CHAPTER 2

Some Basic Concepts of Chemistry

MATTER

A substance which occupies space, possesses mass and can be felt by any one or more of the five senses is called matter.

Physical Classification of Matter

It is based on physical state under ordinary conditions of temperature and pressure.

(*a*) **Solid:** A substance is said to be solid if it possesses a definite volume and a definite shape, e.g. sugar, iron, gold, wood etc.

(*b*) **Liquid:** A substance is said to be liquid if it possesses a definite volume but not definite shape. They take up the shape of the container, e.g. water, milk, oil, mercury, alcohol etc.

(*c*) **Gas:** A substance is said to be gas if it neither possesses a definite volume nor a definite shape. This is because they fill up the whole container, e.g. Hydrogen (H_2), Oxygen (O_2), Carbon dioxide (CO_2) etc.

Chemical Classification of Matter

(*a*) **Pure Substance:** A material containing only one type of substance. Pure Substance can not be separated into simpler substance by physical method.

e.g.: Element = Na, Mg, Ca .... etc.

Compound = HCl, H_2O, CO_2, HNO_3 ....etc.

Pure substance is classified into two types:

(I) Element (II) Compound

(I) **Element:** The pure substance containing only one kind of atoms. It is classified into 3 types

(i) Metal → Zn, Cu, Hg, Ac, Sn, Pb etc.

(ii) Non-metal → N_2, O_2, Cl_2, Br_2, F_2, P_4, S_8 etc.

(iii) Metalloids → B, Si, As, Te etc.

(II) **Compound:** It is defined as pure substance containing more than one kind of elements or atoms which are combined together in a fixed proportion by weight and which can be decomposed into simpler substance by the suitable chemical method. The properties of a compound are completely different from those of its constituent element, e.g. HCl, H_2O, H_2SO_4, $HClO_4$, HNO_3 etc.

(*b*) **Mixture:** A material which contain more than one type of substances and which are mixed in any ratio by weight is called as mixture. The property of the mixture is the property of its components. The mixture can be separated by simple physical method.

Classification of Mixture

(*i*) **Homogeneous mixture:** The mixture, in which all the components are present uniformly is called as homogeneous mixture. Components of mixture are present in a single phase, e.g. Water + Salt, Water + Sugar, Water + alcohol.

Homogeneous substances are of two types:

(*a*) **Pure substances:** Substances which have definite and constant chemical composition are known as pure substances. For example, all elements and compounds are pure substances.

(*b*) **Solutions:** A homogenous mixture of two or more pure substances is known as a solution. For example, air, a mixture of NaCl and water, alcohol and water, etc. A solution does not have a definite composition.

(*ii*) **Heterogeneous mixture:** The mixture in which all the components are present non-uniformly, e.g. Water + Sand, Water + Oil, blood, petrol etc.

ATOMS AND MOLECULES

Atom: The term atom was introduced by Dalton. Atom is the smallest particle of matter that takes part in a chemical reaction. Atom is also defined as the smallest particle of an element that retains all the properties of an element.

Molecule: The term molecule was introduced by Avogadro. Molecule is the smallest particle of matter that exists independently and is formed by the combination of atoms. Molecule is also defined as the smallest particle of matter that can exist and retains all the properties of that substance.

Physical and Chemical Properties:

(*a*) **Physical Property:** The property which can be measured without changing the chemical composition of the substance is known as physical property like mass, volume, density, refractive index etc.

(*b*) **Chemical Property:** The property which can be evaluated at the cost of matter itself is known as chemical property. For example combustible nature of hydrogen gas can be verified by burning of hydrogen. The sweet taste of sugar by consuming it.

Physical Quantity and their Measurements in Chemistry

Physical Quantities

All quantities that can be measured are called physical quantities. eg. time, length, mass, force, work done, etc.

Fundamental Quantities

A set of physical quantities which are completely independent of each other but all other physical quantities can be expressed in terms of these physical quantities is called set of Fundamental Quantities. Fundamental units are those units which can neither be derived from one another nor they can be further resolved into any other units.

The Fundamental Quantities that are currently being accepted by the scientific community are mass, time, length, current, temperature, luminous intensity and amount of substance.

International System (SI) of Units

Table: SI base quantities and their units

S. No.	Physical quantity	unit	Symbol
1	Length	metre	m
2	Mass	kilogram	kg
3	Time	second	s
4	Temperature	kelvin	K
5	Electric current	ampere	A
6	Luminous Intensity	candela	cd
7	Amount of substance	mole	mol

SCIENTIFIC NOTATION

If a number P can be expressed as

$$P = A \times 10^x$$

where $1 \le A < 10$, this is called Scientific Notation and x is called order of magnitude of the number.

SI Prefixes: The magnitudes of physical quantities vary over a wide range. The mass of an electron is 9.1×10^{-31} kg and that of our earth is about 6×10^{24} kg. Standard prefixes for certain power of 10. Table shows these prefixes:

Power of 10	Prefix	Symbol
12	tera	T
9	giga	G
6	mega	M
3	kilo	k
2	hecto	h
1	deca	da
–1	deci	d
–2	centi	c
–3	milli	m
–6	micro	µ
–9	nano	n
–12	pico	p
–15	femto	f

SIGNIFICANT FIGURES OR DIGITS

The significant figures (SF) in a measurement are the figures or digits that are known with certainty plus one that is uncertain.

Larger the number of significant figures obtained in a measurement, greater is its accuracy and vice versa.

1. **Rules to find out the number of significant figures:**

   I Rule: All the non-zero digits are significant e.g. 1984 has 4 SF.

   II Rule: All the zeros between two non-zero digits are significant, e.g. 10806 has 5 SF.

   III Rule: All the zeros to the left of first non-zero digit are not significant, e.g.00108 has 3 SF.

   IV Rule: If the number is less than 1, zeros on the right of the decimal point but to the left of the first non-zero digit are not significant, e.g. 0.002308 has 4 SF.

   V Rule: The trailing zeros (zeros to the right of the last non-zero digit) in a number with a decimal point are significant, e.g. 01.080 has 4 SF.

   VI Rule: The trailing zeros in a number without a decimal point are not significant e.g. 010100 has 3 SF.

   VII Rule: When the number is expressed in exponential form, the exponential term does not affect the number of S.F. For example in $x = 12.3 = 1.23 \times 10^1 = .123 \times 10^2 = 0.0123 \times 10^3 = 123 \times 10^{-1}$, each term has 3 SF only. (**Note:** It has 3 significant figure in each expression.)

2. **Rules for arithmetical operations with significant figures:**

   I Rule: In addition or subtraction the number of decimal places in the result should be equal to the number of decimal places of that term in the operation which contain lesser number of decimal places, e.g. 12.587 – 12.5 = 0.087 = 0.1 ($\because$ second term contain lesser i.e. one decimal place)

   II Rule: In multiplication or division, the number of SF in the product or quotient is same as the smallest number of SF in any of the factors, e.g. $5.0 \times 0.125 = 0.625 = 0.62$

   To avoid the confusion regarding the trailing zeros of the numbers without the decimal point the best way is to report every measurement in scientific notation (in the power of 10). In this notation every number is expressed in the form $a \times 10^b$, where a is the base number between 1 and 10 and b is any positive or negative exponent of 10. The base number a is written in decimal form with the decimal after the first digit. While counting the number of SF only base number is considered (Rule VII).

❖ The change in the unit of measurement of a quantity does not affect the number of SF. For example in 2.308 cm = 23.08 mm = 0.02308 m = 23080 µm each term has 4 SF.

ACCURACY AND PRECISION

The accuracy of a measurement is a measure of how close the measured value is to the true value of the quantity. Precision tells us to what resolution or limit the quantity is measured.

Illustration: Assertion: If the true value for a result is 2.00 g and a student 'A' takes two measurements and reports the results as 1.95 g and 1.93 g. These values are precise as they are close to each other but are not accurate.

Reason: Precision refers to the closeness of various measurements for the same quantity. Whereas, accuracy is the agreement of a particular value to the true value of the result.

In the light of the above statement, choose the correct answer from the options given below:

(*a*) Both Assertion and Reason are true and Reason is correct explanation of Assertion.

(*b*) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion.

(*c*) Assertion is true but Reason is false.

(*d*) Assertion is false but Reason is true.

Sol. (*a*)

Illustration: Assertion: 100 has only one significant figure, but 100.0 has three significant figures and 100.0 has four significant figures.

Reason: Zeros at the end or right of a number are significant provided they are on the right side of the decimal point.

In the light of the above statement, choose the correct answer from the options given below:

(*a*) Both Assertion and Reason are true and Reason is correct explanation of Assertion.

(*b*) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion.

(*c*) Assertion is true but Reason is false.

(*d*) Assertion is false but Reason is true.

Sol. (*a*)

Illustration: Assertion: All the zeros to the left of first non-zero digit are not significant.

Reason: Zeros at the end or right of a non-zero digit are significant provided they are on the right side of the decimal point.

In the light of the above statement, choose the correct answer from the options given below:

(*a*) Both Assertion and Reason are true and Reason is correct explanation of Assertion.

(*b*) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion.

(*c*) Assertion is true but Reason is false.

(*d*) Assertion is false but Reason is true.

Sol. (*b*)

LAWS OF CHEMICAL COMBINATION

The law of conservation of mass (Law of Indestructibility of matter) According to this law, the mass can neither be created nor be destroyed in a balanced chemical reaction but one form is changed into another form. In a chemical change total mass remains conserved i.e., total mass before the reaction is always equal to total mass after the reaction.

$$\begin{array}{lll} H_2(g) \quad + & \frac{1}{2}O_2(g) \rightarrow & H_2O\,(\ell) \\ 1 \text{ mole} & \frac{1}{2} \text{ mole} & 1 \text{ mole} \end{array}$$

Mass before the reaction = $1 \times 2 + \frac{1}{2} \times 32 = 18$ gm

Mass after the reaction = $1 \times 18 = 18$ gm

[Total mass of reactants = Total mass of products + Mass of unreacted reactants]

Law of constant composition (definite proportions): All chemical compounds are found to have constant composition of elements irrespective of their method of preparation or sources. E.g. In H_2O, hydrogen & oxygen combine in 2 : 1 molar ratio, this ratio remains constant whether it is tap water, river water or seawater or produced by any chemical reaction.

Law of Multiple Proportions: When one element combines with the other element to form two or more different compounds, the mass of one element, which combines with a constant mass of the other bear a simple ratio to one another.

Nitrogen and oxygen combine to form five oxides: weights of oxygen which combine with the fixed weight of nitrogen in these oxides are calculated as under:

Oxide	Ratio of weights of nitrogen and oxygen
N_2O	28 : 16
NO	28 : 32
N_2O_3	28 : 48
N_2O_4	28 : 64
N_2O_5	28 : 80

Number of parts by weight of oxygen which combine with 14 parts by weight of nitrogen from the above are 8, 16, 24, 32 and 40 respectively. Their ratio is 1 : 2 : 3 : 4 : 5, which is a simple whole number ratio. Hence, the law of multiple proportion is illustrated.

ADVANCED LEARNING

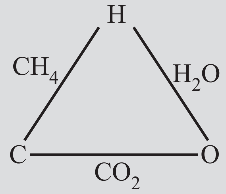
Law of Reciprocal Proportion: The ratio of the masses of two elements A and B which combine separately with a fixed mass of the third element C is either the same or some simple multiple of the ratio of the masses in which A and B combine directly with each other.

Like CH_4, CO_2 and H_2O

$CH_4 \rightarrow C : H = 12 : 4$

$CO_2 \rightarrow C : O = 12 : 32$

$H_2O \rightarrow H : O = 2 : 16$



Gay-Lussac's Law of Combining Volume: Gases combine in a simple whole number ratio of their volumes provided all measurements should be done at the same temperature and pressure.

$H_2(g)$	+ $Cl_2(g)$	$\rightarrow$	$2HCl$
1 vol.	1 vol.		2 vol.

Avogadro's hypothesis: Equal volume of all gases have equal number of molecules (not atoms) at same temperature and pressure condition.
S.T.P. (Standard Temperature and Pressure) Temperature = 0°C or 273 K, Pressure = 1 atm = 760 mm of Hg.
Volume of one mole of gas at STP is found to be experimentally equal to 22.4 litres which is known as molar volume.

- ❖ Measuring the volume is equivalent to counting the number of molecules of the gas.

Train Your Brain

Example 1: A 15.9 g sample of sodium carbonate is added to a solution of acetic acid weighing 20.0 g. The two substances react, releasing carbon dioxide gas to the atmosphere. After reaction, the contents of the reaction vessel weigh 29.3 g. What is the mass of carbon dioxide given off during the reaction?

Sol. The total mass of reactants taken = 15.9 + 20.0 = 35.9 gm. From the conservation of mass, the final mass of the contents of the vessel should also be 35.9 gm. But it is only 29.3 gm. The difference is due to the mass of released carbon dioxide gas. Hence, the mass of carbon dioxide gas released
= 35.9 – 29.3 = 6.6 gm

Example 2: The following are the results of analysis of two samples of the same or two different compounds of phosphorus and chlorine. From these results, decide whether the two samples are from the same or different compounds. Also state the law, which will be obeyed by the given samples.

	Amount of P	Amount of C*l*
Compound A	1.156 gm	3.971 gm
Compound B	1.542 gm	5.297 gm

Sol. The mass ratio of phosphorus and chlorine in compound A, $m_P : m_{Cl} = 1.156:3.971 = 0.2911:1.000$
The mass ratio of phosphorus and chlorine in compound B, $m_P : m_{Cl} = 1.542:5.297 = 0.2911:1.000$
As the mass ratio is same, both the compounds are **same** and the samples obey the **law of definite proportion**.

Example 3: 2.5 ml of a gaseous hydrocarbon exactly requires 12.5 ml oxygen for complete combustion and produces 7.5 ml carbon dioxide and 10.0 ml water vapour. All the volumes are measured at the same pressure and temperature. Show that the data illustrates Gay Lussac's law of volume combination.

Sol. $V_{\text{hydrocarbon}} : V_{\text{oxygen}} : V_{\text{carbon dioxide}} : V_{\text{water vapour}}$
= 2.5 : 12.5 : 7.5 : 10.0
= 1 : 5 : 3 : 4 (simple whole no. ratio)
Hence, the data is according to the **law of volume combination**.

Concept Application

1. A sample of pure carbon dioxide, irrespective of its source contains 27.27% carbon and 72.73% oxygen. The data support:
(*a*) Law of constant composition.
(*b*) Law of conservation of mass.
(*c*) Law of reciprocal proportions.
(*d*) Law of multiple proportions.

2. The percentage of hydrogen in water and hydrogen peroxide is 11.1 and 5.9 respectively. These figures illustrate:
(*a*) Law of multiple proportions.
(*b*) Law of conservation of mass.
(*c*) Law of constant proportions.
(*d*) Law of combining volumes.

3. 1.0 g of an oxide of A contained 0.5 g of A. 4.0 g of another oxide of A contained 1.6 g of A. The data indicate the law of:
(*a*) Reciprocal proportions.
(*b*) Constant proportions.
(*c*) Conservation of energy.
(*d*) Multiple proportions.

4. Carbon is found to form two oxides which contain 42.9% & 27.3% of carbon respectively show that these figures shows the
(*a*) Law of multiple proportion
(*b*) Law of definite proportion
(*c*) Law of mass conservation
(*d*) All of these

ATOMIC MASS & MOLECULAR MASS

Relative Atomic Mass: One of the most important concept from Dalton's atomic theory was that of relative atomic mass or relative atomic weight. This is done by expressing mass of one atom with respect to a fixed standard. Dalton used hydrogen as the standard (H = 1). Later on oxygen (O = 16) replaced hydrogen as the reference.

- ❖ The present standard unit which was adopted internationally in 1961, is based on the mass of one carbon-12 isotopic atom, taken as exactly 12.000 u (amu).

  Relative atomic mass (R.A.M)

$$= \frac{\text{Mass of one atom of an element}}{\frac{1}{12} \times \text{Mass of one } C^{12} \text{ atom}}$$

Atomic Mass Unit (or amu): The atomic mass unit (amu) is equal to $\left(\frac{1}{12}\right)^{th}$ of mass of one atom of carbon-12 isotope.

$$\therefore \quad 1 \text{ amu} = \frac{1}{12} \times \text{mass of one } C^{12} \text{ isotopic atom}$$

$$\simeq \text{mass of one nucleon in } C^{12} \text{ atom.}$$

1 amu = 1.66×10^{-24} gm or 1.66×10^{-27} kg

- Today, amu has been replaced by 'u' which is known as unified atomic mass
- **One amu is also called One Dalton (Da).**
- Atomic mass = R.A.M × 1 amu

- Relative atomic mass indicates the number of nucleons present in the atom.

Average / Mean Atomic Mass

The weighted average of the isotopic masses of the element's naturally occurring isotopes.

Mathematically, average atomic mass of X (A_x)

$$= \frac{a_1x_1 + a_2x_2 + ... + a_nx_n}{100}$$

Where:

a_1, a_2, a_3 .... atomic mass of isotopes.

and x_1, x_2, x_3 .... mole% or % of natural abundance of isotopes.

Key Note

- Atomic weights of many elements are not whole numbers due to the presence of stable isotopes.
- The number of atoms of a particular isotope present in 100 atoms of a natural sample of that element is called its relative abundance which always remains constant for a given element.
- Shortcut for % determination if average atomic weight is given for X having isotopes XA & XB.

$$\% \text{ of XA} = \left| \frac{\text{Average atomic weight} - \text{wt of } X^B}{\text{difference in weight of } X^A \ \& \ X^B} \right| \times 100$$

Illustration: Naturally occurring chlorine is 75% Cl^{35} which has an atomic mass of 35 amu and 25% Cl^{37} which has a mass of 37 amu. Calculate the average atomic mass of chlorine:

(*a*) 35.5amu (*b*) 36.5amu (*c*) 71amu (*d*) 72amu

Sol. (*a*) Average atomic mass

$$= \frac{(\text{\% of I isotope}) \times (\text{its A.M}) + (\text{\% of II isotope}) \times (\text{its A.M.})}{100}$$

$$= \frac{75 \times 35 + 25 \times 37}{100} = 35.5 \text{ amu}$$

Relative molecular mass:

$$= \frac{\textbf{mass of one molecule of the substance}}{\frac{1}{12} \times \textbf{mass of one } C^{12} \textbf{ – atom}}$$

- Molecular mass = Relative molecular mass × 1 amu

Mean Molar Mass or Molecular Mass

The average molar mass of the different substance present in the container $= \frac{n_1M_1 + n_2M_2 + ...n_nM_n}{n_1 + n_2 + ...n_n}$.

Where:

M_1, M_2, M_3 .... are molar masses.

n_1, n_2, n_3 .... are moles of substances.

Formula Mass

The formula mass of a substance is defined as the sum of the atomic masses of constituent atoms in an ionic compound. This is generally used for ionic compounds which do not contain discrete molecules, but ions as their constituent units.

For example: Formula mass of NaCl is:

Formula mass = mass of sodium atom + mass of chlorine atom

= (23 + 35.5) u = 58.5 u

Illustration: The molar composition of polluted air is as follows:

Gas	At. wt.	mole percentage composition
Oxygen	16	16%
Nitrogen	14	80%
Carbon dioxide	-	03%
Sulphur dioxide	-	01%

What is the average molecular weight of the given polluted air? (Given, atomic weights of C and S are 12 and 32 respectively.

Sol. $M_{avg} = \frac{\sum_{j=1}^{j=n} n_jM_j}{\sum_{j=1}^{j=n} n_j}$ Here $\sum_{j=1}^{j=n} n_j = 100$

$$\therefore M_{avg} = \frac{16 \times 32 + 80 \times 28 + 44 \times 3 + 64 \times 1}{100}$$

$$= \frac{512 + 2240 + 132 + 64}{100} = \frac{2948}{100} = 29.48 \text{ Ans.}$$

Train Your Brain

Example 4: Find the relative atomic mass of 'O' atom and its atomic mass.

Sol. The number of nucleons present in 'O' atom is 16.

∴ Relative atomic mass of 'O' atom = 16.

Atomic mass = R.A.M × 1 amu = 16 × 1 amu = 16 amu

Example 5: The weight of one atom of uranium is 235 amu. Its actual weight in g is:

Sol. $235 \times 1.67 \times 10^{-24}$ g

$= 3.95 \times 10^{-22}$ g

Concept Application

5. The Relative molecular mass of ammonia is:
   (*a*) 17 (*b*) 22 (*c*) 28 (*d*) 44
6. The mass of an atom of sodium is:
   (*a*) 23 amu (*b*) 23gm
   (*c*) 46 amu (*d*) 12 amu
7. The atomic mass & molecular mass of hydrogen is:
   (*a*) 1amu & 2amu (*b*) 2 amu & 4 amu
   (*c*) 3amu & 6amu (*d*) 4 amu & 8 amu

8. One 'u' stands for the
   (*a*) mass of an atom of carbon-12 atom.
   (*b*) 1/12th of mass of carbon-12.
   (*c*) 1/12th of mass of hydrogen atom.
   (*d*) mass of one atom of any of the element.
9. Mass of 1 amu in g is equal to:
   (*a*) 1.66×10^{24} g   (*b*) 1.66×10^{-24} g
   (*c*) 1.008 g   (*d*) 9.1×10^{-28} g

MOLE CONCEPT

Mole

Mole is a counting unit mostly used for microscopic particles and is defined as follows:

A mole is the amount of a substance that contains as many entities (atoms, molecules or other particles) as there are atoms in exactly 0.012 kg (or 12 gm) of the carbon-12 isotope.

From mass spectrometer we found that there are 6.022×10^{23} atoms present in 12 gm of C^{12} isotope.

The number of entities in 1 mol is so important that it is given a separate name and symbol known as Avogadro constant denoted by N_A. i.e., on the whole we can say that 1 mole is the collection of 6.022×10^{23} entities. Here entities may represent atoms, ions, molecules or even pens, chair, paper etc but as this number (N_A) is very large therefore it is significant only for very micro-particles.

Illustration: Chlorophyll, the green colouring material of plants contains 3.68 % of magnesium by mass. Calculate the number of magnesium atom in 5.00 g of the complex.

Sol. Mass of magnesium in 5.0 g of complex

$$= \frac{3.68}{100} \times 5.00 = 0.184 \text{ g}$$

Atomic mass of magnesium = 24

24 g of magnesium contain = 6.022×10^{23} atoms

$$0.184 \text{ g of magnesium would contain} = \frac{6.022 \times 10^{23}}{24} \times 0.184 = 4.617 \times 10^{21}$$

Therefore, 5.00 g of the given complex would contain 4.617×10^{21} atoms of magnesium.

How Big is a Mole?

Amount of water in world's oceans (litres)
Age of earth (seconds)
Population of earth

Avogadro's number   602,200,000,000,000,000,000,000

Distance from earth to sun (centimeters)

❖ In modern practice gram-atom and gram-molecule are termed as mole.

Gram Atomic Mass: The atomic mass of an element expressed in gram is called gram atomic mass of the element.

or

It is also defined as mass of 6.022×10^{23} atoms.

or

It is also defined as the mass of one mole atoms.

Eg:

Element	R.A.M. (Relative Atomic Mass)	Atomic mass (mass of one atom)	Gram Atomic mass/weight
N	14	14 amu	14 gm
He	4	4 amu	4 gm
C	12	12 amu	12 gm

For example, for oxygen atom: Atomic mass of 'O' atom = mass of one 'O' atom = 16 amu

Gram atomic mass = mass of 6.022×10^{23} 'O' atoms
$= 16 \text{ amu} \times 6.022 \times 10^{23}$
$= 16 \times 1.66 \times 10^{-24} \text{ g} \times 6.022 \times 10^{23} = 16 \text{ g}$

$(\because 1.66 \times 10^{-24} \times 6.022 \times 10^{23} \simeq 1)$

Gram Molecular Mass: The molecular mass of a compound expressed in gram is called the gram-molecular mass of the compound.

or

It is also defined as mass of 6.022×10^{23} molecules.

or

It is also defined as the mass of one mole molecules.

For example, for 'O_2' molecule: Molecular mass of 'O_2' molecule
= mass of one 'O_2' molecule
= 2 × mass of one 'O' atom = 2 × 16 amu = 32 amu

Gram molecular mass = mass of 6.022×10^{23} 'O_2' molecules
$= 32 \text{ amu} \times 6.022 \times 10^{23}$
$= 32 \times 1.66 \times 10^{-24} \text{ gm} \times 6.022 \times 10^{23} = 32 \text{ gm}$

RELATIONSHIP BETWEEN GRAM AND AMU

$1 \text{ amu} = \frac{1}{12}$ of wt. of one C^{12} atom.

For carbon (C^{12}) atom, 1 mole C = 12 gm = 6.022×10^{23} atoms

wt. of 6.022×10^{23} C^{12} atoms = 12 gm

wt. of 1 atom of $C^{12} = \frac{12}{N_A}$ gm

($N_A \rightarrow$ Avogadro's number = 6.022×10^{23})

$1 \text{ amu} = \frac{1}{12}$ of wt. of one C^{12} atom $= \frac{1}{12} \times \frac{12}{N_A}$ gm

$$\boxed{1 \text{ amu} = \frac{1}{N_A} \text{ gm}}$$

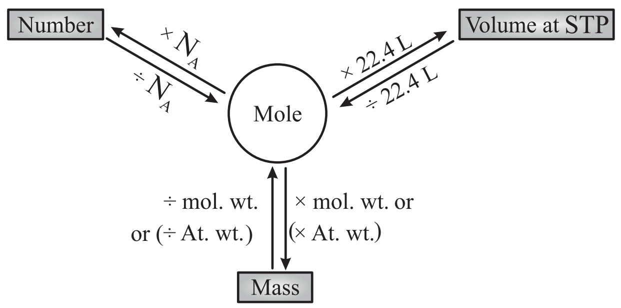
METHODS OF CALCULATIONS OF MOLE

(*a*) If no. of particles of some species is given, then no. of moles $= \frac{\text{Given no. of particles}}{N_A}$

(*b*) If weight of a given species is given, then no. of moles = $\frac{\text{Given wt.}}{\text{Atomic wt.}}$ (for atoms),

or $\frac{\text{Given wt.}}{\text{Molecular wt.}}$ (for molecules) (*c*) If volume of a gas is given along with its temperature (T) and pressure (P) use $n = \frac{PV}{RT}$ (assuming gas to be ideal) where R = 0.0821 lit-atm/mol–K (when P is in atmosphere and V is in litre.)

Y-map: Interconversion of mole - volume, mass and number of particles:



ATOMICITY

It is equal to number of atoms present in one molecule. For example atomicity of H_2, CO_2, O_3, CCl_4, respectively.

DENSITY

For Liquids and Solids,

(*a*) Absolute density

$$\text{Absolute density} = \frac{\text{Mass}}{\text{Volume}}$$

(*b*) Relative density

$$\text{Relative density} = \frac{\text{Density of substance}}{\text{Density of standard substance}}$$

$$\text{e.g., Specific gravity} = \frac{\text{Density of substance}}{\text{Density of } H_2O \text{ at } 4°C}$$

For Gases:

$$\text{Absolute density (mass / volume)} = \frac{PM}{RT}$$

where P is pressure of gas, M = mol. wt. of gas, R is the gas constant, T is the temperature.

Vapour density: It is defined only for gas.

It is a density of gas with respect to H_2 gas at same temperature & pressure.

$$\text{V.D.} = \frac{d_{gas}}{d_{H_2}} = \frac{PM_{gas}/RT}{PM_{H_2}/RT} = \frac{M_{gas}}{M_{H_2}} = \frac{M}{2}$$

$$\boxed{\text{V.D.} = \frac{M}{2}}$$

Key Note

- 1 g O, 1 g O_2, 1 g O_3 each have same number of oxygen atoms.
- Density of liquid water at 4°C is 1 g/mL = 1 g/cc = 10^3 kg/m^3

Train Your Brain

Example 6: Total number of atoms of all elements present in 1 mole of ammonium dichromate is?

(*a*) 14 (*b*) 19
(*c*) 6×10^{23} (*d*) 114×10^{23}

Sol. $(NH_4)_2Cr_2O_7 = 19 \times 6.022 \times 10^{23} \approx 114 \times 10^{23}$ atoms.

Example 7: How many atoms of oxygen are there in 16 g of oxygen?

(*a*) 2 N_A (*b*) N_A (*c*) 1.5 N_A (*d*) 4 N_A

Sol. Let x atoms of oxygen are present

$$\text{So, } 16 \times 1.66 \times 10^{-24} \times x = 16\text{ g} \Rightarrow x = \frac{1}{1.66 \times 10^{-24}} = N_A$$

Example 8: Calculate the volume in litres of 20 g hydrogen gas at STP.

(*a*) 2.24 L (*b*) 22.4 L
(*c*) 224 L (*d*) 4.48 L

Sol. No. of moles of hydrogen gas $= \frac{\text{Mass}}{\text{Molecular mass}}$

$$= \frac{20\text{ gm}}{2\text{ gm}} = 10\text{ mol}$$

Volume of hydrogen gas at STP = 10 × 22.4 L

Example 9: The number of atoms contained in 11.2 L of SO_2 at S.T.P. are:

(*a*) $3/2 \times 6.022 \times 10^{23}$ (*b*) $2 \times 6.022 \times 10^{23}$
(*c*) 6.022×10^{23} (*d*) $4 \times 6.022 \times 10^{23}$

Sol. 22.4 litre gas has = 1 mole

$$1 \text{ litre gas has} = \frac{1}{22.4} \times 11.2 = \frac{1}{2} \text{ mole of molecules}$$

$$= 3 \times \frac{1}{2} \text{ mole of atoms}$$

$$= \frac{3}{2} \times 6.022 \times 10^{23} \text{ atoms}$$

Example 10: 7.5 litre of the particular gas at S.T.P. weighs 16 gram. What is the V.D. of gas?

Sol. Moles at S.T.P. $= \frac{7.5}{22.4} = \frac{16}{M}$

$$M = 48 \text{ gram; V.D.} = \frac{48}{2} = 24.$$

Example 11: Find the density of $CO_2(g)$ with respect to $N_2O(g)$.

Sol. $\text{V.D.} = \frac{\text{M.wt. of } CO_2}{\text{M.wt. of } N_2O} = \frac{44}{44} = 1$

Example 12: Find the vapour density of N_2O_5.

Sol. $\text{V.D.} = \frac{\text{Mol. wt. of } N_2O_5}{2} = \frac{108}{2} = 54$.

Concept Application

10. The number of electrons present in 1 mol of methane molecule are:
(*a*) 6.022×10^{25} (*b*) 6.022×10^{24}
(*c*) 6.022×10^{23} (*d*) 6.022×10^{22}

11. The mass of one molecule of water is approximately:
(*a*) 3×10^{-23} g (*b*) 18 g
(*c*) 1.5×10^{-23} g (*d*) 4.5×10^{-23} g

12. The molar mass of ferrous sulphate ($FeSO_4.7H_2O$) is:
(*a*) 152 gm (*b*) 278 gm
(*c*) 137 gm (*d*) None of these

13. The vapour density of carbon dioxide is:
(*a*) 44 (*b*) 32 (*c*) 22 (*d*) 12

14. The density of air is 0.001293 g/cm^3 at STP. Identify which of the following statement is correct?
(*a*) Vapour density is 12.72.
(*b*) Molecular weight is 28.96.
(*c*) Vapour density is 0.001293 g/cm^3.
(*d*) Vapour density and molecular weight cannot be determined.

ELEMENTAL ANALYSIS

For n mole of a compound ($C_3H_7O_2$);
Moles of C = 3n
Moles of H = 7n
Moles of O = 2n

PERCENTAGE FORMULAE COMPOSITION

% of element in a compound

$$= \frac{\text{Atomic weight of element} \times \text{Number of atom of that element in one molecule} \times 100}{\text{Total molecular weight of compound}}$$

Here we are going to find out the percentage of each element in the compound by knowing the molecular formula of compound.

EMPIRICAL AND MOLECULAR FORMULA

We have just seen that knowing the molecular formula of the compound, we can calculate percentage composition of the elements. Conversely, if we know the percentage composition of the elements initially, we can calculate the relative number of atoms of each element in the molecules of the compound. This gives us the empirical formula of the compound. Further if the molecular mass is known then the molecular formula can easily be determined.

An empirical formula represents the simplest whole number ratio of various atoms present in a compound.

The molecular formula gives the actual number of atoms of each element in a molecule. The molecular formula shows the exact number of different types of atoms present in a molecule of a compound.

The molecular formula is an integral multiple of the empirical formula.

i.e. Molecular formula = Empirical formula × n

where $n = \dfrac{\text{Molecular Formula Mass}}{\text{Empirical Formula Mass}}$

- If sum of mass percent of all elements is less than 100 then difference is due to oxygen.
- Mass % of C = $\dfrac{12}{44} \times \dfrac{m_{CO_2}}{m_{compound}} \times 100$
- Mass % of H = $\dfrac{2}{18} \times \dfrac{m_{H_2O}}{m_{compound}} \times 100$

Train Your Brain

Example 13: Every molecule of ammonia always has formula NH_3 irrespective of method of preparation or sources. i.e. 1 mole of ammonia always contains 1 mol of N and 3 mole of H. In other words 17 gm of NH_3 always contains 14 gm of N and 3 gm of H. Now find out % of each element in the compound.

Sol. Mass % of N in NH_3 =

$$\frac{\text{Mass of N in 1 mole } NH_3}{\text{Mass of 1 mole of } NH_3} \times 100 = \frac{14}{17} \times 100 = 82.35\%$$

Mass % of H in NH_3 =

$$\frac{3 \times \text{Mass of H in 1 mole } NH_3}{\text{Mass of 1 mole of } NH_3} \times 100$$

$$= \frac{3}{17} \times 100 = 17.65\ \%$$

Example 14: Acetylene and benzene both have the empirical formula CH. The molecular masses of acetylene and benzene are 26 and 78 respectively. Deduce their molecular formulae.

Sol. ∵ Empirical Formula is CH

Step-1: The empirical formula of the compound is CH
∴ Empirical formula mass = (1 × 12) + 1 = 13.
Molecular mass = 26

Step-2: To calculate the value of 'n'

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{26}{13} = 2$$

Step-3: To calculate the molecular formula of the Compound.

Molecular formula = n × (Empirical formula of the compound) = 2 × CH = C_2H_2

Thus the molecular formula is C_2H_2

Similarly for benzene

To calculate the value of 'n'

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{78}{13} = 6.$$

Thus the molecular formula is 6 × CH = C_6H_6

Example 15: An organic substance containing carbon, hydrogen and oxygen gave the following percentage composition.

C = 40.684% ; H = 5.085% and O = 54.228%

The molecular weight of the compound is 118. Calculate the molecular formula of the compound.

(*a*) $C_4H_6O_4$ (*b*) $C_2H_3O_2$

(*c*) $C_2H_4O_2$ (*d*) $C_4H_6O_8$

Sol. Step-1: To calculate the empirical formula of the compound.

Element	Symbol	Percentage of element	At. mass of element	Relative no. of atoms = $\frac{\text{Percentage}}{\text{At. mass}}$	Simplest atomic ratio	Simplest whole no. atomic ratio
Carbon	C	40.684	12	$\frac{40.684}{12} = 3.390$	$\frac{3.390}{3.389} = 1$	2
Hydrogen	H	5.085	1	$\frac{5.085}{1} = 5.085$	$\frac{5.085}{3.389} = 1.5$	3
Oxygen	O	54.228	16	$\frac{54.228}{16} = 3.389$	$\frac{3.389}{3.389} = 1$	2

$\therefore$ Empirical Formula is $C_2H_3O_2$

Step-2: To calculate the empirical formula mass.

The empirical formula mass of the compound is $12 \times 2 + 3 \times 1 + 16 \times 2 = 59$.

Step-3: To calculate the value of 'n'

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}} = \frac{118}{59} = 2$$

Step-4: To calculate the molecular formula of the salt.

Molecular formula = n × (Empirical formula)

$= 2 \times C_2H_3O_2 = C_4H_6O_4$

Thus the molecular formula is $C_4H_6O_4$.

Example 16: Acetylene & butene have empirical formula CH & CH_2 respectively. The molecular mass of acetylene and butene are 26 & 56 respectively. Deduce their molecular formula.

Sol.

$$n = \frac{\text{Molecular mass}}{\text{Empirical formula mass}}$$

For Acetylene : $n = \frac{26}{13} = 2$

$\therefore$ Molecular formula = C_2H_2

For Butene: $n = \frac{56}{14} = 4$

$\therefore$ Molecular formula = C_4H_8

Example 17: An oxide of nitrogen gave the following percentage composition by mass:

N = 25.94 and O = 74.06

Calculate the empirical formula of the compound.

(*a*) NO_2 (*b*) N_2O_4 (*c*) N_2O_5 (*d*) N_2O

Sol.

Element	%/Atomic mass	divide by smallest ratio	Simple integer ratio
N	$\frac{25.94}{14} = 1.85$	$\frac{1.85}{1.85} = 1$	2
O	$\frac{74.06}{16} = 4.63$	$\frac{4.63}{1.85} = 2.5$	5

So empirical formula is N_2O_5.

Concept Application

15. A compound contains 25% hydrogen and 75% carbon by mass. Determine the empirical formula of the compound.

(*a*) CH_4 (*b*) C_2H_6

(*c*) C_3H_8 (*d*) C_2H_2

16. The empirical formula of a compound of molecular mass 120 u is CH_2O. The molecular formula of the compound is:

(*a*) $C_2H_4O_2$ (*b*) $C_4H_8O_4$

(*c*) $C_3H_5C_3$ (*d*) All of these

17. Calculate the molecular formula of compound which contains 20% Ca and 80% Br (by wt.) if molecular weight of compound is 200 u. (Atomic wt. Ca = 40. Br = 80)

(*a*) $Ca_{1/2}Br$ (*b*) $CaBr_2$

(*c*) CaBr (*d*) Ca_2Br

CONCENTRATION OF SOLUTION

Concentration of a solution can be expressed in any of the following ways.

(*i*) **% by wt.:** Amount of solute (in g) dissolved in 100 gm of solution.

4.9% H_2SO_4 by wt.

$\Rightarrow$ 100 gm of solution contains 4.9 gm of H_2SO_4.

(*ii*) **% by volume:** Volume of solute (in ml) dissolved in 100 ml of solution.

x% H_2SO_4 by volume

$\Rightarrow$ 100 ml of solution contains x ml H_2SO_4.

(*iii*) **% wt. by volume:** wt. of solute (in g) present in 100 ml of solution.

CONCENTRATION TERMS

Molarity (M): No. of moles of solute present in 1000 ml of solution.

$$\text{Molarity (M)} = \frac{\text{Moles of solute}}{\text{Volume of solution (L)}}$$

Molality (m): No. of moles of solute present in 1000 gm of solvent.

$$m = \frac{\text{Moles of solute}}{\text{wt. of solvent in kg}}$$

Mole fraction: The mole fraction of a particular component in a solution is defined as the number of moles of that component per mole of solution.

If a solution has n_A mole of A & n_B mole of B.

$$\text{mole fraction of A } (X_A) = \frac{n_A}{n_A + n_B}$$

$$\text{mole fraction of B } (X_B) = \frac{n_B}{n_A + n_B}$$

$X_A + X_B = 1$

Parts per million (ppm):

$$= \frac{\text{Mass of solute}}{\text{Mass of solvent}} \times 10^6 \cong \frac{\text{Mass of solute}}{\text{Mass of solution}} \times 10^6$$

CONVERSION OF CONCENTRATION TERMS

1. **Molarity and % solute by mass:** Let d = density of solution in g/mL and let it contains x% (w/w) solute by mass. $\mathbf{M = \frac{x \times d \times 10}{m_A}}$

> ❖ Specific gravity has no units and its numerical value equals density in g/mL.

2. **Molality and mole fraction:** Consider a binary solution consisting of two components A (Solute) and B (Solvent). Let X_A & X_B are the mole fraction of A & B respectively.

$$X_A = \frac{n_A}{n_A + n_B}, \quad X_B = \frac{n_B}{n_A + n_B}$$

If molality of solution be m then:

$$m = \frac{n_A}{\text{mass of solvent}} \times 1000 = \frac{n_A}{n_B \times M_B} \times 1000$$

where M_B is the molecular wt. of the solvent B.

$$m = \frac{X_A}{X_B} \times \frac{1000}{M_B} \Rightarrow m = \frac{\text{mole fraction of A}}{\text{mole fraction of B}} \times \frac{1000}{M_B}$$

$$\boxed{m = \frac{\text{mole fraction of solute}}{\text{mole fraction of solvent}} \times \frac{1000}{\text{molecular wt. of solvent}}}$$

3. **Mole fraction of solute into molarity of solution** $\mathbf{M = \frac{X_2 d \times 1000}{X_1 M_1 + M_2 X_2}}$

Mole fraction of solvent and solute are X_1 and X_2 so $X_1 + X_2 = 1$

Suppose total mole of solution is = 1 then mole of solute and solute and solvent are X_2 & X_1 respectively

weight of solute = X_2M_2, weight of solvent = X_1M_1

& total wt of solution = $X_1M_1 + X_2M_2$

$$\text{volume of solution} = \frac{X_1M_1 + X_2M_2}{d} \text{ ml} = \frac{X_1M_1 + X_2M_2}{d \times 1000} \text{ L}$$

$$\text{molarity (M)} = \frac{X_2 \times d \times 1000}{X_1M_1 + X_2M_2}$$

4. **Molarity into mole fraction X_2 = 1000M/ [1000d – MM_2]**

Molarity = M moles solute in 1000 ml of solution

So, moles of solute = M & mass of solution = d × 1000

wt. of solute = MM_2 & wt. of solvent = 1000d – MM_2

Where M_2 is molar mass of solute

mole fraction of solute = 1000M / [1000d – MM_2]

5. **Molality into mole fraction $\mathbf{X_2 = \frac{mM_1}{1000 + mM_1}}$**

Molality = moles of solute in 1000 gm of solvent = m

$$\text{moles of solvent} = \frac{1000}{M_1} \text{ where } M_1 \text{ is molar mass of solvent}$$

$$\text{mole fraction } X_2 = \frac{m}{\frac{1000}{M_1} + m} = \frac{mM_1}{1000 + mM_1}$$

6. **Molality into molarity $\mathbf{M = \frac{md \times 1000}{1000 + mM_2}}$**

Molality = m moles of solute in 1000 gm of solvent

mole of solute = m & weight of solute = mM_2

Weight of solution = 1000 + mM_2

$$\text{volume of solution} = \frac{1000 + mM_2}{d} \text{ mL} = \frac{1000 + mM_2}{d \times 1000} \text{ L}$$

$$\text{molarity} = \frac{m \times d \times 1000}{1000 + mM_2}$$

7. **Molarity into Molality $\mathbf{m = \frac{M \times 1000}{1000d - MM_2}}$**

M_1 and M_2 are molar masses of solvent and solute.

Molarity = M mole of solute in 1000 ml of solution

moles of solute = M & weight of solute = MM_2

weight of solution = 1000d

mass of solvent = 1000d – MM_2

$$\text{molality} = \frac{M \times 1000}{1000d - MM_2}$$

$$\text{on simplifying } \boxed{d = M\left[\frac{1}{m} + \frac{M_2}{1000}\right]}$$

DILUTION & MIXING OF TWO LIQUIDS

❖ Upon dilution no. of moles of solute remains constant. If a particular solution having volume V_1 mL and molarity M_1 is diluted upto volume V_2 mL.

$M_1V_1 = M_2V_2$

M_2 : final molarity

❖ If a solution having volume V_1 and molarity M_1 is mixed with another solution of same solute having volume V_2 & molarity M_2 then $M_1V_1 + M_2V_2 = MR\,(V_1 + V_2)$

$$MR = \text{Resultant molarity} = \frac{M_1V_1 + M_2V_2}{V_1 + V_2}$$

Key Note

❍ Molality is the most convenient method to express the concentration because it involves the mass of liquids rather than their volumes. It is also independent of the variation in temperature.

- No. of moles of solute = Molarity × volume of solution (in L)
- No. of millimoles of solute = Molarity × volume of solution (in mL)
- 1 mole = 1000 millimole
- All those concentration terms which does not involve volume terms e,g., ppm, mass %, molality, mole fraction are independent of temperature of the solution.
- For dilue aqueous solution, molarity = molality
- Concentration of solids or pure liquids is constant. (C = n/V = d/M)

Train Your Brain

Example 18: 0.2 mole of HCl and 0.1 mole of barium chloride were dissolved in 0.5 L of water to produce solution. The molarity of the Cl^- ions is:

(*a*) 0.06 M (*b*) 0.09 M
(*c*) 0.12 M (*d*) 0.80 M

Sol. $HCl \longrightarrow Cl^-$

0.2 mole

$BaCl_2 \longrightarrow 2\,Cl^-$

$2 \times 0.1 = 0.2$

Total moles of Cl^- = 0.4 $\Rightarrow$ $M = \dfrac{w \times 1000}{m \times v}$

$$\text{Molarity} = \frac{0.4 \times 1000}{500} = 0.8 \quad \because \left(\frac{w}{m} = 0.4\right)$$

Example 19: 149 g of potassium chloride (KCl) is dissolved in 10 L of an aqueous solution. Determine the molarity of the solution. (K = 39, Cl = 35.5)

(*a*) 0.2 M (*b*) 0.4 M (*c*) 0.5 M (*d*) 2.2 M

Sol. Molecular mass of KCl = 39 + 35.5 = 74.5 g

$\therefore$ Moles of KCl = $\dfrac{149\,g}{74.5\,g} = 2$

$\therefore$ Molarity of the solution = $\dfrac{2}{10} = 0.2M$

Example 20: 255 g of an aqueous solution contains 5 g of urea. What is the concentration of the solution in terms of molality? (Mol. wt. of urea = 60)

(*a*) 0.222 m (*b*) 0.333 m
(*c*) 2.22 m (*d*) 3.33 m

Sol. Mass of urea = 5 g

Molecular mass of urea = 60

Number of moles of urea = $\dfrac{5}{60} = 0.083$

Mass of solvent = (255 – 5) = 250 g

$\therefore$ Molality of the solution

$$= \frac{\text{Number of moles of solute}}{\text{Mass of solvent in gram}} \times 1000$$

$$= \frac{0.083}{250} \times 1000 = 0.332\ m$$

Example 21: 117 g NaCl is dissolved in 500 ml aqueous solution. Find the molarity of the solution.

Sol. Molarity = $\dfrac{117/58.5}{500/1000} = 4M.$

Example 22: Calculate the resultant molarity of following:

(*a*) 200 ml 1M HCl + 300 ml water

(*b*) 1500 ml 1M HCl + 18.25 g HCl

(*c*) 200 ml 1M HCl + 100 ml 0.5 M H_2SO_4

(*d*) 200 ml 1M HCl + 100 ml 0.5 M HCl

Sol. (*a*) Final molarity = $\dfrac{200 \times 1 + 0}{200 + 300} = 0.4M.$

(*b*) Final molarity = $\dfrac{1500 \times 1 + \dfrac{18.25 \times 1000}{36.5}}{1500} = 1.33\,M$

(*c*) Final molarity of $H^+ = \dfrac{200 \times 1 + 100 \times 0.5 \times 2}{200 + 100} = 1M$

(*d*) Final molarity = $\dfrac{200 \times 1 + 100 \times 0.5}{200 + 100} = 0.83M.$

Example 23: 518 g of an aqueous solution contains 18 g of glucose (mol.wt. = 180). What is the molality of the solution?

Sol. wt. of solvent = 518 – 18 = 500 g.

$\Rightarrow$ So molarity = $\dfrac{18/180}{500/1000} = 0.2M$

Example 24: 0.25 g of a substance is dissolved in 6.25 g of a solvent. Calculate the percentage amount of the substance in the solution.

Sol. Wt. of solution = 0.25 + 6.25 = 6.50

So % (w/w) = $\dfrac{0.25}{6.50} \times 100 = 3.8\%$

Example 25: An aqueous solution is 1.33 molal in methanol. Determine the mole fraction of methanol & H_2O.

Sol. Molality

$$= \frac{\text{Mole fraction of solute}}{\text{Mole fraction of solvent} \times \text{mol.wt. of solvent}} \times 1000$$

$$1.33 = \frac{X_A}{X_B \times M_B} \times 1000\,;\ \frac{1.33 \times 18}{1000} = \frac{X_A}{X_B}\,;\ \frac{23.94}{1000} = \frac{X_A}{X_B}$$

$\Rightarrow$ $X_A = 0.02394\,X_B$, $X_A + X_B = 1$ $\Rightarrow$ $1.02394\,X_B = 1$

$X_B = \dfrac{1}{1.02394} = 0.98$, $X_A = 0.02$

2nd Method: Let wt. of solvent = 1000 gm, molality = 1.33 means 1.33 moles of solute are present in 1000 g solvent mole fraction of solute

$$= \frac{\text{moles of solute}}{\text{moles of solute} + \text{moles of solvent}},$$

$$= \frac{m}{m + \frac{1000}{18}} = \frac{1.33}{1.33 + (1000/18)}$$

Mole fraction of solute = 0.02

Mole fraction of solvent = 1 – 0.02 = 0.98

Concept Application

18. If 500 ml of 1 M solution of glucose is mixed with 500 ml of 1 M solution of glucose, final molarity of solution will be:

(*a*) 1 M (*b*) 0.5 M (*c*) 2 M (*d*) 1.5 M

19. The volume of water that must be added to a mixture of 250 ml of 0.6 M HCl and 750 ml of 0.2 M HCl to obtain 0.25 M solution of HCl is:

(*a*) 750 ml (*b*) 100 ml (*c*) 200 ml (*d*) 300 ml

20. The molarity of Cl^- in an aqueous solution which was (w/v) 2% NaCl, 4% $CaCl_2$ and 6% NH_4Cl will be:

(*a*) 0.342 (*b*) 0.721 (*c*) 1.12 (*d*) 2.18

21. 2M of 100 ml Na_2SO_4 is mixed with 3M of 100 ml NaCl solution and 1 M of 200 ml $CaCl_2$ solution. Then the ratio of the concentration of cation and anion.

(*a*) 1/2 (*b*) 2 (*c*) 1.5 (*d*) 1

22. Equal moles of H_2O and NaCl are present in a solution. Hence, molality of NaCl solution is :

(*a*) 0.55 (*b*) 55.5 (*c*) 1.00 (*d*) 0.18

23. Mole fraction of A in H_2O is 0.2. The molality of A in H_2O is:

(*a*) 13.9 (*b*) 15.5 (*c*) 14.5 (*d*) 16.8

24. What is the molarity of H_2SO_4 solution that has a density of 1.84 g/cc and contains 98% by mass of H_2SO_4? (Given atomic mass of S = 32)

(*a*) 4.18 M (*b*) 8.14M (*c*) 18.4 M (*d*) 18 M

25. The molarity of the solution containing 2.8% (mass/volume) solution of KOH is : (Given atomic mass of K = 39) is :

(*a*) 0.1 M (*b*) 0.5 M (*c*) 0.2 M (*d*) 1 M

STOICHIOMETRY BASED CONCEPT (PROBLEMS BASED ON CHEMICAL REACTION)

All chemical reaction are represented by chemical equations by using chemical formulae of reactants and products. Qualitatively a chemical equation simply describes what the reactants and products are. However, a balanced chemical equation gives us a lot of quantitative information mainly the molar ratio in which reactants combine and the molar ratio in which products are formed.

Example:

When potassium chlorate ($KClO_3$) is heated it gives potassium chloride (KCl) and oxygen (O_2).

$KClO_3 \longrightarrow KCl + O_2$ (unbalanced chemical equation)

$2KClO_3 \longrightarrow 2KCl + 3O_2$ (balanced chemical equation)

Attributes of a balanced chemical equation:

(*a*) It contains an equal number of atoms of each element on both sides of equation.

(*b*) It should follow law of charge conservation on either side.

(*c*) Physical states of all the reagents should be included in brackets.

(*d*) All reagents should be written in their standard molecular forms (not as atoms)

(*e*) The coefficients give the relative molar ratios of each reagent.

Balancing a chemical equation

Many chemical equations can be balanced by trial and error. Let us take the reactions of a few metals and non-metals with oxygen to give oxides

For Example:

Combustion reaction of C_2H_6 : $C_2H_6 + O_2 \rightarrow CO_2 + H_2O$ (skeleton equation)

Balance carbon atoms: $C_2H_6 + O_2 \rightarrow 2CO_2 + H_2O$

Now balance hydrogen atoms: $C_2H_6 + O_2 \rightarrow 2CO_2 + 3H_2O$

Now balance oxygen atoms: $C_2H_6 + \frac{7}{2}O_2 \rightarrow 2CO_2 + 3H_2O$

Always remember that subscripts in formula of reactants and products cannot be changed to balance an equation.

One of the most important aspects of a chemical equation is that when it is written in the balanced form, it gives quantitative relationships between the various reactants and products in terms of moles, masses, molecules and volumes.

Mole - Mole Analysis

This analysis is very much important for quantitative analysis point of view.

Consider the decomposition of $KClO_3$.

$$2KClO_3 \longrightarrow 2KCl + 3O_2$$

In very first step of mole-mole analysis you should read the balanced chemical equation like **2 moles $KClO_3$ on decomposition gives you 2 moles KCl and 3 moles O_2** and from the stoichiometry of reaction we can write

$$\frac{\text{Moles of } KClO_3}{2} = \frac{\text{Moles of KCl}}{2} = \frac{\text{Moles of } O_2}{3}$$

Now for any general balanced chemical equation like

$$aA + bB \longrightarrow cC + dD$$

you can write.

$$\frac{\text{Moles of A reacted}}{a} = \frac{\text{Moles of B reacted}}{b} = \frac{\text{Moles of C produced}}{c} = \frac{\text{Moles of D produced}}{d}$$

Further, a balanced chemical equation along with the quantitative information conveyed by it is given below:

$CaCO_3$	+ $2HCl \longrightarrow$	$CaCl_2$	+ H_2O	+ CO_2
1 Mole	2 Mole	1 Mole	1 Mole	1 Mole
40+12+3×16	2(1 + 35.5)	40+2×35.5	2×1+16	12+2×16
= 100 g	= 73 g	= 111 g	= 18 g	= 44 g or 22.4 L at STP

Thus,

(*i*) 1 mole of calcium carbonate reacts with 2 moles of hydrochloric acid to give 1 mole of calcium chloride, 1 mole of water and 1 mole of carbon dioxide.

(*ii*) 100 g of calcium carbonate react with 73 g hydrochloric acid to give 111 g of calcium chloride, 18 g of water and 44 g (or 22.4 litres at STP) of carbon dioxide.

Stoichiometry:

N_2	+ $3H_2$	$\rightarrow$ $2NH_3$
1 mole	3 mole	2 mole
22.4 litre	3 × 22.4 litre	2 × 22.4 litre (at STP)
1 litre	3 litre	2 litre
1000 mL	3000 mL	2000 mL
1 mL	3 mL	2 mL
28 gm	6 gm	34 g

(law of conservation of mass is followed).

- Mass can not be represented by stoichiometry.
- The quantitative information conveyed by a chemical equation helps in a number of calculations. The problems involving these calculations may be classified into the following different types:

Type (I) Mass - Mass Relationships i.e. mass of one of the reactants or products is given and the mass of some other reactant or product is to be calculated.

Mass - Mass Analysis

Consider the reaction $2\,KClO_3 \rightarrow 2KCl + 3O_2$

According to stoichiometry of the reaction

mass-mass ratio = 2 × 122.5 : 2 × 74.5 : 3 × 32

or $\dfrac{\text{Mass of } KClO_3}{\text{Mass of } KCl} = \dfrac{2\times122.5}{2\times74.5}$

$$\frac{\text{Mass of } KClO_3}{\text{Mass of } O_2} = \frac{2\times122.5}{3\times32}$$

Illustration: Calculate the weight of iron which will be converted into its oxide by the action of 36 g of steam.

(Given : $3Fe + 4H_2O \longrightarrow Fe_3O_4 + H_2$)

Sol. Mole ratio of reaction suggests,

$$\frac{\text{Mole of Fe}}{\text{Mole of } H_2O} = \frac{3}{4}$$

$$\therefore \text{Mole of Fe} = \frac{3}{4} \times \text{mol of } H_2O = \frac{3}{4}\times\frac{36}{18} = \frac{3}{2}$$

$$\text{wt. of Fe} = \frac{3}{2}\times 56 = 84\text{ g}$$

Illustration: What amount of silver chloride is formed by the action of 5.850 g of sodium chloride on an excess of silver nitrate?

Sol. Writing the balanced equation for the reaction

NaCl	+ $AgNO_3 \longrightarrow$	AgCl	+ $NaNO_3$
1 mol	1 mol	1 mol	1 mol

$$n_{NaCl} = \frac{\text{Weight}}{M_w} = \frac{5.85}{58.5} = 0.1\text{ mol}$$

$$\frac{\text{mole(NaCl)}}{\text{mole(AgCl)}} = \frac{1}{1}$$

$$\Rightarrow \text{mole (AgCl)} = 0.1 = \frac{\text{Weight}}{M_w} = \frac{\text{Weight}}{143.5}$$

$\Rightarrow$ weight = 0.1 × 143.5 g = 14.35 g.

Illustration: How much iron can be theoretically obtained in the reduction of 1 kg of Fe_2O_3?

Sol. Writing the balanced equation for the decomposition reaction. $Fe_2O_3 \rightarrow 2Fe + \frac{3}{2}O_2$

$$n_{Fe_2O_3} = \frac{\text{Weight}}{M_w} = \frac{1000}{160}\text{ mol}$$

$$\frac{\text{mole}(Fe_2O_3)}{\text{mole(Fe)}} = \frac{1}{2}$$

$$\Rightarrow \text{moles of Fe} = \frac{2\times1000}{160} = 12.5\text{ mol}$$

$$= \frac{\text{Weight}}{\text{Atomic weight}} = \frac{\text{Weight}}{56}$$

Weight of iron obtained = 12.5 × 56 g = 700 g

Type (II) Mass - Volume Relationships i.e. mass/volume of one of the reactants or products is given and the volume/mass of the other is to be calculated.

$$2KClO_3 \longrightarrow 2KCl + 3O_2$$

Mass volume ratio =

2 × 122.5 g : 2 × 74.5 g : 3 × 22.4 L at STP

we can use two relation for volume of oxygen

$$\frac{\text{Mass of } KClO_3}{\text{Volume of } O_2 \text{ at STP}} = \frac{2\times122.5\text{ g}}{3\times22.4\text{ L}} \quad \text{...(i)}$$

and $\dfrac{\text{Mass of KCl}}{\text{Volume of } O_2 \text{ at STP}} = \dfrac{2\times74.5\text{ g}}{3\times22.4\text{ L}}$ ...(ii)

Illustration: How much marble of 90.5% purity would be required to prepare 10 litres of CO_2 at STP when the marble is acted upon by dilute HCl?

Sol. $\underset{100\text{ g}}{CaCO_3} + 2HCl \longrightarrow CaCl_2 + H_2O + \underset{22.4\text{litre}}{CO_2}$

22.4 L of CO_2 at STP will be obtained from 100 g of $CaCO_3$

$\therefore$ 10 L of CO_2 at STP will be obtained from pure

$$CaCO_3 = \frac{100}{22.4}\times10 = 44.64\text{ g}$$

$$\therefore \text{Impure marble required} = \frac{100}{90.5}\times 44.64 = 49.326\text{ g}$$

Illustration: At 100°C for complete combustion of 3g ethane the required volume of O_2 & produced volume of CO_2 at STP will be?

Sol. $\underset{2}{2C_2H_6} + \underset{7}{7O_{2(g)}} \rightarrow \underset{4}{4CO_{2(g)}} + \underset{6}{6H_2O_{(g)}}$

$$n_{C_2H_6} = \frac{\text{Weight}}{M_w} = \frac{3}{30} = \frac{1}{10} = 0.1 \text{ mol}$$

$\therefore$ Required moles of $O_2 = \frac{7}{2} \times 0.1 = 0.35$ mol.

Required Volume of O_2 at STP = 0.35 × 22.4 = 7.84 L.

And produced moles of $CO_2 = \frac{4}{2} \times 0.1 = 0.2$ mol.

Volume of CO_2 obtained at STP = 0.2 × 22.4 = 4.48 L.

Illustration: In the following reaction, if 10 g of H_2 is reacted with N_2, what will be the volume of NH_3 produced at STP?

$$N_2 + 3H_2 \longrightarrow 2NH_3$$

Sol. $N_2 + 3H_2 \longrightarrow 2NH_3$

$$n_{H_2} = \frac{\text{Weight}}{M_w} = \frac{10}{2} = 5 \text{ mol.}$$

Produced moles of $NH_3 = \frac{2}{3} \times 5 = \frac{10}{3}$.

Volume of NH_3 produced at STP $= \frac{10}{3} \times 22.4 = 74.67$ L

Type (III) Volume - Volume Relationships i.e. volume of one of the reactants or the products is given and the volume of the other is to be calculated.

Illustration: At 100°C for complete combustion of 1.12 litre of butane (C_4H_{10}), the produced volume of H_2O(g) & CO_2 at STP will be.

Sol. 1 $\quad 13/2 \quad 4 \quad 5$

$C_4H_{10(g)} + 13/2\ O_{2(g)} \rightarrow 4CO_{2(g)} + 5H_2O_{(g)}$

1.12 litre

Volume of $H_2O_{(g)}$ at STP = 5 × 1.12 = 5.6 litre

Volume of $CO_{2(g)}$ at STP = 4 × 1.12 = 4.48 litre

Illustration: At 25°C for complete combustion of 5 mole propane (C_3H_8), the required volume of O_2 at STP will be?

Sol. For C_3H_8, the combustion reaction is

$C_3H_{8(g)} + 5O_{2(g)} \longrightarrow 3CO_{2(g)} + 4H_2O_{(g)}$

5 mol

Required moles of $O_2 = 5 \times 5 = 25 \text{ mol} = \frac{V}{22.4}$.

Volume of O_2 gas at STP (V) = 25 × 22.4 = 560 L.

Illustration: 3 litre of mixture of propane (C_3H_8) & butane (C_4H_{10}) on complete combustion give 10 litre CO_2. Find the composition of the mixture.

Sol. Let the volume of propane in the mixture = x litre,

$\therefore$ The volume of butane in the mixture = (3 – x) litre

Now let us calculate the volume of CO_2 evolved with the help of chemical equation.

Step-I: Calculation of volume of CO_2 from x litre of propane.

$C_3H_8 + 5O_2 \longrightarrow 3CO_2 + 4H_2O$

x litre $\quad$ 3x litre

Step-II: Calculation of volume of CO_2 from (3 – x) litre of butane. The combustion equation for butane is:

$C_4H_{10} + \frac{13}{2}O_2 \longrightarrow 4CO_2 + 5H_2O$

(3–x) litre $\quad$ 4(3–x) litre

Step-III: Calculation of composition of the mixture.

Total volume of CO_2 formed in the step (I) and step (II) = [3x + 4(3 – x)] litre

But the volume of CO_2 actually formed = 10 litre

3x + 4(3 – x) = 10

or 3x + 12 – 4x = 10 $\quad$ or $\quad$ x = 2 litre

$\therefore$ Volume of propane = x litre = 2 litre

$\therefore$ Volume of butane = (3 – x) litre = (3 – 2) = 1 litre

Train Your Brain

Example 26: Write a balanced chemical equation for the following reaction:

When ammonia (NH_3) decompose into nitrogen (N_2) gas & hydrogen (H_2) gas.

Sol. $NH_3 \rightarrow \frac{1}{2}N_2 + \frac{3}{2}H_2$ or $2NH_3 \rightarrow N_2 + 3H_2$

Example 27: When 170 g NH_3 (M =17) decomposes, how many grams of N_2 & H_2 is produced?

Sol. $NH_3 \rightarrow \frac{1}{2}N_2 + \frac{3}{2}H_2$

$$\frac{\text{moles of } NH_3}{1} = \frac{\text{moles of } N_2}{1/2} = \frac{\text{moles of } H_2}{3/2}$$

So, moles of $N_2 = \frac{1}{2} \times \frac{170}{17} = 5$

So, wt. of N_2 = 5 × 28 = 140 g

Similarly moles of $H_2 = \frac{3}{2} \times \frac{170}{17} = 15$

So, wt. of H_2 = 15 × 2 = 30 g.

Example 28: When 340 g NH_3 (M = 17) decomposes, how many litres of nitrogen gas is produced at STP?

(*a*) 2.24 L (*b*) 22.4 L (*c*) 224 L (*d*) None

Sol. $NH_3 \rightarrow \frac{1}{2}N_2 + \frac{3}{2}H_2$

Moles of $NH_3 = \frac{340}{17} = 20$

So moles of $N_2 = \frac{1}{2} \times 20 = 10$

$\therefore$ Vol. of N_2 at STP = 10 × 22.4 = 224 L.

Concept Application

26. If 1.5 moles of dioxygen combine with Al to form Al_2O_3, the weight of Al used in the reaction is:
(*a*) 27 g (*b*) 40.5 g (*c*) 54 g (*d*) 81 g

27. How many litres of CO_2 at STP will be formed when 0.01 mol of H_2SO_4 reacts with excess of Na_2CO_3?
$Na_2CO_3 + H_2SO_4 \longrightarrow Na_2SO_4 + CO_2 + H_2O$
(*a*) 22.4 L (*b*) 2.24 L (*c*) 0.224 L (*d*) 1.12L

28. How many moles of potassium chlorate need to be heated to produce 11.2 litre oxygen at S.T.P.?

$$KClO_3 \longrightarrow KCl + \frac{3}{2}O_2$$

(*a*) $\frac{1}{2}$mol (*b*) $\frac{1}{3}$mol
(*c*) $\frac{1}{4}$mol (*d*) $\frac{2}{3}$mol

LIMITING REAGENT (L.R.) CONCEPT

Quite often one of the reactants is present in larger amount than the other as required according to the balanced equation. The amount of the product formed then depends upon the reactant which has reacted completely. This reactant is called the limiting reactant. The excess of the other is left unreacted.

Limiting Reagent (L.R.): The reactant which is completely consumed in a reaction is called as L.R.

Calculation of Limiting Reagent:

(*a*) By calculating the required amount by the equation and comparing it with given amount. [Useful when only two reactant are there]

(*b*) By calculating amount of any one product obtained taking each reactant one by one irrespective of other reactants. The one giving least product is limiting reagent.

(*c*) Divide given moles of each reactant by their stoichiometric coefficient, the one with least ratio is limiting reagent. [Useful when number of reactants are more than two.]

Ex.	A	+	2B	$\longrightarrow$	C	+	2D
Given moles	3		9		0		0
	3 – 3		9 – 6				
	0		3		3		6

A is L.R.

Formula for checking L.R. =

$$\frac{\text{Given value (moles, volume, or molecules)}}{\text{Stoichiometry Coefficient}}$$

Least value indicate the L.R.

Ex. A B

$\frac{3}{1} = 3$ $\frac{9}{2} = 4.5$

3 < 4.5 So, A is L.R

PERCENTAGE YIELD

The percentage yield of product

$$= \frac{\text{Actual yield}}{\text{theoretical maximum yield}} \times 100$$

The actual amount of any limiting reagent consumed is given by (% yield × given moles of limiting reagent).

Train Your Brain

Example 29: $\underset{10\text{mole}}{A} + \underset{10\text{mole}}{5B} \longrightarrow C + 3D$, in this reaction which is a L.R.?

Sol. For A For B

$\frac{10}{1} = 10$ $\frac{10}{5} = 2$

2 < 10 So, B is L.R.

Example 30: $\underset{4g}{H_2(g)} + \underset{32g}{\frac{1}{2}O_2(g)} \longrightarrow H_2O(g)$; in the above reaction, what is the volume of water vapour produced at STP?

(*a*) 4.48 L (*b*) 44.8 L
(*c*) 2.24 L (*d*) 11.2 L

Sol. $\underset{4g}{H_2(g)} + \underset{32g}{\frac{1}{2}O_2(g)} \longrightarrow H_2O(g)$

For H_2 For O_2

$n = \frac{4}{2} = 2\text{mol}$ $n = \frac{32}{32} = 1\text{mol}$

For L.R. $\frac{2}{1} = 2$ $\frac{1}{\frac{1}{2}} = 2$ mol

Moles of $H_2O_{(g)}$ produced = 2 mol = $\frac{V}{22.4}$

Both H_2 & O_2 are L.R.

Volume of $H_2O_{(g)}$ produced at STP = 22.4 × 2

= 44.8 litre

Example 31: At STP, In a container 100 mL N_2 and 100 mL of H_2 are mixed together. Then find out the produced volume of NH_3.

(*a*) 6.66 mL (*b*) 66.6 mL
(*c*) 3.33 mL (*d*) 5.55 mL

Sol. Balanced equation will be $N_2 + 3H_2 \rightarrow 2NH_3$.

Given 100mL 100mL

For determination of Limiting reagent. Divide the given quantities by stoichiometry coefficients

$\frac{100}{1} = 100$ $\frac{100}{3} = 33.3$ (Limiting reagent)

In this reaction H_2 is limiting reagent so reaction will proceed according to H_2.

According to stoichiometry from 3 mL of H_2 produced volume of NH_3 = 2 ml

That is from 100 ml of H_2 produced volume of

$NH_3 = \frac{2}{3} \times 100 = 66.6$ mL

Example 32: Number of moles of NH_3 produced if 140 gm of N_2 reacts with 40 gm of hydrogen. (Given % yield of reaction is 50%)

(*a*) 12 (*b*) 10 (*c*) 5 (*d*) 6

Sol. $N_2 + 3H_2 \xrightarrow{50\%} 2NH_3$

140 gm 40 gm

or 5 mol 20 mol

$\therefore$ Number of moles of NH_3 produced = 5×2×0.5 = 5 mole

Concept Application

29. 4 mole of $MgCO_3$ is reacted with 6 moles of HCl solution. Find the volume of CO_2 gas (in litres) produced at STP, the reaction is:

$MgCO_3 + 2HCl \rightarrow MgCl_2 + CO_2 + H_2O$.

(*a*) 11.2 (*b*) 22.4

(*c*) 67.2 (*d*) 44.8

30. For a reaction, $N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$; which of the following reaction mixtures has dihydrogen (H_2) as a limiting reagent, :

(*a*) 14g of N_2 + 4g of H_2 (*b*) 35g of N_2 + 8g of H_2

(*c*) 28g of N_2 + 6g of H_2 (*d*) 56g of N_2 + 10g of H_2

31. The percent yield for the following reaction carried out in carbon tetrachloride (CCl_4) solution is 80%.

$Br_2 + Cl_2 \longrightarrow 2BrCl$

How many moles of BrCl is formed from the reaction of 0.025 mol Br_2 and 0.025 mol Cl_2?

(*a*) 0.04 (*b*) 0.08]

(*c*) 0.02 (*d*) 0.01

32. If 240 g of carbon is taken in a container to convert it completely to CO_2 but in industry it has been found that 280 g of CO was also formed along with CO_2. Find the mole percentage yield of CO_2. The reactions occurring are:

$$C + O_2 \longrightarrow CO_2; C + \frac{1}{2}O_2 \longrightarrow CO$$

(*a*) 25 (*b*) 50 (*c*) 75 (*d*) 35

ADVANCED LEARNING

SEQUENTIAL REACTION

Here, we solve problems in which the products of one reaction are used up in one or more subsequent reactions. In order to attempt such problems the following solving strategy has to be used.

(*i*) The balanced and molecular equations are written for all reactions involved separately.

(*ii*) Later the equations are multiplied, as a whole, by suitable factors, so that products of one reaction which are utilized in subsequent reactions are cancelled out.

(*iii*) The final reaction obtained is used to find out the required quantities.

Illustration: How many kilograms of pure H_2SO_4 could be obtained from one kilogram of pure iron pyrites (FeS_2) according to the following reactions?

$4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + 8SO_2$

$2SO_2 + O_2 \longrightarrow 2SO_3$

$SO_2 + H_2O \longrightarrow H_2SO_4$

(*a*) 0.184kg (*b*) 1.633kg

(*c*) 2.643kg (*d*) 3.234kg

Sol. Gram molecular weight of FeS_2 = 120g

Gram molecular weight of H_2SO_4 = 98 g

Let us multiply the equations with suitable factors.

$4FeS_2 + 11\ O_2 \longrightarrow 2Fe_2O_3 + 8\ SO_2$

$2SO_2 + O_2 \longrightarrow 2SO_3 \times 4$

$SO_3 + H_2O \longrightarrow H_2SO_4 \times 8$

$$\left\{\begin{array}{l} 4FeS_2 + 11O_2 \longrightarrow 2Fe_2O_3 + \cancel{8SO_2} \\ \cancel{8SO_2} + 4O_2 \longrightarrow \cancel{8SO_3} \\ \cancel{8SO_3} + 8H_2O \longrightarrow 8H_2SO_4 \end{array}\right.$$

$$\underline{4FeS_2 + 15O_2 + 8H_2O \longrightarrow 2Fe_2O_3 + 8H_2SO_4}$$

From the above, it is clear that, 4 moles of FeS_2 produces 8 moles of H_2SO_4 (or)

1 mole of $FeS_2 \xrightarrow{\text{produces}}$ 2 moles of H_2SO_4

$\therefore$ 120g (1 mole) of $FeS_2 \xrightarrow{\text{produces}}$ 2 × 98 g (2 moles) of H_2SO_4

$\therefore$ 1000g (1 kg) of $FeS_2 \xrightarrow{\text{produces}} \frac{1000\times2\times98}{120} = 1633.33$ g

or 1.633 kg of H_2SO_4

Therefore, 1.633 kg of H_2SO_4 is produced from 1 kg of iron pyrites.

Illustration: 20 g of $KC1O_3$ on heating give enough oxygen to react completely with hydrogen produced by the action of dil. H_2SO_4 on zinc. Find the weight of zinc required for the purpose. The reactions are as follows: (K = 39, Zn = 65, Cl = 35.5)

(*i*) $2KClO_3 \longrightarrow 2KCl + 3O_2$
(*ii*) $Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2$
(*iii*) $H_2 + O_2 \longrightarrow H_2O$

(*a*) 13.84g (*b*) 21.48g
(*c*) 31.84g (*d*) 43.48g

Sol. Gram molecular weight of $KClO_3$ = 122.5 g
Gram atomic weight of zinc = 65 g
Let us multiply the equations with suitable factors.

$$\left.\begin{array}{l} 2KClO_3 \longrightarrow 2KCl + 3O_2 \\ Zn + H_2SO_4 \longrightarrow ZnSO_4 + H_2 \times 6 \\ H_2 + \tfrac{1}{2} O_2 \longrightarrow H_2O \times 6 \end{array}\right\}$$

$$2KClO_3 \longrightarrow 2KCl + \cancel{3O_2}$$
$$6Zn + 6H_2SO_4 \longrightarrow 6ZnSO_4 + \cancel{6H_2}$$
$$\cancel{6H_2} + \cancel{3O_2} \longrightarrow 6H_2O$$
$$2KClO_3 + 6Zn + 6H_2SO_4 \longrightarrow 2KCl + 6ZnSO_4 + 6H_2O$$

From the above, it is clear that, 2 moles of $KClO_3$ requires 6 moles of Zn (or)

1 mole of $KClO_3 \xrightarrow{\text{requires}}$ 3 moles of Zn

$\therefore$ 122.5 g (l mole) of $KClO_3 \xrightarrow{\text{requires}} 3\times 65$ g (3 moles) of Zn

$\therefore$ 20 g of $KClO_3 \xrightarrow{\text{requires}} \dfrac{20\times3\times65}{122.5}$ = 31.84 g of Zn

Therefore, 31.84 g of Zn is required for the given purpose.

POAC

POAC is based upon law of conservation of mass. Atoms are conserved, hence moles of atoms shall also be conserved in a chemical reaction (but not in nuclear reactions.)

Consider the reaction:

$KClO_3(s) \rightarrow KCl(s) + O_2(g)$ (unbalanced chemical reaction)

Apply POAC for K atoms.

Moles of K atoms in reactant ($KClO_3$) = moles of K atoms in product (KCl)

Moles of K atoms in $KClO_3$ = 1 × moles of $KClO_3$
and moles of K atoms in KCl = 1 × moles of KCl.
$\therefore$ moles of $KClO_3$ = moles of KCl

or $\dfrac{\text{wt. of } KClO_3 \text{ in g}}{\text{mol. wt. of } KClO_3} = \dfrac{\text{wt. of KCl in g}}{\text{mol. wt. of KCl}}$

Again, applying the POAC for O atoms,
moles of O in $KClO_3$ = 3 × moles of $KClO_3$
moles of O in O_2 = 2 × moles of O_2
$\therefore$ 3 × moles of $KClO_3$ = 2 × moles of O_2

or $3\times\dfrac{\text{wt. of } KClO_3}{\text{mol. wt. of } KClO_3} = 2\times\dfrac{\text{vol. of } O_2 \text{ at STP}}{22.4 \text{ L}}$

Illustration: 0.32 mole of $LiAlH_4$ in ether solution was placed in a flask and 74 g (1 moles) of t-butyl alcohol was added. The product is $LiAlHC_{12}H_{27}O_3$. Find the weight of the product if lithium atoms are conserved.

[Li = 7, Al = 27, H = 1, C = 12, O = 16]

Sol. Applying POAC for lithium atoms,

1 × moles of $LiAlH_4$ = 1× moles of LiAlH $C_{12}H_{27}O_3$

$0.32 = 1 \times \dfrac{\text{weight of LiAlH } C_{12}H_{27}O_3}{254}$

wt. of LiAlH $C_{12}H_{27}O_3$ = 81.28 g.

Illustration: 27.6 g K_2CO_3 was treated by a series of reagents so as to convert all of its carbon to $K_2Zn_3\,[Fe(CN)_6]_2$. Calculate the weight of the product.

[mol. wt. of K_2CO_3 = 138 and mol. wt. of $K_2Zn_3\,[Fe(CN)_6]_2$ = 698]

Sol. Here we have not knowledge about series of chemical reactions but we known about initial reactant and final product accordingly

$K_2CO_3 \xrightarrow[\text{Steps}]{\text{Several}} K_2Zn_3\,[Fe(CN)_6]_2$

Since C atoms are conserved, applying POAC for C atoms,

moles of C in K_2CO_3 = moles of C in $K_2Zn_3\,[Fe(CN)_6]_2$

1 × moles of K_2CO_3 = 12 × moles of $K_2Zn_3\,[Fe(CN)_6]_2$

$\dfrac{\text{wt. of } K_2CO_3}{\text{mol. wt. of } K_2CO_3} = 12\times\dfrac{\text{wt. of the product}}{\text{mol. wt. of product}}$

wt. of $K_2Zn_3\,[Fe(CN)_6]_2 = \dfrac{27.6}{138}\times\dfrac{698}{12}$ = 11.6 g

STRENGTH (LABELLING) OF OLEUM

Oleum is SO_3 dissolved in 100% H_2SO_4. Sometimes, oleum is reported as more than 100% by weight, say y% (where y > 100). This means that (y - 100) grams of water, when added to 100 g of given oleum sample, will combine with all the free SO_3 in the oleum to give 100% sulphuric acid. Hence,

weight % of free SO_3 in oleum = 80 (y–100)/18.

Example: If in a sample of oleum, mole fraction of SO_3 is 0.5. Label the oleum sample.

Sol. Total moles = 1

Moles of SO_3 = mole of H_2SO_4 = 0.5

Total Mass of SO_3 & H_2SO_4 = 40 + 49 = 89 gm

$SO_3 + H_2O \longrightarrow H_2SO_4$

0.5 0.5

Mass of H_2O required = 0.5 × 18 = 9 gm

89 gm require 9 gm H_2O

100 gm require = $\dfrac{9}{89}\times100 = 10.11$ gm

% Labelling = (100 + 10.11) = 110.11%

AARAMBH (SOLVED EXAMPLES)

1. 1.80 g of a certain metal burnt in oxygen gave 3.0 g of its oxide. 1.50 g of the same metal heated in steam gave 2.50 g of its oxide. The law shown by above data is:

(*a*) Law of constant proportion
(*b*) Law of multiple proportion
(*c*) Law of reciprocal proportion
(*d*) All of the above

Sol. In the first sample of oxide,

Weight of metal = 1.80 g;

Weight of oxygen = (3.0 – 1.80) g = 1.2 g

$$\therefore \frac{\text{wt of metal}}{\text{wt of oxygen}} = \frac{1.80\text{g}}{1.2\text{g}} = 1.5$$

In the second sample of the oxide,

Weight of metal = 1.50 g;

Weight of oxygen = (2.50 - 1.50) g = 1 g

$$\frac{\text{wt of metal}}{\text{wt of oxygen}} = 1.5$$

Thus, in both samples of the oxide, the proportions of the weights of the metal and oxygen are fixed. Hence the results follow the law of constant proportion.

Therefore, option (*a*) is the correct answer.

2. Calculate the total charge present on 4.2 gm of N^{3-}.

(*a*) 8.67×10^4 C (*b*) 9.05×10^4 C
(*c*) 8.67×10^3 C (*d*) 7.67×10^4 C

Sol. Mole = $\frac{\text{wt. in gm}}{\text{Ionic wt.}} = \frac{4.2}{14} = 0.3$

Total no. of ions = $0.3 \times N_A$ ions.

Total charge = $0.3\, N_A \times 3 \times 1.6 \times 10^{-19}$ C

= $0.3 \times 6.022 \times 10^{23} \times 3 \times 1.6 \times 10^{-19} = 8.67 \times 10^4$ C

Therefore, option (*a*) is the correct answer.

3. How many carbon atoms are present in 0.35 mol of $C_6H_{12}O_6$?

(*a*) 6.022×10^{23} carbon atoms.
(*b*) 1.26×10^{23} carbon atoms.
(*c*) 1.26×10^{24} carbon atoms.
(*d*) 6.022×10^{24} carbon atoms.

Sol. $\because$ 1 mol of $C_6H_{12}O_6$ has 6 N_A atoms of C

$\therefore$ 0.35 mol of $C_6H_{12}O_6$ has $6 \times 0.35\, N_A$ atoms of C

= $2.1\, N_A$ atoms = $2.1 \times 6.022 \times 10^{23} = 1.26 \times 10^{24}$ carbon atoms.

Therefore, option (*c*) is the correct answer.

4. How many molecules are present in 5.23 gm of glucose ($C_6H_{12}O_6$)?

(*a*) 1.65×10^{22} (*b*) 1.75×10^{22}
(*c*) 1.75×10^{21} (*d*) None of these

Sol. $\because$ 180 gm glucose has = N_A molecules

$\therefore$ 5.23 gm glucose has = $\frac{5.23 \times 6.022 \times 10^{23}}{180}$

= 1.75×10^{22} molecules

Therefore, option (*b*) is the correct answer.

5. A sample of (C_2H_6) ethane has the same mass as 10^7 molecules of methane. How many C_2H_6 molecules does the sample contain?

(*a*) 5.34×10^6 (*b*) 1.26×10^8
(*c*) 4.26×10^6 (*d*) 6.022×10^6

Sol. Moles of $CH_4 = \frac{10^7}{N_A}$

Mass of $CH_4 = \frac{10^7}{N_A} \times 16$ = mass of C_2H_6

So Moles of $C_2H_6 = \frac{10^7 \times 16}{N_A \times 30}$

So no. of molecules of $C_2H_6 = \frac{10^7 \times 16}{N_A \times 30} \times N_A = 5.34 \times 10^6$.

Therefore, option (*a*) is the correct answer.

6. From 160 g of SO_2 (g) sample, 1.2046×10^{24} molecules of SO_2 are removed then find out the volume of left over SO_2 (g) at STP.

(*a*) 11.2 L (*b*) 12.5 L
(*c*) 9.5 L (*d*) 10.8 L

Sol. Given moles = $\frac{160}{64}$ = 2.5.

Removed moles = $\frac{1.2046 \times 10^{24}}{6.022 \times 10^{23}}$ = 2.

So left moles = 0.5.

Volume left at STP = 0.5×22.4 = 11.2 L.

Therefore, option (*a*) is the correct answer.

7. 14 g of Nitrogen gas and 22 g of CO_2 gas are mixed together. Find the volume of gaseous mixture at STP.

(*a*) 10.2 L (*b*) 12.2 L
(*c*) 15.5 L (*d*) 22.4 L

Sol. Moles of $N_2 = \frac{14}{28}$ = 0.5.

Moles of $CO_2 = \frac{22}{44}$ = 0.5.

So total moles = 0.5 + 0.5 = 1.

So vol. at STP = 1×22.4 = 22.4 L.

Therefore, option (*d*) is the correct answer.

8. How many years it would take to spend Avogadro's number of rupees at the rate of 1 million rupees per second?

(*a*) 19.098×10^{19} years (*b*) 19.098 years
(*c*) 19.098×10^9 years (*d*) None of these

Sol. $\because$ 10^6 rupees are spent in 1 sec.

$\therefore$ 6.022×10^{23} rupees are spent in

$\frac{1\times6.022\times10^{23}}{10^6}$ sec

or $\frac{1\times6.022\times10^{23}}{10^6\times60\times60\times24\times365}$ years = 19.098×10^9 years

Therefore, option (*c*) is the correct answer.

9. The density of O_2 at STP is 1.429g/litre. Calculate the standard molar volume of gas.

(*a*) 22.4 lit. (*b*) 11.2 lit (*c*) 33.6 lit (*d*) 5.6 lit.

Sol. $\because$ 1.429 gm of O_2 gas occupies volume = 1 litre.

$\therefore$ 32 gm of O_2 gas occupies = $\frac{32}{1.429}$ = 22.4 litre/mol.

Therefore, option (*a*) is the correct answer.

10. Calculate the weight of lime (CaO) obtained by heating 200 kg of 95% pure lime stone ($CaCO_3$).

(*a*) 104.4 kg (*b*) 105.4 kg

(*c*) 212.8 kg (*d*) 106.4 kg

Sol. $\because$ 100 kg impure sample has pure

$CaCO_3$ = 95 kg

$\therefore$ 200 kg impure sample has pure $CaCO_3$

$= \frac{95\times200}{100}$ = 190 kg.

$CaCO_3 \rightarrow CaO + CO_2$

$\because$ 100 kg $CaCO_3$ gives CaO = 56 kg.

$\therefore$ 190 kg $CaCO_3$ gives CaO = $\frac{56\times190}{100}$ = 106.4 kg.

Therefore, option (*d*) is the correct answer.

11. A compound containing beryllium has the following composition, Be = 6.1%, N = 37.8%, Cl=48%, H = 8.1%. One mole of the compound has mass of 148g and average atomic mass of beryllium is 9. The molecular formula of the compound is:

(*a*) $BeN_4H_{12}Cl_2$ (*b*) $BeN_2H_{10}Cl$

(*c*) $BeN_4H_2Cl_3$ (*d*) $Be_2N_4H_{10}Cl_2$

Sol.

Element	%	%/A	Simplest ratio
Be	6.1	6.1/9 = 0.677	1
N	37.8	37.8/14 = 2.7	4
Cl	48	48/35.5 = 1.35	2
H	8.1	8.1/1 = 8.1	12

Empirical formula = $BeN_4Cl_2H_{12}$

= 9 + 56 + 71 +12

= 148 $\Rightarrow$ n = 1

Molecular formula = $BeN_4Cl_2H_{12}$

Therefore, option (*a*) is the correct answer.

12. One litre of a mixture of CO and CO_2 is passed through red hot charcoal in tube. The new volume becomes 1.4 litre. Find out % composition of mixture by volume. All measurements are made at same P and T.

(*a*) CO_2 40%, CO 60% (*b*) CO_2 60%, CO 40%

(*c*) CO_2 25%, CO 75% (*d*) CO_2 30%, CO 70%

Sol. On passing through charcoal only CO_2 reduces to CO.

	$CO + C \longrightarrow$ No reaction	
Volume	a	
	$CO_2 + C \longrightarrow 2\,CO$	
Volume before reaction	b	0
Volume after reaction	0	2b
As given	a + b = 1 and	a + 2b = 1.4

$\therefore$ b = 0.4 litre $\therefore$ % of b = $\frac{0.4}{1}\times100 = 40$ %

$\therefore$ a = 0.6 litre $\therefore$ % of a = $\frac{0.6}{1}\times100 = 60$ %

Therefore, option (*a*) is the correct answer.

13. Calculate the molarity of H^+ ion in the resulting solution when 200 ml 0.5M HCl is mixed with 200 ml 0.5M H_2SO_4

Sol. n_{H^+} = 0.1 (from HCl) & n_{H^+} = 0.2 (from H_2SO_4)

Total $H^+ = n_{H^+}$ (from HCl) + n_{H^+} (from H_2SO_4) = 0.1 + 0.2 = 0.3

Total volume = 200 + 200 = 400 mL = 0.4 L

MR = Resultant molarity = $\frac{n_{H^+}}{V_{solution}} = \frac{0.3}{0.4}$ = 0.75 M Ans.

Therefore, [0.75] is the correct answer.

14. What are the final concentration of all the ions when following are mixed 50 ml of 0.12 M $Fe(NO_3)_3$ + 100 ml of 0.1 M $FeCl_3$ + 100 ml of 0.26 M $Mg(NO_3)_2$.

Sol. $[NO_3^-] = \frac{50\times0.12\times3+100\times0.26\times2}{250} = \frac{18+52}{250} = \frac{70}{250} = 0.28$

$[Cl^-]$ = 0.12 M; $[Mg^{++}]$ = 0.104 M; $[Fe^{3+}]$ = 0.064 M

Therefore, [0.064] is the correct answer.

15. A sample of 3 g containing Na_2CO_3 and $NaHCO_3$ loses 0.248 g when heated to 300°C, the temperature at which $NaHCO_3$ decomposes to Na_2CO_3, CO_2 and H_2O. What is the percentage of Na_2CO_3 in the given mixture?

Sol. The loss in weight is due to removal of CO_2 and H_2O which escape out on heating.

wt. of Na_2CO_3 in the product = 3.00 – 0.248 = 2.752 g

Let wt. of Na_2CO_3 in the mixture be x g

$\therefore$ wt. of $NaHCO_3$ = (3.00 – x) g

Since Na_2CO_3 in the products contains x g of unchanged reactant Na_2CO_3 and rest produced from $NaHCO_3$.

The wt. of Na_2CO_3 produced by $NaHCO_3$ = (2.752 – x)g

$NaHCO_3 \longrightarrow Na_2CO_3 + (H_2O + CO_2)\uparrow$

(3.0 – x) (2.752 – x)

Applying POAC for Na atom

1 × moles of $NaHCO_3$ = 2 × moles of Na_2CO_3

$\Rightarrow \frac{(3-x)}{84} = 2\times\frac{(2.752-x)}{106}$

$\therefore$ x = 2.328 g

$\therefore$ % of Na_2CO_3 = $\frac{2.328}{3}\times100 = 77.6$ %

Therefore, [77.6] is the correct answer.

SCHOOL LEVEL PROBLEMS

SINGLE CORRECT TYPE QUESTIONS

1. 6.02×10^{20} molecules of urea are present in 100 mL of its solution. The concentration of the solution is

(*a*) 0.02 M (*b*) 0.01 M
(*c*) 0.001 M (*d*) 0.1 M

2. 10 mol of Zn react with 10 mol of HCl. Calculate the number of moles of H_2 produced.

(*a*) 5 mol (*b*) 10 mol
(*c*) 20 mol (*d*) 2.5 mol

3. One mole of any substance contains 6.022×10^{23} atoms/molecules. Number of molecules of H_2SO_4 present in 100 mL of 0.02M H_2SO_4 Solution is

(*a*) 12.044×10^{20} molecules
(*b*) 6.022×10^{23} molecules
(*c*) 1×10^{23} molecules
(*d*) 12.044×10^{23} molecules

4. What is the mass percent of carbon in carbon dioxide?

(*a*) 0.034% (*b*) 27.27%
(*c*) 3.4% (*d*) 28.7%

5. Which of the following statements about a compound is incorrect?

(*a*) A molecule of a compound has atoms of different elements.
(*b*) A compound cannot be separated into its constituent elements by physical methods of separation.
(*c*) A compound retains the physical properties of its constituent elements.
(*d*) The ratio of atoms of different elements in a compound is fixed.

6. Which of the following statements is correct about the reaction given below:

$$4Fe(s) + 3O_2(g) \rightarrow 2Fe_2O_3(g)$$

(*a*) Total mass of iron and oxygen in reactants = total mass of iron and oxygen in product therefore it follows law of conservation of mass.
(*b*) Total mass of reactants = total mass of product; therefore, law of multiple proportions is followed.
(*c*) Amount of Fe_2O_3 can be increased by taking any one of the reactants (iron or oxygen) in excess.
(*d*) Amount of Fe_2O_3 produced will decrease if the amount of any one of the reactants (iron or oxygen) is taken in excess.

7. Number of atoms of He in 100 u of He (Atomic mass of He is 4 u)

(*a*) 25 (*b*) 50
(*c*) 100 (*d*) 400

8. A gaseous hydrocarbons gives upon combustion, 0.72 g of water and 3.08 g of CO_2. The empirical formula of the hydrocarbon is:

(*a*) C_6H_5 (*b*) C_7H_8
(*c*) C_2H_4 (*d*) C_3H_4

9. **Assertion:** No. of moles of H_2 in 0.224 L of hydrogen is 0.01 mole.

Reason: 22.4 L of H_2 at STP contain 6.022×10^{23} moles.

(*a*) Both Assertion and Reason are true and Reason is correct explanation of Assertion.
(*b*) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion.
(*c*) Assertion is true but Reason is false.
(*d*) Assertion is false but Reason is true.

10. **Assertion:** The empirical mass of ethene is half of its molecular mass.

Reason: The empirical formula represents the whole number ratio of various atoms present in a compound.

(*a*) Both Assertion and Reason are true and Reason is correct explanation of Assertion.
(*b*) Both Assertion and Reason are true but Reason is not a correct explanation of Assertion.
(*c*) Assertion is true but Reason is false.
(*d*) Assertion is false but Reason is true.

MATCH THE COLUMN TYPE QUESTIONS

11. Match the following:

List-I		List-II	
(i)	Molarity	p.	For very dilute solution
(ii)	Molality	q.	No units
(iii)	mole fraction	r.	Mol L^{-1}
(iv)	ppm	s.	independent of temperature

12. Match the following:

List-I		List-II	
(i)	88 g of CO_2	p.	0.25 mol
(ii)	6.022×10^{23} molecules of H_2O	q.	2 mol
(iii)	5.6 litres of O_2 at STP	r.	1 mol
(iv)	96 g of O_2	s.	6.022×10^{23} molecules
(v)	1 mol of any gas		3 mol

SHORT ANSWER TYPE QUESTIONS

13. Volume of a solution changes with change in temperature, then, will be molality of the solution be affected by temperature? Give reason for your answer.

14. If 4 g of NaOH dissolves in 36 g of H_2O, calculate the mole fraction of each component in the solution. Also, determine the molarity of solution (specific gravity of solution is 1g mL^{-1}).

15. A solution is prepared by adding 2g of a substance A to 18 g of water. Calculate the mass per cent of the solute.

16. How many atoms and molecules are present in 124 gm of phosphorus (P_4).

17. The cost of table salt (NaCl) is Rs. 10 per Kg. Calculate its cost per mole. (Molar mass of NaCl is 58.5 g mol^{-1})

18. Calculate the mole fraction of the solute in a 1.00 molal aqueous solution.

LONG ANSWER TYPE QUESTIONS

19. A vessel contains 1.6 g of dioxygen at STP (273.15 K, 1 atm pressure). The gas is now transferred to another vessel at constant temperature, where pressure becomes half of the original pressure. Calculate

(*a*) volume of the new vessel.

(*b*) number of molecules of dioxygen.

20. Calcium carbonate reacts with aqueous HCl to give $CaCl_2$ and CO_2 according to the reaction given below:

$CaCO_3(s) + 2HCl(aq) \rightarrow CaCl_2(aq) + CO_2(g) + H_2O(l)$

What mass of $CaCl_2$ will be formed when 250 mL of 0.76 M HCl reacts with 1000 g of $CaCO_3$? Name the limiting reagent. Calculate the number of moles of $CaCl_2$ formed in the reaction.

21. In a compound $C_xH_yO_z$, the mass % of C and H is 6 : 1 and the amount of oxygen present is equal to the half of the oxygen required to react completely C_xH_y. Find the empirical formula of the compound.

22. An LPG cylinder weighs 14.8 Kg when empty. When full, it weighs 29.0 kg and shows a pressure of 2.5 atm. In the course of use at 27°C, the weight of cylinder is reduced to 23.2 Kg. Find the volume of n-butane in cubic meters used up at 27°C and 1 atm (Molecular weight of n-butane = 58).

23. A box contains some identical red coloured balls, labelled as A, each weighing 2 grams. Another box contains identical bule coloured balls, labelled as B, each weighing 5 grams. Consider the combinations AB, AB_2, A_2B and A_2B_3 and show that law of multiple.

CASE STUDY BASED QUESTIONS

24. The ideas underlying our modern understanding of thermodynamics and kinetic theory were developed during the nineteenth century. Central to these developments was the discovery that matter reacting chemically does not do so simply between equal masses of the samples involved. We now call the study of this phenomenon 'stoichiometry', defined as: 'the relationship between the amounts of substance that react together, and the products that are formed'.

Another development during the nineteenth century that was central to our modern understanding of the chemical nature of matter was the observation by Avogadro that 'equal volumes of ideal or perfect gases, at the same temperature and pressure, contain the same number of particles, or molecules'. This is now known as Avogadro's law. It provides the motivation to formulate expressions for the quantity of a sample that reacts with another sample. The most notable example of such a formulation is the gram-molecule, which has been used to refer to both a unit and a quantity.

The following questions are multiple choice questions. Choose the most appropriate answer:

I. The concept of stoichiometry mentioned in the study is based on the

(*a*) formation of chemical bonds.

(*b*) amount of reactant and product involved in a chemical reaction.

(*c*) idea of temperature and pressure required for the reaction to occur.

(*d*) oxidation states of reactant and product involved.

II. How much gram-molecules of H_2O are produced on combustion of 32 g of methane in excess oxygen?

(*a*) 72 (*b*) 4

(*c*) 2 (*d*) 36

III. When an antacid tablet is used, $Ca(OH)_2$ reacts with HCl in the stomach to form inert $CaCl_2$ and H_2O. If the molar mass of $Ca(OH)_2$ is 75 g/mol, how many moles of HCl are required to fully react with 150 g of $Ca(OH)_2$?

(*a*) 4 (*b*) 1

(*c*) 8 (*d*) 2

IV. What must be held constant when applying Avogadro's law?

(*a*) pressure and temperature

(*b*) volume and temperature

(*c*) moles and temperature

(*d*) pressure and volume

FUNDAMENTAL QUANTITIES, LAWS OF CHEMICAL COMBINATION

1. Express the result of (0.582 + 324.65) to the appropriate number of significant figures:
(*a*) 325.24 (*b*) 325.23
(*c*) 325.2 (*d*) 325.232

2. The correctly reported answer of the area of rectangle which is 12.34 cm long and 1.23 cm wide is :
(*a*) 15.2 m^2 (*b*) 15.2 cm^2
(*c*) 15.1 cm^2 (*d*) 15.17 cm^2

3. If an object has a mass of 0.2876 g, then find the mass of nine such objects:
(*a*) 2.5884 g (*b*) 2.5886 g (*c*) 2.588 g (*d*) 2.5 g

4. Two elements X and Y combine in gaseous state to form XY in the ratio 1:35.5 by mass. The mass of Y that will be required to react with 2 g of X is:
(*a*) 7.1 g (*b*) 3.55 g (*c*) 71 g (*d*) 35.5 g

5. 4.4 g of an oxide of nitrogen gives 2.24 L of nitrogen and 60 g of another oxide of nitrogen gives 22.4 L of nitrogen at S.T.P. The data illustrates:
(*a*) Law of conservation of mass
(*b*) Law of constant proportions
(*c*) Law of multiple proportions
(*d*) Law of reciprocal proportions

6. Two elements X and Y combine to form compounds A, B and C. The ratio of different masses of Y which combine with a fixed mass of X in A, B and C is 1 : 3 : 5. If 32 parts by mass of X combines with 84 parts by mass of Y in B, then in C, 16 parts by mass of X will combine with;
(*a*) 14 parts by mass of Y (*b*) 42 parts by mass of Y
(*c*) 70 parts by mass of Y (*d*) 84 parts by mass of Y

ATOMIC MASS & MOLECULAR MASS, MOLE CONCEPT AND APPLICATIONS

7. 1 amu is equal to:
(*a*) $\frac{1}{12}$ of mass of C^{12} atom
(*b*) $\frac{1}{14}$ of mass of O^{16} atom
(*c*) 1 g of H_2
(*d*) 1.66×10^{-23} kg

8. 1 mol of CH_4 contains:
(*a*) 6.02×10^{23} atoms of H
(*b*) 4 *g*-atom of Hydrogen
(*c*) 1.81×10^{23} molecules of CH_4
(*d*) 3.0 *g* of carbon

9. 7.5 grams of a gas occupy 5.6 litres of volume at STP, the gas is:
(*a*) NO (*b*) N_2O (*c*) CO (*d*) CO_2

10. The number of atoms in 4.25 *g* of NH_3 is approximately:
(*a*) 1×10^{23} (*b*) 2×10^{23} (*c*) 4×10^{23} (*d*) 6×10^{23}

11. One litre of a gas at STP weighs 1.16 *g*. The possible gas is:
(*a*) C_2H_2 (*b*) CO
(*c*) O_2 (*d*) CH_4

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

13. If N_A is Avogadro's number, then number of valence electrons in 4.2 *g* of nitride ions (N^{3-}) is:
(*a*) 2.4 N_A (*b*) 4.2 N_A
(*c*) 1.6 N_A (*d*) 3.2 N_A

14. The number of molecules at STP in 1 ml of an ideal gas will be:
(*a*) 6×10^{23} (*b*) 2.69×10^{19}
(*c*) 2.69×10^{23} (*d*) None of these

15. Volume of a gas at STP is 1.12×10^{-7} cc. The number of molecules in it are:
(*a*) 3.01×10^{20} (*b*) 3.01×10^{12}
(*c*) 3.01×10^{23} (*d*) 3.01×10^{24}

16. 4.4 g of an unknown gas occupies 2.24 L of volume at standard temperature and pressure. The gas may be:
(*a*) Carbon dioxide (*b*) Carbon monoxide
(*c*) Oxygen (*d*) Sulphur dioxide

17. The number of oxygen atoms in 4.4 *g* of CO_2 is approx.:
(*a*) 1.2×10^{23} (*b*) 6×10^{22}
(*c*) 6×10^{23} (*d*) 12×10^{23}

18. The total number of protons in 10 *g* of calcium carbonate is: ($N_A = 6.022 \times 10^{23}$)
(*a*) 1.5057×10^{24} (*b*) 2.0478×10^{24}
(*c*) 3.0115×10^{24} (*d*) 4.0956×10^{24}

19. Number of molecules in 100 ml each of O_2,NH_3 and CO_2 at STP are:
(*a*) In the order: $CO_2 < O_2 < NH_3$
(*b*) In the order: $NH_3 < O_2 < CO_2$
(*c*) The same in all
(*d*) In the order: $NH_3 < CO_2 < O_2$

20. The number of water molecules in 1 litre of water is:
(*a*) 18 (*b*) 18 × 1000
(*c*) N_A (*d*) 55.55 N_A

21. 2 g of oxygen contains number of atoms equal to that in:
(*a*) 0.5 g of hydrogen (*b*) 4 g of sulphur
(*c*) 7 g of nitrogen (*d*) 2.3 g of sodium

PERCENTAGE COMPOSITION, EMPIRICAL FORMULA & MOLECULAR FORMULA

22. Caffeine has a molecular weight of 194. If it contains 28.9% by mass of nitrogen, number of atoms of nitrogen in one molecule of caffeine is:
(*a*) 4 (*b*) 6 (*c*) 2 (*d*) 3

23. The percentage of oxygen in NaOH is:
(*a*) 40 (*b*) 60 (*c*) 8 (*d*) 10

24. A compound (60 *g*) on analysis gave C = 24 g, H = 4 *g*, O = 32 *g*. Its empirical formula is:
(*a*) $C_2H_2O_2$ (*b*) C_2H_2O (*c*) CH_2O_2 (*d*) CH_2O

25. What is the % of H_2O in $Fe(CNS)_3.3H_2O$?
(*a*) 45 (*b*) 30 (*c*) 19 (*d*) 25

26. A hydrocarbon contains 86% carbon, Then, the hydrocarbon is an:
(*a*) Alkane (*b*) Alkene (*c*) Alkyne (*d*) Arene

27. The simplest formula of a compound containing 50% of element X (atomic mass 10) and 50% of element *Y* (atomic mass 20) is:
(*a*) XY (*b*) X_2Y (*c*) XY_3 (*d*) X_2Y_3

28. Haemoglobin contains 0.33% of iron by weight. The molecular weight of haemoglobin is approximately 67,200. The number of iron atoms (At. wt. of Fe = 56) present in one molecule of haemoglobin is:
(*a*) 6 (*b*) 1 (*c*) 4 (*d*) 2

CONCENTRATION TERMS

29. What is the molarity of NaOH solution if 250 mL of it contains 1 mg of NaOH?
(*a*) 10^{-1} M (*b*) 10^{-2} M (*c*) 10^{-4} M (*d*) 10^{-3} M

30. Molarity of H_2SO_4 (density 1.8 g/mL) is 18 M. The molality of this H_2SO_4 is:
(*a*) 36 (*b*) 200 (*c*) 500 (*d*) 18

31. The percentage of sodium in a breakfast cereal be labeled as 110 mg of sodium per 100 g of cereal is
(*a*) 11% (*b*) 1.10% (*c*) 0.11% (*d*) 1.10%

32. 200 ml, 3M NaOH is mixed with 300 ml 2 M NaOH forming a solution of density 1200 Kg/m^3 . Then molality of final solution is :
(*a*) 2.2 m (*b*) 3 m (*c*) 2.4 m (*d*) 2 m

33. Calculate molality of 0.2 M urea solution having density 1.2 gm/ml.
(*a*) $\approx \frac{1}{6}$m (*b*) $\approx \frac{1}{3}$m (*c*) $\approx \frac{1}{9}$m (*d*) $\approx \frac{1}{12}$m

34. Commercial HNO_2(aq) has density 1.41 g/ml and is 10M. Then mass percentage of solution is :
(*a*) $\frac{100}{3}$% (*b*) 50% (*c*) 75% (*d*) 25%

35. 0.02 gm of an unknown substance is dissolved in 3.9 gm of benzene. The molality of solution is 0.08 m.Calculate the molecular mass of unknown substance:
(*a*) 60 g/mol (*b*) 164 g/mol
(*c*) 264 g/mol (*d*) 64.1 g/mol

36. A 500 g solution has 0.1 g fluoride concentration. Then fluoride concentration in term of ppm will be:
(*a*) 200 ppm (*b*) 100 ppm
(*c*) 400 ppm (*d*) 50 ppm

STOICHIOMETRY, EQUATION BASED CALCULATIONS

37. In the reaction;
$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(g)$, when 1 mole of ammonia and 1 mole of O_2 are made to react to completion:
(*a*) 1.0 mole of H_2O is produced.
(*b*) 1.0 mole of NO will be produced.
(*c*) All the oxygen will be consumed.
(*d*) All the ammonia will be consumed.

38. H_2 evolved at STP on complete reaction of 27 g of aluminium with excess of aqueous NaOH would be:

$$Al + H_2O + NaOH \rightarrow NaAlO_2 + \frac{3}{2}H_2$$

(*a*) 22.4 litres (*b*) 44.8 litres
(*c*) 67.2 litres (*d*) 33.6 litres

39. 12 g of Mg (at. mass 24) will react completely with acid to give:
(*a*) One mole of H_2
(*b*) 1/2 mole of H_2
(*c*) 2/3 mole of O_2
(*d*) Both 1/2 mol of H_2 and 1/2 mol of O_2

40. 100 g $CaCO_3$ reacts with 1 litre 1 N HCl. On completion of reaction, how much weight of CO_2 will be obtained?
(*a*) 5.5 g (*b*) 11 g (*c*) 22 g (*d*) 33 g

41. What weight of HNO_3 is needed to convert 5 g of iodine into iodic acid according to the reaction,

$$I_2 + 10HNO_3 \rightarrow 2HIO_3 + 10NO_2 + 4H_2O$$

(*a*) 12.4 g (*b*) 24.8 g (*c*) 0.248 g (*d*) 49.6 g

42. How much Cl_2 at STP is liberated when 1 mole $KMnO_4$ reacts with HCl?
(*a*) 11.2 L (*b*) 22.4 L (*c*) 44.8 L (*d*) 56 L

43. 27 g of Al will react completely with how many grams of oxygen?
(*a*) 8 g (*b*) 16 g (*c*) 32 g (*d*) 24 g

44. If 0.50 mole of $BaC1_2$ is mixed with 0.20 mol of Na_3PO_4, the maximum number of moles of $Ba_3(PO_4)_2$ that can be formed is:
(*a*) 0.70 (*b*) 0.50 (*c*) 0.20 (*d*) 0.10

45. 0.5 mole of H_2SO_4 is mixed with 0.2 mole of $Ca(OH)_2$. The maximum number of moles of $CaSO_4$ formed is:
(*a*) 0.2 (*b*) 0.5 (*c*) 0.4 (*d*) 1.5

PRABAL (JEE MAIN LEVEL)

1. A sample of calcium phosphate $Ca_3(PO_4)_2$ contains 8 mol of O atoms. The number of mole of Ca atoms in the sample is:
(*a*) 4 (*b*) 1.5 (*c*) 3 (*d*) 8

2. Ratio of masses of H_2SO_4 and $Al_2(SO_4)_3$ each containing 32 grams of S is __________.
(*a*) 0.86 (*b*) 1.72 (*c*) 0.43 (*d*) 2.15

3. Which has maximum number of atoms of oxygen?
(*a*) 10 ml $H_2O(l)$
(*b*) 0.1 mole of V_2O_5
(*c*) 12 gm $O_3(g)$
(*d*) 12.044×10^{22} molecules of CO_2

4. Mass of one atom of the element A is 3.9854×10^{-23}g. How many atoms are contained in 1g of the element A?
(*a*) 2.509×10^{22} (*b*) 6.022×10^{23}
(*c*) 12.044×10^{23} (*d*) None of these

5. The number of atoms present in 0.5 g-atoms of nitrogen is same as the atoms in:
(*a*) 12 g of C (*b*) 32 g of S
(*c*) 8 g of oxygen (*d*) 24 g of Mg

6. How many moles of magnesium phosphate $Mg_3(PO_4)_2$ will contain 0.25 mole of oxygen atoms?
(*a*) 0.02 (*b*) 3.125×10^{-2}
(*c*) 1.25×10^{-2} (*d*) 2.5×10^{-2}

7. 64 g of an organic compound has 24 g carbon and 8 g hydrogen and the rest is oxygen. The empirical formula of the compound is:
(*a*) CH_4O (*b*) CH_2O
(*c*) C_2H_4O (*d*) None of these

8. Two elements X (atomic mass = 75) and Y (atomic mass = 16) combine to give a compound having 75.8% of X. The formula of the compound is:
(*a*) X_2Y_3 (*b*) X_2Y (*c*) X_2Y_2 (*d*) XY

9. A definite amount of gaseous hydrocarbon was burnt with just sufficient amount of O_2. The volume of all reactants was 600 ml, after the explosion the volume of the products [$CO_2(g)$ and $H_2O(g)$] was found to be 700 ml under the similar conditions. The possible molecular formula of the compound is:
(*a*) C_3H_8 (*b*) C_3H_6 (*c*) C_3H_4 (*d*) C_4H_{10}

10. Mole fraction of ethyl alcohol in aqueous ethyl alcohol (C_2H_5OH) solution is 0.25. Hence, percentage of ethyl alcohol by weight is:
(*a*) 54% (*b*) 25%
(*c*) 75% (*d*) 46%

11. 74 gm of sample on complete combustion gives 132 gm CO_2 and 54 gm of H_2O. The molecular formula of the compound may be:
(*a*) C_5H_{12} (*b*) $C_4H_{10}O$
(*c*) $C_3H_6O_2$ (*d*) $C_3H_7O_2$

12. Weight of oxygen in Fe_2O_3 and FeO in the simple ratio for the same amount of iron, is:
(*a*) 3 : 2 (*b*) 1 : 2
(*c*) 2 : 1 (*d*) 3 : 1

13. A person needs on average of 2.0 mg of riboflavin (vitamin B_2) per day. How many gm of butter should be taken by the person per day if it is the only source of riboflavin? Butter contains 5.5 microgram riboflavin per gm.
(*a*) 363.6 gm (*b*) 2.75 mg
(*c*) 11 gm (*d*) 19.8 gm

14. The oxide of a metal contains 30% oxygen by weight. If the atomic ratio of metal and oxygen is 2 : 3, determine the atomic weight of metal.
(*a*) 12 u (*b*) 56 u (*c*) 27 u (*d*) 52 u

15. When a mixture of 10 mole of SO_2 and 15 mole of O_2 was passed over catalyst, 8 mole of SO_3 was formed. How many mole of $SO_2$and O_2 did not enter into combination?
(*a*) 2 moles of SO_2, 11 moles of O_2
(*b*) 3 moles of SO_2, 11.5 moles of O_2
(*c*) 2 moles of SO_2, 4 moles of O_2
(*d*) 8 moles of SO_2, 4 moles of O_2

16. $C_6H_5OH(g) + O_2(g) \rightarrow CO_2(g) + H_2O(l)$
Magnitude of volume change if 30 ml of C_6H_5OH (g) is burnt with excess amount of oxygen, is:
(*a*) 30 ml (*b*) 60 ml
(*c*) 20 ml (*d*) 10 ml

17. Mass of sucrose $C_{12}H_{22}O_{11}$ produced by mixing 84 gm of carbon, 12 gm of dihydrogen and 56 lit. O_2 at 1 atm & 273 K according to given reaction, is:
$C(s) + H_2(g) + O_2(g) \rightarrow C_{12}H_{22}O_{11}(s)$
(*a*) 138.5 (*b*) 155.5
(*c*) 172.5 (*d*) 199.5

18. What volume (in ml) of 0.2 M H_2SO_4 solution should be mixed with the 40 ml of 0.1 M NaOH solution such that the resulting solution has the concentration of H_2SO_4 as $\frac{6}{55}$M.
(*a*) 70 (*b*) 45
(*c*) 30 (*d*) 58

19. For the reaction; $2x + 3y + 4z \rightarrow 5w$, initially 1 mol of x, 3 mol of y and 4 mol of z is taken. If 1.25 mol of w is obtained then % yield of this reaction is:
(*a*) 50% (*b*) 60%
(*c*) 70% (*d*) 40%

20. If 10 g of Ag reacts with 1 g of sulphur, the amount of Ag_2S formed will be:
(a) 7.75 g (b) 0.775 g
(c) 11 g (d) 10 g

21. A solution of A (MM = 20) and B (MM = 10), [Mole fraction $X_B = 0.6$] having density 0.7 gm/ml then molarity and molality of B in this solution will be ________ and ________ respectively.
(a) 30 M, 75 m
(b) 40 M, 75 m
(c) 30 M, 65 m
(d) 50 M, 55 m

22. 125 ml of 8% w/w NaOH solution (sp. gravity = 1) is added to 125 ml of 10 % w/v HCl solution. The nature of resultant solution would be ________.
(a) Acidic (b) Basic
(c) Neutral (d) None of these

23. 36.5 % (w/w) HCl has density equal to 1.20 g mL^{-1}. The molarity (M) and molality (m), respectively, are:
(a) 15.7, 15.7 (b) 12, 12
(c) 15.7, 12 (d) 12, 15.7

24. An aqueous solution of ethanol has density 1.025 g/mL and it is 2 M. What is the molality of this solution?
(a) 1.79 (b) 2.143
(c) 1.951 (d) None of these.

25. 500 mL of a glucose solution contains 6.02×10^{22} molecules of glucose. The concentration of the solution is:
(a) 0.1 M (b) 1.0 M
(c) 0.2 M (d) 2.0 M

26. Equal moles of H_2O and NaCl are present in a solution. Hence, molality of NaCl solution is:
(a) 0.55 (b) 55.5
(c) 1.00 (d) 0.18

27. Decreasing order of mass of pure NaOH in each of the aqueous solution.
I. 50 g of 40% (w/w) NaOH
II. 50 ml of 50% (w/v) NaOH (d_{sol} = 1.2 g/ml).
III. 50 g of 15 M NaOH (d_{sol} = 1 g/ml).
(a) I, II, III (b) III, II, I
(c) II, III, I (d) III = II = I

28. A solution of $FeCl_3$ is $\frac{M}{30}$, its molarity for Cl^- ion will be:
(a) $\frac{M}{90}$ (b) $\frac{M}{30}$
(c) $\frac{M}{10}$ (d) $\frac{M}{5}$

29. What volume of a 0.8 M solution contains 100 milli moles of the solute?
(a) 100 mL (b) 125 mL
(c) 500 mL (d) 62.5 mL

30. 4.4 g of CO_2 and 2.24 litre of H_2 at STP are mixed in a container. The total number of molecules present in the container will be:
(a) 6.022×10^{23} (b) 1.2046×10^{23}
(c) 6.022×10^{22} (d) 6.022×10^{24}

31. 10 g of $CaCO_3$ on heating gives 5 g of the residue (as CaO). The percent yield of the reaction is approximately:
(a) 50% (b) 72% (c) 89% (d) 100%

32. 33.6 g of an impure sample of sodium bicarbonate when heated strongly gave 4.4 g of CO_2. The percentage purity of $NaHCO_3$ would be:
(a) 25% (b) 50%
(c) 75% (d) 100%

33. A gaseous mixture contains oxygen and nitrogen in the ratio of 1 : 4 by weight. Therefore the ratio of their number of molecules is:
(a) 1 : 4 (b) 1 : 8
(c) 7 : 32 (d) 3 : 16

34. 2.76 g of silver carbonate on being strongly heated yields a residue weighing:
(a) 2.16 g (b) 2.48 g
(c) 2.32 g (d) 2.64 g

35. 12 g of alkaline earth metal gives 14.8 g of its nitride. Atomic weight of metal is:
(a) 12 (b) 20
(c) 40 (d) 14.8

36. How many liters of CO_2 at STP will be formed when 0.01 mol of H_2SO_4 reacts with excess of Na_2CO_3.
$Na_2CO_3 + H_2SO_4 \rightarrow Na_2SO_4 + CO_2 + H_2O$
(a) 22.4 L (b) 2.24 L
(c) 0.224 L (d) 1.12 L

37. Equal weight of 'X' (At. wt. = 36) and 'Y' (At. wt. = 24) are reacted to form the compound X_2Y_3. Then
(a) X is the limiting reagent
(b) Y is the limiting reagent
(c) No reactant is left over and mass of X_2Y_3 formed is double the mass of 'X' taken
(d) None of these

38. A person adds 1.71 gram of sugar ($C_{12}H_{22}O_{11}$) in order to sweeten his tea. The number of carbon atoms added are (mol. mass of sugar = 342)
(a) 3.6×10^{22} (b) 7.2×10^{21}
(c) 0.05×10^{20} (d) 6.6×10^{22}

39. A compound contains 38.8 % C, 16.0 % H and 45.2 % N. The formula of the compound would be

(*a*) CH_3NH_2 (*b*) CH_3CN

(*c*) C_2H_5CN (*d*) $CH_2(NH)_2$

40. When 100 g of ethylene polymerises entirely to polyethene, the weight of polyethene formed as per the equation $n(C_2H_4) \longrightarrow (-CH_2-CH_2-)_n$ is:

(*a*) (n/2)g (*b*) 100g

(*c*) (100/n)g (*d*) 100ng

41. What is the concentration of nitrate ions if equal volumes of 0.1 M $AgNO_3$ and 0.1 M NaCl are mixed together?

(*a*) 0.1 N (*b*) 0.2 M

(*c*) 0.05 M (*d*) 0.25 M

42. 0.16 g of dibasic acid required 25 ml of M/10 NaOH for complete neutralization. Molecular weight of acid is:

(*a*) 32 (*b*) 64 (*c*) 128 (*d*) 256

43. An aqueous solution of 6.3 g oxalic acid dihydrate is made up to 250 ml. The volume of 0.1 M NaOH required to completely neutralize 10 ml of this solution is:

(*a*) 40 ml (*b*) 20 ml

(*c*) 10 ml (*d*) 4 ml

44. Which of the following contains the greatest number of oxygen atoms?

(*a*) 1g of O (*b*) 1g of O_2

(*c*) 1g of O_3 (*d*) All same

45. For sequential reaction :

$$A \longrightarrow B + C \qquad ...(i)$$

$$2B \longrightarrow C + 2D \qquad ...(ii)$$

If % yield of (i) and (ii) reactions are 90% and 80% respectively then the overall % yield is expected to be:

(*a*) 90% (*b*) 80% (*c*) 72% (*d*) 10%

46. If 32 g of O_2 contains 6.022×10^{23} molecules at STP then 32 g of S, under the same conditions, will contain,

(*a*) 6.022×10^{23} S atoms (*b*) 3.011×10^{23} S atoms

(*c*) 12.044×10^{23} S atoms (*d*) 1×10^{23} S atoms

INTEGER TYPE QUESTIONS

47. The specific gravity of a solution is 1.8, having 62% by weight of acid. It is to be diluted to specific gravity of 1.2. What volume of water (in mL) should be added to 100 ml of this solution?

48. Carbon disulphide, CS_2, can be made from by-product SO_2. The overall reaction is

$$5C + 2SO_2 \longrightarrow CS_2 + 4CO$$

How much CS_2 (in kg) can be produced from 440 kg of waste SO_2 with 60 kg of coke if the SO_2 conversion is 80%?

49. Pure iron pyrite, FeS_2, is burnt with 50% excess air than required for complete oxidation of FeS_2, in a closed vessel.

$$4FeS_2(s) + 11O_2(g) \longrightarrow 2Fe_2O_3(s) + 8SO_2(g)$$

Air contains 20% O_2 and 80% N_2, by volume. The mole percent of N_2 gas in the gaseous mixture, after complete reaction, is.

50. An element A forms both a dichloride (ACl_2) and a tetrachloride (ACl_4). Treatment of 27.8 g ACl_2 with excess chlorine forms 34.9 g ACl_4. Then atomic mass (in g/mol) of ‘A’ is:

51. Mixture of 10 moles of Fe_2S_3, 20 moles of H_2O and 30 mole of O_2 react with 30% yield of given reaction:

$$Fe_2S_3 + H_2O + O_2 \rightarrow Fe(OH)_3 + S$$

Calculate moles of $Fe(OH)_3$ that can be produced in above reaction.

52. In order to obtain NaBr following set of reactions are involved.

$$Fe + Br_2 \rightarrow FeBr_2 \qquad I$$

$$FeBr_2 + Br_2 \rightarrow Fe_3Br_8 \qquad II$$

$$Fe_3Br_8 + Na_2CO_3 \rightarrow NaBr + CO_2 + Fe_3O_4 \qquad III$$

If % yield of reaction I, II & III are 60%, 20% & 30% respectively then calculate mass of iron required (in g) to obtain 20.6 kg of NaBr.

53. A solution of A (MM=20) and B (MM= 10), [Mole fraction $X_B = 0.6$] has density 0.7 gm/ml then molarity and molality of B in this solution will be _____M and ____m respectively.

54. A piece of aluminium weighing 2.7 g is heated with 75.0 ml of H_2SO_4 (sp. gr. 1.2 containing 25% H_2SO_4 by mass). After the metal is completely dissolved, the solution is diluted to 400ml. What is the molarity of the free H_2SO_4 in the resulting solution (Multiply final answer by 10)?

55. The odour of skunk is caused by chemical compounds called thiols ($C_4H_{10}S$). These can be deodorized by reaction with household bleach (NaOCl) according to following unbalanced reaction:

$$C_4H_{10}S + NaOCl(aq) \rightarrow C_8H_{18}S_2 + NaCl(aq) + H_2O(aq)$$

How many gram of thiol can be deodorized by 74.5 gm of NaOCl?

PARIKSHIT (JEE ADVANCED LEVEL)

SINGLE CORRECT TYPE QUESTIONS

1. (i) $2Al + 6HCl \longrightarrow 2AlCl_3 + 3H_2$

(ii) $AlCl_3 + 3NaOH \longrightarrow Al(OH)_3 + 3NaCl$

(iii) $Al(OH)_3 + NaOH \longrightarrow NaAlO_2 + 2H_2O$

Above series of reactions are carried out starting with 18 g of Al and 109.5 g of HCl in first step and further 100 g of NaOH is added for step (ii) and (iii). Find out limiting reagent in each step and calculate the maximum amount of $NaAlO_2$ that can be produced in step (iii). (Assume reactions are taken in sequence and also that each reaction goes to 100% completion)

	L.R. in step (I)	L.R. in step (II)	L.R. in step (III)	Moles of $NaAlO_2$
(*a*)	Al	$AlCl_3$	$Al(OH)_3$	0.66
(*b*)	Al	Na(OH)	$Al(OH)_3$	0.5
(*c*)	Al	$AlCl_3$	NaOH	0.5
(*d*)	HCl	$AlCl_3$	NaOH	0.5

2. A mixture of CH_4 and C_2H_2 was completely burnt in an excess of oxygen yielding equal volumes of CO_2 and steam, measured at the same temperature and pressure. The mole percent of CH_4 in the original mixture is

(*a*) 25% (*b*) 30%
(*c*) 75% (*d*) 50%

3. The strength of 10^{-2} M Na_2CO_3 solution in terms of molality will be (density of solution = 1.10 g mL^{-1}). (Molecular weight of Na_2CO_3 = 106 g mol^{-1})

(*a*) 9.00×10^{-3} (*b*) 1.5×10^{-2}
(*c*) 5.1×10^{-3} (*d*) 11.2×10^{-3}

4. 10 moles of X, 12 mole of Y and 20 moles of Z are mixed to produce a final product P, according to the given balanced reactions:

$$X + 2Y \longrightarrow I$$
$$I + Z \longrightarrow Y + P$$

then the maximum moles of P, which can be produced assuming that the products formed can also be reused in the reaction?

(*a*) 6 mole (*b*) 9 mole
(*c*) 10 mole (*d*) 12 mole

5. A compound contains 4% oxygen, $\frac{14}{3}$% nitrogen, 4% sulphur. Then empirical formula of compound contains __________ number of nitrogen atoms.

(*a*) 6 (*b*) 8
(*c*) 3 (*d*) Can not be determined

6. 56 gm of N_2 and 9 gm of H_2 are made to react completely to produce a mixture of NH_3 and N_2H_4. The ratio of moles of NH_3 and N_2H_4 is:

(*a*) 1 : 1 (*b*) 3 : 2
(*c*) 2 : 3 (*d*) None of these

7. 100 gm of an oleum sample (labelled as 109%) is mixed with 300 gm of another oleum sample (labelled as 118%). The new labelling of resulting oleum sample becomes

(*a*) 115.75% (*b*) 106.75%
(*c*) 163% (*d*) 15.75%

8. Iodobenzene is prepared from aniline ($C_6H_5NH_2$) in a two-step process as shown here.

$C_6H_5NH_2 + HNO_2 + HC1 \rightarrow C_6H_5N_2^+Cl^- + 2H_2O$

$C_6H_5N_2^+Cl^- + KI \rightarrow C_6H_5I + N_2 + KCl$

In an actual preparation, 9.30 g of aniline was converted to 16.32 g of iodobenzene. The percentage yield of iodobenzene is (I = 127)

(*a*) 8% (*b*) 50%
(*c*) 75% (*d*) 80%

9. A protein isolated from a bovine preparation, was subjected to amino acid analysis. The amino acid present in the smallest amount was lysine, $C_6H_{14}N_2O_2$ and the amount of lysine was found to be 365 mg per 100 g protein. What is the minimum molecular mass (in g/mol) of the protein?

(*a*) 40,000,000 (*b*) 40,000
(*c*) 40 (*d*) 4,00,000

MULTIPLE CORRECT TYPE QUESTIONS

10. Which is/are correct statements about 1.7 g of NH_3?

(*a*) It contain 0.3 mol H – atoms.
(*b*) It contain 2.408×10^{23} atoms.
(*c*) Mass % of hydrogen is 17.65%.
(*d*) It contains 0.3 mol N-atoms.

11. If 27 g of carbon is mixed with 88 g of oxygen and is allowed to burn to produce CO_2, then:

(*a*) Oxygen is the limiting reagent.
(*b*) Volume of CO_2 gas produced at STP is 50.4 L.
(*c*) C and O combine in mass ratio of 3.8.
(*d*) Volume of unreacted O_2 at STP is 11.2 L.

12. For the following reaction : $Na_2CO_3 + 2HCl \longrightarrow 2NaCl + CO_2 + H_2O$

106.0 g of Na_2CO_3 reacts with 109.5 g of HCl.

Which of the following is/are correct?

(*a*) The HCl is in excess amount.
(*b*) 117.0 g of NaCl is formed.
(*c*) The volume of CO_2 produced at NTP is 22.4 L.
(*d*) None of these

13. A sample of a mixture of $CaCl_2$ and NaCl weighing 4.44 g was treated to precipitate all the Ca as $CaCO_3$, which was then heated and quantitatively converted to 1.12 g of CaO. (At . wt. Ca = 40, Na = 23, Cl = 35.5)

(*a*) Mixture contains 50% NaCl by mass
(*b*) Mixture contains 60% $CaCl_2$ by mass
(*c*) Mass of $CaCl_2$ is 2.22 g in the mixture
(*d*) Mass of $CaCl_2$ is 1.11 g in the mixture

14. $A + B \rightarrow A_3B_2$ (unbalanced)
$A_3B_2 + C \rightarrow A_3B_2C_2$ (unbalanced)
Above two reactions are carried out by taking 3 moles each of A and B and one mole of C. Then, which option is/are correct?
(*a*) 1 mole of $A_3B_2C_2$ is formed.
(*b*) 1/2 mole of $A_3B_2C_2$ is formed.
(*c*) 1/2 mole of A_3B_2 is formed.
(*d*) 1/2 mole of A_3B_2 is left finally.

15. The **incorrect** statement(s) regarding 2 M $MgCl_2$ aqueous solution is/are: ($d_{solution}$ = 1.09 gm/ml)
(*a*) Molality of Cl^- is 4.44 m.
(*b*) Mole fraction of $MgCl_2$ is approximately 0.035.
(*c*) The conc. of $MgCl_2$ is 19% w/v. (approx)
(*d*) The conc. of $MgCl_2$ is 19×10^4 ppm.

16. Solution containing 23 g HCOOH is/are:
(*a*) 46 g of 70% $\left(\frac{w}{v}\right)$ HCOOH ($d_{solution}$ = 1.40 g/mL)
(*b*) 50 g of 10 M HCOOH ($d_{solution}$ = 1 g/mL)
(*c*) 50 g of 25% $\left(\frac{w}{w}\right)$ HCOOH
(*d*) 46 g of 5 M HCOOH ($d_{solution}$ = 1 g/mL)

17. A student was carrying out the following chemical reaction in Lab
$$2A + 3B \longrightarrow 6C \text{ (balanced reaction)}$$
He used 30 mole of A and 30 mole of B and at the end of reaction he found 40 moles of C were formed. Identify the correct statement(s).
(*a*) Total mass before and after the reaction will remain same.
(*b*) B is limiting reagent
(*c*) % yield is 60.
(*d*) At 50% yield 30 moles of C will be formed.

18. Which of the following contain same number of entities?
(*a*) Number of atoms in 1 mole $CuSO_4 \cdot 5H_2O$
(*b*) Number of neutrons in 3.5 mole of CH_4
(*c*) Number of atoms in 2 mole of $FeCr_2O_4$
(*d*) Number of electrons in 2.1 mole of NH_4^+

COMPREHENSION BASED QUESTIONS

Comprehension (Q. 19 to 21): A chemist decided to determine the molecular formula of an unknown compound. He collects following informations:

I. Compound contain 2 : 1 'H' to 'O' atoms (number of atoms).
II. Compound has 40% C by mass.
III. Approximate molecular mass of the compound is 178 g.
IV. Compound contains C, H and O only.

19. What is the % by mass of oxygen in the compound?
(*a*) 53.33% (*b*) 88.88%
(*c*) 33.33% (*d*) None of these

20. What is the empirical formula of the compound?
(*a*) CH_3O (*b*) CH_2O
(*c*) C_2H_2O (*d*) CH_3O_2

21. Which of the following could be molecular formula of compound?
(*a*) $C_6H_6O_6$ (*b*) $C_6H_{12}O_6$
(*c*) $C_6H_{14}O_{12}$ (*d*) $C_6H_{14}O_6$

Comprehension (Q. 22 to 24): Oleum is considered as a solution of SO_3 in H_2SO_4, which is obtained by passing SO_3 in solution of H_2SO_4. When 100 g sample of oleum is diluted with desired weight of H_2O then the total mass of H_2SO_4 obtained after dilution is known as % labelling in oleum.

For example, a oleum bottle labelled as 109% H_2SO_4 means the 109g total mass of pure H_2SO_4 will be formed when 100 g of oleum is diluted by 9 g of H_2O which combines with all the free SO_3 to form H_2SO_4 as
$$SO_3 + H_2O \longrightarrow H_2SO_4$$

22. What is the % of free SO_3 in an oleum that is labelled as '104.5% H_2SO_4'?
(*a*) 10 (*b*) 20
(*c*) 40 (*d*) None of these

23. If excess water is added into a 100 g bottle sample labelled as 112% H_2SO_4 and is reacted with 5.3g Na_2CO_3, then find the volume of CO_2 evolved at 1 atm pressure and 300 k temperature after the completion of the reaction: [R = 0.0821 L atom mol^{-1} K^{-1}]
$$H_2SO_4 + Na_2CO_3 \longrightarrow Na_2SO_4 + H_2O + CO_2$$
(*a*) 2.46 L (*b*) 24.6 L (*c*) 1.23 L (*d*) 123

24. 1g of oleum sample is diluted with water. The solution required 54 ml of 0.4 N NaOH for compete neutralisation. The % of free SO_3 in the sample is:
(*a*) 74 (*b*) 26
(*c*) 20 (*d*) None of these

MATCH THE COLUMN TYPE QUESTIONS

25.

	Column-I		Column-II
A.	100 mL of 0.2 M $AlCl_3$ solution + 400 ml of 0.1 M HCl solution	p.	Total concentration of cation(s) = 0.12 M
B.	50 mL of 0.4 M KCl + 50 ml H_2O	q.	$[SO_4^{2-}]$ = 0.06 M
C.	30 mL of 0.2 M K_2SO_4 + 70 ml H_2O	r.	$[SO_4^{2-}]$ = 2.5 M
D.	200 mL 24.5% (w/v) H_2SO_4	s.	$[Cl^-]$ = 0.2 M

(*a*) A → r,s; B → s; C → p,q; D → r
(*b*) A → p,s; B → s; C → p,q; D → r
(*c*) A → p,s; B → s; C → s,q; D → r
(*d*) A → p,s; B → p,s; C → p,q; D → r

NUMERICAL TYPE QUESTIONS (UPTO ONE DECIMAL)

26. Nitric acid can be produced from ammonia in three step process.

$4NH_3(g) + 5O_2(g) \longrightarrow 4NO(g) + 6H_2O(g)$ ...(i)

$2NO(g) + O_2(g) \longrightarrow 2NO_2(g)$ ...(ii)

$3NO_2(g) + H_2O(l) \longrightarrow 2HNO_3(aq.) + NO(g)$ ...(iii)

Calculate weight of $NH_3(g)$ (in kg) required to produce 1260 kg of HNO_3. (When % yield of 1st, 2nd and 3rd reaction are respectively 69%, 60% and 68% respectively.)

27. The mineral Argyrodite is a stoichiometric compound that contain silver, sulphur (–2) and an unknown element Y (+4). The mass-ratio of silver and Y in the compound is,

$$m (Ag) : m (Y) = 11.88$$

Y forms a reddish brown lower sulphide on heating the mineral in stream of H_2 (g), in which Y is in +2 state. The residue are Ag_2S and H_2S. To convert 10 g Argyrodite completely, 0.295 L of H_2 (g) measured at 400 K and 1.0 atmosphere is required. Determine molar mass of Y = p and empirical formula of mineral = $Ag_qY_rS_d$. Find sum of p + q + r + s + d.

INTEGER TYPE QUESTIONS

28. Sample of an element "X" consist of its three isotopes A_1, A_2 & A_3 and population of A_2 is three times the population of A_3. If the average molar mass of sample is 1.25. Determine percentage population of A_1 (Molar masses of isotopes A_1, A_2 & A_3 are 1, 2 and 3 gm respectively.)

29. A solution contain substances A and B in H_2O (solvent). The mole fraction of 'A' is 0.05 and molarity of 'B' is 7 M. The solution has density 1.14 gm/ml. Calculate "molarity of A".

[Molecular weight of A = 10 gm/mol; molecular weight of B = 30 gm/mol]

30. A fluorine disposal plant was constructed to carryout the following reactions:

$$F_2 + 2NaOH \longrightarrow \frac{1}{2}O_2 + 2NaF + H_2O$$

$$2NaF + CaO + H_2O \longrightarrow CaF_2 + 2NaOH$$

Over a period of operation, 1900 kg of fluorine was fed into a plant and 10,000 kg of lime was required. What was the percentage utilisation of lime ? [Lime : CaO]

PYQ'S (PAST YEAR QUESTIONS)

UNCERTAINTY IN MEASUREMENT AND LAWS OF CHEMICAL COMBINATIONS

1. Which of the following have same number of significant figures? **[8 April, 2023 (Shift-II)]**

A. 0.00253 B. 1.0003

C. 15.0 D. 163

Choose the correct answer from the options given below

(*a*) A, B and C only (*b*) C and D only

(*c*) A, C and D only (*d*) B and C only

2. Using the rules for significant figures, the correct answer for the expression $\frac{0.02858 \times 0.112}{0.5702}$ **[29 June, 2022 (Shift-II)]**

(*a*) 0.005613 (*b*) 0.00561

(*c*) 0.0056 (*d*) 0.006

3. The number of significant figures in 50000.020×10^{-3} is_______. **[26 Feb, 2021 (Shift-I)]**

4. To check the principle of multiple proportions, a series of pure binary compounds (P_mQ_n) were analyzed and their composition is tabulated below. The correct option(s) is(are) **[JEE Adv 2022]**

Compound	Weight % of P	Weight % of Q
1	50	50
2	44.4	55.6
3	40	60

(*a*) If empirical formula of compound 3 is P_3Q_4. then the empirical formula of compound 2 is P_3Q_5.

(*b*) If empirical formula of compound 3 is P_3Q_2 and atomic weight of clement P is 20, then the atomic weight of Q is 45.

(*c*) If empirical formula of compound 2 is PQ, then the empirical formula of the compound 1 is P_5Q_4.

(*d*) If atomic weight of P and Q are 70 and 35, respectively, then the empirical formula of compound 1 is P_2Q.

ATOMIC & MOLECULAR MASSES

5. The average molar mass of chlorine is 35.5 g mol^{-1}. The ratio of ^{35}Cl to ^{37}Cl in naturally occurring chlorine is close to: **[6 Sept, 2020 (Shift-II)]**

(*a*) 4 : 1 (*b*) 3 : 1

(*c*) 2 : 1 (*d*) 1 : 1

MOLE CONCEPT AND MOLAR MASSES

6. Match List-I with List-II. **[10 April, 2023 (Shift-II)]**

	Column-I		Column-II
A.	16g of CH_4(g)	p.	Weighs 28 g
B.	1g of H_2(g)	q.	60.2×10^{23} electrons
C.	1 mole of N_2(g)	r.	Weighs 32g
D.	0.5 mol of SO_2(g)	s.	Occupies 11.4 L volume at STP

Choose the correct answer from the options given below:

(*a*) (A)-(p), (B)-(r), (C)-(q), (D)-(s)
(*b*) (A)-(q), (B)-(r), (C)-(r), (D)-(p)
(*c*) (A)-(q), (B)-(s), (C)-(r), (D)-(p)
(*d*) (A)-(q), (B)-(s), (C)-(p), (D)-(r)

7. When 0.01 mol of an organic compound containing 60% carbon was burnt completely, 4.4 g of CO_2 was produced. The molar mass of compound is _________ g mol^{-1} (Nearest integer) **[29 Jan, 2023 (Shift-II)]**

8. Production of iron in blast furnace follows the following equation $Fe_3O_4(s) + 4CO(g) \longrightarrow 3Fe(l) + 4CO_2(g)$

When 4.640 kg of Fe_3O_4 and 2.520 kg of CO are allowed to react then the amount of iron (in g) produced is:

[Given: Molar Atomic mass (g mol^{-1}); Fe = 56
Molar Atomic mass (g mol^{-1}); O = 16
Molar Atomic mass (g mol^{-1}); C = 12]

[29 June, 2022 (Shift-I)]

(*a*) 1400 (*b*) 2200 (*c*) 3360 (*d*) 4200

9. Number of grams of bromine that will completely react with 5.0 g of pent-1-ene is _______________ $\times 10^{-2}$ g. (Atomic mass of Br = 80 g/mol) (Nearest Integer)

[25 June, 2022 (Shift-I)]

10. 4g equimolar mixture of NaOH and Na_2CO_3 contains x g of NaOH and y g of Na_2CO_3. The value of x is _________ g. (Nearest Integer) **[20 July, 2021 (Shift-II)]**

11. $NaClO_3$ is used, even in spacecraft, to produce O_2. The daily consumption of pure O_2 by a person is 492L at 1 atm, 300 K. How much amount of $NaClO_3$, in grams, is required to produce O_2 for the daily consumption of a person at 1 atm, 300 K?

$NaClO_3(s) + Fe(s) \rightarrow O_2(g) + NaCl(s) + FeO(s)$

R = 0.082 L atm mol^{-1} K^{-1}. **[8 Jan, 2020 (Shift-II)]**

12. 5 moles of AB_2 weigh 125×10^{-3} kg and 10 moles of A_2B_2 weigh 300×10^{-3} kg. The molar mass of $A_{(M_A)}$ and molar mass of $B_{(M_B)}$ in kg mol^{-1} are: **[12 April, 2019 (Shift-I)]**

(*a*) $M_A = 50 \times 10^{-3}$ and $M_B = 25 \times 10^{-3}$
(*b*) $M_A = 25 \times 10^{-3}$ and $M_B = 50 \times 10^{-3}$
(*c*) $M_A = 5 \times 10^{-3}$ and $M_B = 10 \times 10^{-3}$
(*d*) $M_A = 10 \times 10^{-3}$ and $M_B = 5 \times 10^{-3}$

13. Aluminium reacts with sulfuric acid to form aluminium sulfate and hydrogen. What is the volume of hydrogen gas in liters (L) produced at 300 K and 1.0 atm pressure, when 5.4 g of aluminium and 50.0 mL of 5.0 M sulfuric acid are combined for the reaction?

(Use molar mass of aluminium as 27.0 g mol^{-1}, R = 0.082 atm L mol^{-1} K^{-1}) **[JEE Adv 2020]**

14. The mole fraction of urea in an aqueous urea solution containing 900 g of water is 0.05. If the density of the solution is 1.2 g cm^{-3}, the molarity of urea solution is ___. **[JEE Adv 2019]**

(Given data: Molar masses of urea and water are 60 g mol^{-1} and 18 g mol, respectively)

PERCENTAGE COMPOSITION AND EMPIRICAL & MOLECULAR FORMULA

15. A metal chloride contains 55.0% of chlorine by weight. 100 mL vapours of the metal chloride at STP weigh 0.57 g. The molecular formula of the metal chloride is

(Given: Atomic mass of chlorine is 35.5 u)

[12 April, 2023 (Shift-I)]

(*a*) MCl_2 (*b*) MCl_4
(*c*) MCl_3 (*d*) MCl

16. An organic compound gives 0.220 g of CO_2 and 0.126 g of H_2O on complete combustion. If the % of carbon is 24, then the % hydrogen is ________ $\times 10^{-1}$. (Nearest integer)

[13 April, 2023 (Shift-I)]

17. 116 g of a substance upon dissociation reaction yields 7.5 g of hydrogen, 60g of oxygen and 48.5 g of carbon. Given that the atomic masses of H, O and C are 1,16 and 12 g/mol respectively. The data agrees with how many formulae of the following? **[27 June, 2022 (Shift-II)]**

(*a*) CH_3COOH (*b*) HCHO
(*c*) CH_3OOCH_3 (*d*) CH_3CHO

18. A 2.0 g sample containing MnO_2 is treated with HCl liberating Cl_2. The Cl_2 gas is passed into a solution of KI and 60.0 mL of 0.1 M $Na_2S_2O_3$ is required to titrate the liberated iodine. The percentage of MnO_2 in the sample is____. (Nearest integer)

[Atomic masses (in u) Mn = 55; Cl = 35.5; O = 16, I = 127, Na = 23, K = 39, S = 32] **[28 June, 2022 (Shift-I)]**

19. Complete combustion of 750g of an organic compound provides 420 g of CO_2 and 210 g of H_2O. The percentage composition of carbon and hydrogen in organic compound is 15.3 and _________ respectively. (Round off to the nearest Integer). **[16 March, 2021 (Shift-I)]**

20. A 10 mg effervescent tablet containing sodium bicarbonate and oxalic acid releases 0.25 ml of CO_2 at T = 298.15 K and p = 1 bar. If molar volume of CO_2 is 25.0 L under such condition, what is the percentage of sodium bicarbonate in each tablet? [Molar mass of $NaHCO_3$ = 84 g mol^{-1}]

[11 Jan, 2019 (Shift-I)]

(*a*) 0.84 (*b*) 33.6
(*c*) 16.8 (*d*) 8.4

STOICHIOMETRY & STOICHIOMETRIC CALCULATIONS

21. When a hydrocarbon A undergoes combustion in the presence of air, it requires 9.5 equivalents of oxygen and produces 3 equivalents of water. What is the molecular formula of A? **[29 Jan, 2023 (Shift-II)]**

(*a*) C_8H_6 (*b*) C_9H_9
(*c*) C_6H_6 (*d*) C_9H_6

22. 1 g of a carbonate (M_2CO_3) on treatment with excess HCl produces 0.01 mol of CO_2. The molar mass of M_2CO_3 is ___ g mol^{-1}. (Nearest integer) **[13 April, 2023 (Shift-II)]**

23. If a rocket runs on a fuel ($C_{15}H_{30}$) and liquid oxygen, the weight of oxygen required and CO_2 released for every litre of fuel respectively are: **[24 June, 2022 (Shift-I)]**

(Given: density of the fuel is 0.756 g / mL)

(*a*) 1188 g and 1296 g

(*b*) 2376 g and 2592 g

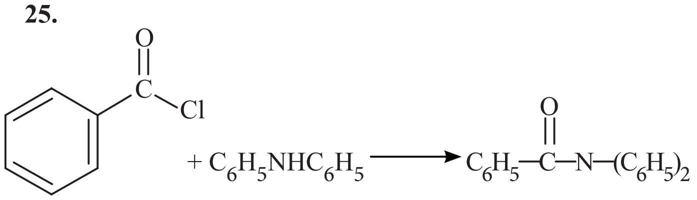
(*c*) 2592 g and 2376 g

(*d*) 3429 g and 3142 g

24. A 0.166 g sample of an organic compound was digested with conc. H_2SO_4 and then distilled with NaOH. The ammonia gas evolved was passed through 50.0 mL of 0.5 N H_2SO_4. The used acid required 30.0 mL of 0.25 N NaOH for complete neutralization. The mass percentage of nitrogen in the organic compound is__________.

[24 June, 2022 (Shift-I)]

25.



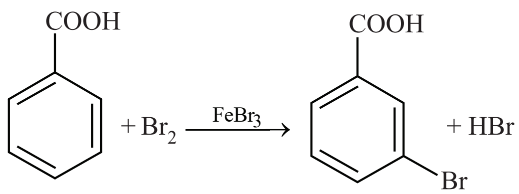
0.140g 0.388g 0.210g

Consider the above reaction. The percentage yield of amide product is _______.

(Round off to the nearest integer).

(Given : Atomic mass : C : 12.0 u, H : 1.0 u, N : 14.0 u, O : 16.0 u, Cl : 35.5 u) **[17 March, 2021 (Shift-II)]**

26.

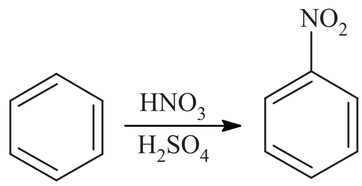


Consider the above reaction where 6.1 g of Benzoic acid is used to get 7.8g of m- bromobenzoic acid. The percentage yield of the product is________. (Round off to the nearest integer).

[Given: Atomic masses: C : 12.0 u, H : 1.0 u, O : 16.0 u, Br : 80.0 u]

[18 March, 2021 (Shift-II)]

27.



In the above reaction, 3.9 g of benzene on nitration gives 4.92 g of nitrobenzene. The percentage yield of nitrobenzene in the above reaction is_____________ %

(Round off to the nearest integer).

(Given atomic mass : C : 12.0 u, H : 1.0 u, O : 16.0 u, N : 14.0 u)

[17 March, 2021 (Shift-I)]

28. A solution of phenol in chloroform when treated with aqueous NaOH gives compound P as a major product. The mass percentage of carbon in P is ___________. (to the nearest integer) (Atomic mass: C = 12 ; H = 1 ; O = 16)

[6 September, 2020 (Shift-II)]

29. For a reaction,

$N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)$;

Identify dihydrogen (H_2) as a limiting reagent in the following reaction mixtures. **[9 April, 2019 (Shift-I)]**

(*a*) 14 g of N_2 + 4 g of H_2

(*b*) 28 g of N_2 + 6 g of H_2

(*c*) 56 g of N_2 + 10 g of H_2

(*d*) 35 g of N_2 + 8 g of H_2

30. The stoichiometric reaction of 516 g of dimethyl dichlorosilane with water results in a tetrameric cyclic product X in 75% yield. The weight (in g) of X obtained is___.

[Use, molar mass (g mol^{-1}): H = 1, C = 12, O = 16, Si = 28, Cl = 35.5] **[JEE Adv 2023]**

PW CHALLENGERS

NUMERICAL TYPE QUESTIONS (ANSWER UPTO TWO DECIMAL PLACE)

1. Excess of calcium orthophosphate is reacted with magnesium to from Ca_3P_2 along with MgO. Ca_3P_2 on reaction with water liberated PH_3 along with $Ca(OH)_2$. PH_3 is burnt in excess of oxygen to form P_2O_5 along with water. Oxides of magnesium and phosphorous react to give magnesium metaphosphate. Calculate grams of magnesium metaphosphate obtained if 1.92 gm of Mg is taken?

2. In one process for waterproofing, a fabric is exposed to $(CH_3)_2SiCl_2$ vapour. The vapour reacts with hydroxyl groups on the surface of the fabric or with traces of water to form the waterproofing film $[(CH_3)_2SiO]_n$, by the reaction

$n[(CH_3)_2SiCl_2 + 2nOH^- \rightarrow 2nCl^- + nH_2O + [(CH_3)_2SiO]_n$

Where n stands for a large integer. The waterproofing film is deposited on the fabric layer upon layer. Each layer is 6.0 Å thick [the thickness of the $(CH_3)_2SiO$ group]. How much (in g) $(CH_3)_2SiCl_2$ is needed to waterproof one side of a piece of fabric, 1.00 m by 3.70 m, with a film 300 layers thick? The density of the film is 1.0 g/cm^3. (Si = 28)

Molar mass of $(CH_3)_2SiO$ = 74 g/mol

Molar mass of $(CH_3)_2SiCl_2$ = 129 g/mol

INTEGER TYPE QUESTIONS

3. Cis-platin $[Pt(NH_3)_2Cl_2]$, a compound used in cancer treatment is prepared by the reaction of ammonia with potassium tetrachloroplatinate.

$K_2PtCl_4 + 2NH_3 \rightarrow 2KCl + Pt(NH_3)Cl_2$

(i) How many grams of cis-platin are formed from 41.7 gm K_2PtCl_4 amd 34 gm NH_3, if the reaction takes place in 90% yield? (Ans. x)

(ii) What is the maximum mass (in g) of KCl which can be produced if initially total 9 moles of reactant are taken. Assuming 100% reaction? (Ans. y)

What is the value of (x + y)? [Pt = 195]

4. The number of Alkoxy groups in an organic compound $A(OR)_x$ may be determined by the sequential reaction.

$$A(OR)_x + xHI \rightarrow AI(OH)_x + xRI$$
$$RI + Ag^+ + H_2O \rightarrow ROH + AgI(s) + H^+$$

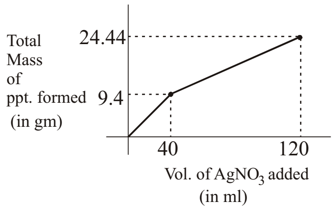
When 4.8 gm of organic compound $A(OR)_x$ (molar mass = 240 gm mol^{-1}) is treated as above, 9.4 gm AgI is precipitated. Then, calculate number of alkoxy groups in the compound $A(OR)_x$.

5. A sample of ammonia contains only H^1 and H^2 isotopes of hydrogen in 4:1 ratio and N^{14} and N^{15} isotopes of nitrogen in 3 : 1 ratio. How many neutrons are present in 1.785 mg of ammonia? (Answer in the order of 10^{18}) ($N_A = 6 \times 10^{23}$)

6. In order to determine the composition of a mixture of halides containing MBr_2 & NaI, 14 gm mixture was dissolved in water. To this solution, $AgNO_3$ solution of certain molarity was added gradually. The mass of precipitate produced (in gm) were measured and it was plotted against volume of $AgNO_3$ solution added (in ml). If it is known that AgI is precipitated first precipitation of Br^- does not start until the already precipitating I^- precipitates completely. Find out the value of AB × CD where:

AB = Atomic weight of metal 'M'

CD = Mole percent of NaI in original mixture.



(Molar mass of NaI = 149.89g/mol, Br = 79.9g/mol, AgI = 234.77g/mol)

7. A mixture of gases liberated upon decomposition of 33.12 gm $Pb(NO_3)_2$ is dissolved in 10ml of water. What is the mass (in g) of 0.1M KOH solution with density 1.05 g/ml required to neutralise this acid. The reactions involved are: (at. mass of Pb = 207)

$$2Pb(NO_3)_2 \xrightarrow{\Delta} 2PbO + 4NO_2 + O_2$$
$$4NO_2 + 2H_2O + O_2 \rightarrow 4HNO_3$$
$$KOH + HNO_3 \rightarrow KNO_3 + H_2O$$

8. Water is the working Fluid in a thermal plant for producing electricity. Coal is Combusted for Generating heat as per reaction, $C + O_2 \rightarrow CO_2$. 0.01% of the released CO_2 gas is absorbed in water and gets converted into weak acid, H_2CO_3 which dissociate to give H^+ as $H_2CO_3 \rightarrow 2H^+ + CO_3^{-2}$. The % dissociation of acid is 5%. Assume no ionisation of H_2O. If in a certain application $[H^+]$ concentration can maximum be 10^{-5} M, then

(a) Calculate maximum no. of moles of H^+(x) and CO_3^{-2} (y) in water if 10^9 litres of H_2O is used.

(b) Calculate maximum no. of mole of carbon (z) which can be burnt so that water remains fit to be used.

What is the value of xy^2/z?

9. A mother cell disintegrates into 60 identical cells and each daughter cell of mother disintegrates into 24 smaller cells, The smallest cell is uniform cylindrical in shape with diameter 120Å and each cell is 6000Å long. Determine molar mass of the mother cell, if density of the smallest cell is 1.12 gm/cm^3. Using scientific notation if your answer is $x \times 10^y$, their write the value of [x] + y, where [ ] is an integer function. Take Avogadro number as 6×10^{23}.

10. Once Tom & Jerry entered a chemistry lab where a chemist was preparing 3L H_2SO_4 solution. He labelled the solution as 10 m ($d_{solution}$ = 3.3 gm/ml). As the chemist left the lab, a mischief came in Tom's mind. He tried to throw the solution on Jerry but failed. In doing so some of the H_2SO_4 solution fell on the floor, so he added water to make it again to 3L. The chemist returned back & got astonished when he saw the result of analysis, that were d = 1.5 gm/ml and % w/w = 98. Find out the number of moles of H_2SO_4 which fell down on the floor.

11. A polymeric substance, tetrafluoroethylene, can be represented by the formula $(C_2F_4)_x$, where x is a large number. The material was prepared by polymerizing C_2F_4 in the presence of a sulphur bearing catalyst that serves as a nucleus upon which the polymer grew. The final product was found to contain 0.012% S. What is the value of x, if each polymeric molecule contains one sulphur atom? Assume that the catalyst contributes a negligible amount to the total mass of the polymer. (F = 19, s = 32)

SINGLE CORRECT TYPE QUESTIONS

12. Density of water varies with temperature as shown.

$d_{t°C} = d_{0°C} - (0.002 \times t°C)$; where

$d_{t°C}$ = density at t°C and $d_{0°C}$ is density at 0°C = 1gm/ml

Calculate % change in molarity and molality respectively of pure water due to change in temperature from 0°C to 100°C.

(*a*) 10%, no change (*b*) no change, 20%

(*c*) 20%, no change (*d*) 20%, 20%

Answer Key

CONCEPT APPLICATION

1. (a) **2.** (a) **3.** (d) **4.** (a) **5.** (a) **6.** (a) **7.** (a) **8.** (b) **9.** (b) **10.** (b)
11. (a) **12.** (b) **13.** (c) **14.** (b) **15.** (a) **16.** (b) **17.** (b) **18.** (a) **19.** (c) **20.** (d)
21. (d) **22.** (b) **23.** (a) **24.** (c) **25.** (b) **26.** (c) **27.** (c) **28.** (b) **29.** (c) **30.** (d)
31. (a) **32.** (b)

SCHOOL LEVEL PROBLEMS

1. (b) **2.** (a) **3.** (a) **4.** (b) **5.** (c) **6.** (a) **7.** (a) **8.** (b) **9.** (c) **10.** (a)
11. (i)-(r), (ii)-(s), (iii)-(q), (iv)-(p) **12.** (i)-(q), (ii)-(r), (iii)-(p), (iv)-(t), (v)-(s) **24.** I-(b), II-(b), III-(a), IV-(a)

PRARAMBH (TOPICWISE)

1. (b) **2.** (b) **3.** (c) **4.** (c) **5.** (c) **6.** (c) **7.** (a) **8.** (b) **9.** (a) **10.** (d)
11. (a) **12.** (a) **13.** (a) **14.** (b) **15.** (b) **16.** (a) **17.** (a) **18.** (c) **19.** (c) **20.** (d)
21. (b) **22.** (a) **23.** (a) **24.** (d) **25.** (c) **26.** (b) **27.** (b) **28.** (c) **29.** (c) **30.** (c)
31. (c) **32.** (a) **33.** (a) **34.** (a) **35.** (d) **36.** (a) **37.** (c) **38.** (d) **39.** (b) **40.** (c)
41. (a) **42.** (d) **43.** (d) **44.** (d) **45.** (a)

PRABAL (JEE MAIN LEVEL)

1. (c) **2.** (a) **3.** (c) **4.** (a) **5.** (c) **6.** (b) **7.** (a) **8.** (a) **9.** (a) **10.** (d)
11. (c) **12.** (a) **13.** (a) **14.** (b) **15.** (a) **16.** (b) **17.** (b) **18.** (a) **19.** (a) **20.** (a)
21. (a) **22.** (a) **23.** (d) **24.** (b) **25.** (c) **26.** (b) **27.** (b) **28.** (c) **29.** (b) **30.** (b)
31. (c) **32.** (b) **33.** (c) **34.** (a) **35.** (c) **36.** (c) **37.** (c) **38.** (a) **39.** (a) **40.** (b)
41. (c) **42.** (c) **43.** (a) **44.** (d) **45.** (c) **46.** (a) **47.** [300] **48.** [76] **49.** [83] **50.** [207]
51. [4] **52.** [1167] **53.** [30M, 75m] **54.** [2] **55.** [180]

PARIKSHIT (JEE ADVANCED LEVEL)

1. (c) **2.** (d) **3.** (a) **4.** (c) **5.** (b) **6.** (c) **7.** (a) **8.** (d) **9.** (b) **10.** (a,b,c)
11. (b,c,d) **12.** (a,b,c) **13.** (a,c) **14.** (b,d) **15.** (b,d) **16.** (a,b) **17.** (a,b,d) **18.** (a,b,d) **19.** (a) **20.** (b)
21. (b) **22.** (d) **23.** (c) **24.** (b) **25.** (b) **26.** [1811.5] **27.** [87.6] **28.** [80] **29.** [3] **30.** [28]

PYQ's (PAST YEAR QUESTIONS)

1. (c) **2.** (b) **3.** [8] **4.** (b, c) **5.** (b) **6.** (d) **7.** [200] **8.** (c) **9.** [1143] **10.** [1]
11. [2130] **12.** (c) **13.** [6.15] **14.** [2.98 or 2.99] **15.** (a) **16.** [56] **17.** [2] **18.** [13] **19.** [3]
20. (d) **21.** (a) **22.** [100] **23.** (c) **24.** [63] **25.** [77] **26.** [78] **27.** [80] **28.** [69] **29.** (c)
30. [222]

PW CHALLENGERS

1. [1.82] **2.** [1.16] **3.** [474] **4.** [2] **5.** [471] **6.** [4994] **7.** [2100] **8.** [250] **9.** [16] **10.** [5]
11. [2667] **12.** (c)