
$= 0.2$ moles of Fe

1 mole of ferric sulphate contains 3 moles of sulphur

0.1 mole of ferric sulphate contains = 3×0.1
$= 0.3$ moles of S

1 mole of ferric sulphate contains 12 moles of oxygen

0.1 mole of ferric sulphate contains = 12×0.1
$= 1.2$ moles of O

31. No. of moles of $KClO_3 = \frac{122.5}{122.5} = 1$

(mol. wt. of $KClO_3$ = 122.5)

From the formula $KClO_3$, we know that 1 mole of $KClO_3$ contains 1 mole of K atoms, 1 mole of Cl atoms and 3 moles of O atoms.

$\therefore$ No. of atoms of K = 6.022×10^{23}

No. of atoms of Cl = 6.022×10^{23}

No. of atoms of O = $3 \times 6.022 \times 10^{23} = 18.066 \times 10^{23}$

32. (a) Let the element be represented by the symbol *E*.

Formula of oxide in which valency of *E* = 4 are E_2O_4 or EO_2

Formula of oxide in which valency of *E* = 6 are E_2O_6 or EO_3

(b) Formula of oxide of the element = A_2O_5

(i) The valency of the element *A* in the oxide = 5

(ii) The formula of the chloride of the element *A* = ACl_5

33. (a) Mass of 1 mole nitrogen atoms

= number of moles × atomic mass = 1 × 14 = 14 g

(b) Mass of 4 moles aluminium atoms = 4 × atomic mass

= 4 × 27 = 108 g

(c) Mass of $Na_2SO_3 = 2 \times 23 + 32 + 16 \times 3$

$= 46 + 32 + 48 = 126$ g

1 mole of Na_2SO_3 = 126 g

$\therefore$ 10 moles of $Na_2SO_3 = (10 \times 126)$ g = 1260 g

34. We know that equal number of moles of different elements contain equal number of atoms. Thus, we shall convert masses of sodium and calcium to find which has more number of moles.

(i) For sodium

Gram atomic mass of sodium = 23 g

Mass of sodium = 11.5 g

$\therefore$ No. of moles of sodium = $\frac{\text{Mass of sodium in grams}}{\text{Gram atomic mass of sodium}}$

$= \frac{11.5\text{ g}}{23\text{ g}} = 0.5$ mole

(ii) For calcium

Gram atomic mass of calcium = 40 g

Mass of calcium = 15 g

$\therefore$ No. of moles of calcium

$= \frac{\text{Mass of calcium in grams}}{\text{Gram atomic mass of calcium}} = \frac{15\text{ g}}{40\text{ g}} = 0.375$ moles

Therefore, sodium has more number of atoms than calcium.

35. In flask *P* :

1 molecule of oxygen (O_2) = 2 atoms of oxygen

1 mole of oxygen gas = 6.022×10^{23} molecules

0.5 mole of oxygen gas = $6.022 \times 10^{23} \times 0.5$ molecules

$= 6.022 \times 10^{23} \times 0.5 \times 2$ atoms = 6.022×10^{23} atoms

In flask *Q* :

1 molecule of ozone (O_3) = 3 atoms of oxygen

1 mole of ozone gas = 6.022×10^{23} molecules

0.4 mole of ozone gas = $6.022 \times 10^{23} \times 0.4$ molecules

$= 6.022 \times 10^{23} \times 0.4 \times 3$ atoms = 7.23×10^{23} atoms

$\therefore$ Flask *Q* has a greater number of oxygen atoms as compared to flask *P*.

36. Mass of phosphorus = 100 g

Atomic mass of P = 31.0 u

So, molar mass of P atom = 31 g

Therefore,

Number of moles of P atoms in 100 g of phosphorus

$= \frac{100}{31.0} = 3.22$ mol

If phosphorus is considered to be present as P_4 molecules, then

No. of moles of P_4 molecules in 100 g of phosphorus

$= \frac{\text{No. of moles of P atoms in 100 g of phosphorus}}{4}$

$= \frac{3.22\text{ mol}}{4} = 0.805$ mol

Thus, 100 g of phosphorus contains 3.22 moles of P atoms and 0.805 moles of P_4 molecules.

37. Experiment I

Weight of copper = 4.32 g

Weight of copper oxide = 5.40 g

$\therefore$ Weight of oxygen = Weight of copper oxide – Weight of copper

= 5.40 – 4.32 = 1.08 g

Experiment II

Weight of copper = 1.84 g

Weight of copper oxide = 2.30 g

$\therefore$ Weight of oxygen = Weight of copper oxide – Weight of copper

= 2.30 – 1.84 = 0.46 g

Now, from experiment I	from experiment II
Ratio of copper and oxygen	Ratio of copper and oxygen
$\frac{\text{Mass of copper}}{\text{Mass of oxygen}} = \frac{4.32}{1.08} = \frac{4}{1}$	$\frac{\text{Mass of copper}}{\text{Mass of oxygen}} = \frac{1.84}{0.46} = \frac{4}{1}$

As the ratio of copper and oxygen (by mass) is same in the two experiments, law of constant proportions is verified.

38. Mass of ammonia = 2.00 g

Molar mass of ammonia (NH_3) = 1×14 +3 × 1

= 17 g mol^{-1}

So, amount of ammonia $= \dfrac{\text{Mass of ammonia}}{\text{Molar mass of ammonia}}$

$= \dfrac{2.00\text{ g}}{17\text{ g mol}^{-1}} = \dfrac{2.00}{17}\text{ mol}$

Similarly, from the given data,

Amount of sulphur dioxide (SO_2)

$= \dfrac{\text{Mass of sulphur dioxide } (m)}{\text{Molar mass of sulphur dioxide}}$

Molar mass of sulphur dioxide (SO_2)

$= 1 \times 32 + 2 \times 16 = 64$

So, amount of $SO_2 = \dfrac{m}{64}$

According to the mole concept, equal number of moles of all substances contain the same number of molecules. So,

$$\frac{m}{64} = \frac{2.00}{17}\text{ mol}$$

$$m = \frac{2.00}{17}\text{ mol} \times 64\text{ g mol}^{-1} = 7.53\text{ g}$$

39. According to given data

$$\underset{1\text{ mol}}{I_2} + \underset{2\text{ mol}}{2Cl_2} \rightarrow \underset{1\text{ mol}}{ICl} + \underset{1\text{ mol}}{ICl_3}$$

1 mol of I_2 = 254 g

Moles of I_2 available $= \dfrac{25.4}{254} = 0.1$ mol

Moles of Cl_2 available $= \dfrac{14.2}{71} = 0.2$ mol

1 mol of I_2 yields = 1 mole ICl

$\therefore$ 0.1 mol of I_2 yields = 0.1 mol ICl

And 1 mol of I_2 yields = 1 mol ICl_3

$\therefore$ 0.1 mol of I_2 yields = 0.1 mol ICl_3

$\therefore$ Ratio of the moles of ICl and $ICl_3 = \dfrac{0.1}{0.1} = 1:1$

40. (i) Mass of 6.022×10^{23} hydrogen atoms = 1 g

Mass of 1 hydrogen atom $= \dfrac{1\text{g}}{6.022 \times 10^{23}}$

$= 1.66 \times 10^{-24}$ g $= 1.66 \times 10^{-27}$ kg

(ii) Number of $(NH_4)_3PO_4$ molecules= $1.5 \times 6.022 \times 10^{23}$

One molecule of $(NH_4)_3PO_4$ contains 3 NH_4^+ ions. Hence, total number of NH_4^+ ions

$= 3 \times 1.5 \times 6.022 \times 10^{23} = 27.1 \times 10^{23}$

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