CHEMISTRY

MOLE CONCEPT

Achiever's Comprehensive Course (ACC)

BANSAL CLASSES
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Ideal for Scholars

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PHYSICAL CHEMISTRY

MOLE CONCEPT

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1. MOLE

A mole is the amount of substance that contains as many species [Atoms, molecules, ions or other particles] as there are atoms in exactly 12 gm of C-12.

$$\boxed{1\,mole = 6.022 \times 10^{23}\text{ species}}$$

2.1 Atomic mass

Atomic mass of an element can be defined as the number which indicates how many times the mass of one atom of the element is heavier in comparison to $\frac{1}{12}$th part of the mass of one atom of Carbon-12.

$$\text{Atomic mass} = \frac{[\text{Mass of an atom of the element}]}{\frac{1}{12}\times[\text{Mass of an atom of carbon -12}]} = \frac{\text{Mass of an atom in amu}}{1\text{ amu}}$$

2.2 Atomic mass unit (amu) or Unified mass (u)

The quantity [$\frac{1}{12}$ × mass of an atom of C–12] is known as atomic mass unit.

The actual mass of one atom of C-12 = 1.9924×10^{-26} kg

$$\therefore\ 1\text{ amu} = \frac{1.9924 \times 10^{-26}}{12}\text{ kg}$$

$$= 1.66 \times 10^{-27}\text{ kg} = 1.66 \times 10^{-24}\text{ gm} = \frac{1}{N_A}\text{ gm}$$

2.3 Gram atomic mass

The gram atomic mass can be defined as the mass of 1 mole atoms of an element.

e.g., Mass of one oxygen atom = 16 amu = $\frac{16}{N_A}$ gm.

Mass of N_A oxygen atom = $\frac{16}{N_A}.N_A = 16$ gram

Illustration

(a) What is the mass of one atom of Cl? (b) What is the atomic mass of Cl?

(c) What is the gram atomic mass of Cl?

Sol. (a) Mass of one atom of Cl = 35.5 amu.

(b) Atomic mass of Cl = $\dfrac{\text{Mass of an atom in amu}}{1\text{amu}} = \dfrac{35.5\text{amu}}{1\text{amu}} = 35.5$

(c) Gram atomic mass of Cl = [Mass of 1 Cl atom × N_A]

$= 35.5 \text{ amu} \times N_A = \dfrac{35.5}{N_A} \times N_A \text{ gram} = 35.5 \text{ gram}$

Exercise

(a) What is the mass of one atom of S?

(b) What is the atomic mass of S ?

(c) What is the gram atomic mass of S?

Ans. (a) 32 amu, (b) 32, (c) 32 gram

3.1 Molecular mass

Molecular mass is the number which indicates how many times one molecule of a substance is heavier in comparison to $\dfrac{1}{12}$th of the mass of one atom of C-12.

$$\text{Molecular mass} = \frac{\text{Mass of one molecule of the substance (in amu)}}{\frac{1}{12} \times [\text{Mass of an atom of C-12}]}$$

$$= \frac{\text{Mass of one molecule of the substance (in amu)}}{1\text{amu}}$$

3.2 Gram Molecular mass

Gram molecular mass can be defined as the mass of 1 mole of molecules.

e.g., Mass of one molecule of O_2 = 32 amu = $\dfrac{32}{N_A}$ gram.

Mass of N_A molecules of $O_2 = \dfrac{32}{N_A} \times N_A \text{gm} = 32 \text{ gm}$

Illustration

(a) What is the mass of one molecule of HNO_3?

(b) What is the molecular mass of HNO_3?

(c) What is the gram molecular mass of HNO_3?

Sol. (a) Mass of one molecule of $HNO_3 = (1 + 14 + 3 \times 16)$ amu = 63 amu.

(b) Molecular mass of $HNO_3 = \dfrac{63\ amu}{1\ amu} = 63$

(c) Gram molecular mass of HNO_3 = Mass of 1-molecule of $HNO_3 \times N_A$

$$= 63 \text{ amu} \times N_A = \frac{63}{N_A} \text{ gm} \times N_A = 63 \text{ gram}$$

Exercise

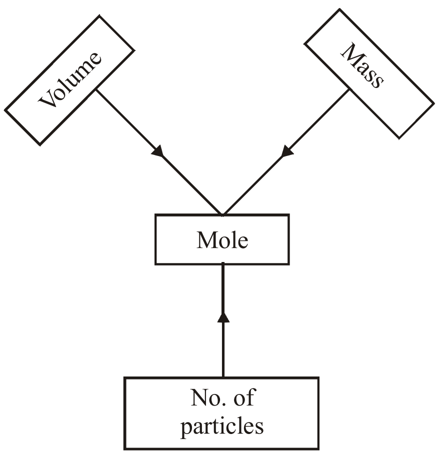
(a) What is the mass of one molecule of H_2SO_4.

(b) What is the molecular mass of H_2SO_4.

(c) What is the gram molecular mass of H_2SO_4.

Ans. (a) 98 amu (b) 98 (c) 98 gram

4. METHODS TO CALCULATE MOLES



4.1 From number of particles :

$$\boxed{\text{No. of mole} = \frac{\text{Given no. of Paritcles [atoms/molecules/ ions]}}{N_A}}$$

Illustration

A piece of Cu contains 6.022×10^{24} atoms. How many mole of Cu atoms does it contain?

Sol. No. of mole = $\dfrac{6.022 \times 10^{24}}{N_A} = \dfrac{6.022 \times 10^{24}}{6.022 \times 10^{23}}$ = 10 mole

Exercise

5 mole of CO_2 are present in a gaseous sample. How many molecules of CO_2 are present in the sample?

Ans. 5 N_A

4.2 From given Mass :

(a) For atoms : No. of mole = $\dfrac{\text{Given mass of the substance(gm)}}{\text{Gram atomic mass}}$ = No. of g-atoms

(b) For molecules : No. of mole = $\dfrac{\text{Given mass of the substance(gm)}}{\text{Gram molecular mass}}$ = No. of g-molecules

Illustration

What will be the mass of 5 mole of SO_2?

Ans. Molecular mass of SO_2 = 64 gm

$$5 = \frac{\text{mass (gm)}}{64}$$

$\therefore$ mass = 320 gm

Exercise

(a) How many mole of O atoms are present in 88 gm CO_2?

(b) What will be the mass of 10 mole of H_3PO_4?

Ans. (a) 4 mole (b) 980 gm

4.3 From the given volume of a gas :

$$\boxed{n = \frac{\textit{volume of gas at 1 bar pressure and 273 K (in litre)}}{22.7}}$$

S.T.P.: 1 bar pressure and 273 K.

$$\boxed{n = \frac{\text{volume of gas at 1 atm and 273K (in litre)}}{22.4}}$$

Note: According to old IUPAC agreement, STP condition was 1 atm pressure and 273 K temperature but according to new agreement it is 1 bar pressure and 273K temperature. Although many books are still using the condition of 1 atm and 273K for STP.

If volume is given under any other condition of temperature and pressure, then use the ideal gas equation to find the no. of moles.

$$\boxed{\text{No. of mole(n)} = \frac{PV}{RT}}$$

Units of Pressure :

1 atm = 76 cm Hg = 760 torr = 1.01325 bar = 1.01325 × 10^5 pa.

Units of temperature :

$$\boxed{K = {}^\circ C + 273}$$

Value of R :
R = 0.0821 litre-atm/mole.K
= 8.314 J/mole.K = 1.987 $\approx$ 2 cal/mole.K

Units of volume :

$$1\,dm^3 = 10^3\,cm^3 = 1\,\text{litre} = 10^{-3}\,m^3 = 10^3\,ml$$

$$1m^3 = 10^3 \text{ litre}$$

Illustration

A sample of He gas occupies 5.6 litre volume at 1 atm and 273 K. How many mole of He are present in the sample?

Sol. No. of mole $= \frac{5.6}{22.4} = 0.25$

Exercise

How much volume will be occupied by 2 mole CO_2 gas at STP?

Ans. 45.4 L

Note : We can use the following relationship as per requirement of question.

$$\text{No. of mole} = \frac{\text{No. of particle}}{N_A} = \frac{\text{mass (gm)}}{[\text{gm at. or mol. mass}]}$$

$$= \frac{V(\ell)\text{ occupied by a Gas at STP}}{22.7} = \frac{V(\ell)\text{ occupied by a Gas at 1atm and 273K}}{22.4}$$

Illustration

How many molecules of O_2 are present in 5.6 litres of O_2 at 1 atm and 273 K?

Sol. $\dfrac{\text{No. of molecules}}{N_A} = \dfrac{V(\ell)\text{ at 1 atm and 273 K}}{22.4}$

$\dfrac{\text{No. of molecules}}{N_A} = \dfrac{5.6}{22.4} = \dfrac{1}{4} \Rightarrow \text{No. of molecule} = \dfrac{N_A}{4} = 1.505 \times 10^{23}$

Exercise

How many molecules of water are present in 9 gram of water?

Ans. 3.011×10^{23}

5. LAWS OF CHEMICAL COMBINATION

5.1 Law of conservation of mass (Lavoisier – 1774) :

In any physical or chemical change, mass can neither be created nor be destroyed.

It means :

Total mass of the reactants = total mass of the products.

This relationship holds good when reactants are completely converted into products.

In case the reacting material are not completely consumed the relationship will be –

Total mass of the reactants = Total mass of the products + mass of unreacted reactants

Limitation : In nuclear reactions, some mass of reactant is converted into energy, so mass of reactant is always less than that of product.

Illustrations

1.7 gram of silver nitrate dissolved in 100 gram of water is taken. 0.585 gram of sodium chloride dissolved in 100 gram of water is added to it and chemical reaction occurs. 1.435 gm of AgCl and 0.85 gm $NaNO_3$ are formed. Show that these results illustrate the law of conservation of mass.

Sol. Total mass before chemical change = mass of $AgNO_3$ + Mass of NaCl + Mass of water

= 1.70 + 0.585 + 200 = 202.285 gram

Total mass after the chemical reaction = mass of AgCl + Mass of $NaNO_3$ + Mass of water

= 1.435 + 0.85 + 200 = 202.285 gram

Thus in the given reaction

Total mass of reactants = Total mass of the products.

Exercise

If 6.3 gram of $NaHCO_3$ are added to 15 gram CH_3COOH solution. The residue is found to weigh 18 gram. What is the mass of CO_2 released in this reaction?

Ans. 3.3 gram

5.2 Law of constant composition : [Proust 1799]

A chemical compound always contains the same element combined together in fixed proportion by mass.

Limitations : In case of isotopes, ratio is not fixed

e.g.	$^{12}CO_2$	$^{14}CO_2$
	12: 32	14 : 32
	3 : 8	7 : 16

Illustration

1.08 gram of Cu wire was allowed to react with nitric acid. The resulting solution was dried and ignited when 1.35 gram of copper oxide was obtained. In another experiment 2.3 gram of copper oxide was heated in presence of Hydrogen yielding 1.84 gram of copper. Show that the above data are in accordance with law of constant composition?

Sol. **Case-I**

$$Cu \xrightarrow{HNO_3} Cu(NO_3)_2 \xrightarrow{\Delta} CuO$$

1.08 gram 1.35 gram

1.35 gram CuO contains $\longrightarrow$ 1.08 gram Cu.

$$100 \text{ gram CuO contains} \longrightarrow \frac{1.08}{1.35} \times 100 = 80 \text{ gram Cu}$$

% Cu in CuO = 80%

% O in CuO = 20%

Case-II

$$CuO + H_2 \longrightarrow Cu + H_2O$$

2.3 gram 1.84 gram

2.30 gram CuO contains $\longrightarrow$ 1.84 gram Cu.

$$100 \text{ gram CuO contains} \longrightarrow \frac{1.84 \times 100}{2.30} = 80 \text{ gram Cu}$$

% Cu in CuO = 80%

% O in CuO = 20%

Both sample have the same composition & hence the data are in accordance with law of constant composition.

Exercise

7.95 gram of cupric oxide was reduced by heating in a current of hydrogen and the weight of copper that remained was 6.35 gram. In another experiment, 19.05 gram of Cu was dissolved in the nitric acid and the resulting copper nitrate is converted into cupric oxide by ignition. The weight of cupric oxide formed was 23.85 gram. Show that these results illustrate the law of constant composition.

5.3 Law of multiple proportion : [Dalton 1806]

When two elements combine to form two or more compounds, the different masses of one element which combine with a fixed mass of the other element, bear a simple ratio to one another.

Illustration

Two compounds each containing only tin and oxygen had the following composition.

	Mass % of Tin	**Mass % of oxygen**
Compound A	78.77	21.23
Compound B	88.12	11.88

Show that these data illustrate the law of multiple proportion?

Sol.

In compound A

21.23 parts of oxygen combine with 78.77 parts of tin.

1 part of oxygen combine with $\frac{78.77}{21.23} = 3.7$ parts of Sn.

In compound B

11.88 parts of oxygen combine with 88.12 parts of tin.

1 part of oxygen combined with $\frac{88.12}{11.88} = 7.4$ parts of tin.

Thus the mass of Tin in compound A and B which combine with a fixed mass of oxygen are in the ratio 3.7 : 7.4 or 1 : 2. This is a simple ratio. Hence the data illustrate the law of multiple proportion.

Exercise

Carbon and oxygen are known to form two compounds. The carbon content in one of these is 42.9% while in the other it is 27.3%. Show that these data are in agreement with the law of multiple proportion.

5.4 Law of reciprocal proportion : [Richter 1794]

When two different elements combine with the same mass of a third element, the ratio in which they do so will be same or simple multiple if both directly combined with each other.

Illustration

The % composition of NH_3, H_2O and N_2O_3 is as given below :

$NH_3 \longrightarrow$ 82.35% N and 17.65% H.

$H_2O \longrightarrow$ 88.9% O and 11.1% H

$N_2O_3 \longrightarrow$ 63.15% O and 36.85% N

On the basis of above data prove the law of reciprocal proportion?

Sol. (i) For NH_3 1-part of hydrogen reacts with $= \frac{82.35}{17.65} = 4.67$ part N.

(ii) For H_2O 1-part of hydrogen reacts with $= \frac{88.90}{11.10} = 8.01$ part O.

Thus the ratio N : O = 4.67 : 8.01 = 1: 1.71

(iii) For N_2O_3 : N and O reacts with each other N : O = 36.85 : 63.15 = 1 : 1.71

Because the two ratios are same, thus law of reciprocal proportion is proved.

5.5 Gay-Lussac's law of gaseous volumes [Gay-Lussac–1808] :

When gases combined or produced in a chemical reaction, they do so in a simple ratio by volume provided all the gases are at same temperature and pressure.

6. SIGNIFICANCE OF CHEMICAL EQUATIONS

A chemical equation describes the chemical process both qualitatively and quantitatively. The stoichiometric coefficients in the chemical equation give the quantitative information of the chemical process. These coefficients represent the relative number of molecules or moles of the reactants and products, e.g.,

	$2\ NH_3\ (g)$	$\rightarrow$	$N_2\ (g)$	+	$3\ H_2\ (g)$
	2 molecules		1 molecule		3 molecules
or	2 N molecules		N molecules		3 N molecules
or	2 moles		1 mole		3 moles

Again, Avogadro's principle states that under the same conditions of temperature and pressure, equal volumes of gases contain the same number of molecules. Thus, for homogeneous gaseous reactions, the stoichiometric coefficients of the chemical equation also signify the relative volumes of each reactant and product under the same conditions of temperature and pressure, e.g.,

	$H_2(g)$	+	$I_2\ (g)$	$\rightarrow$	$2\ HI\ (g)$
	1 molecule		1 molecule		2 molecule
or	1 mole		1 mole		2 mole
or	1 volume		1 volume		2 volume (T & P constant)
or	1 pressure		1 pressure		2 pressure (T & V constant)

6.1 LIMITING REAGENT

The reactant which gives least amount of product on being completely consumed is known as limiting reagent. It may also be defined as the reactant that is completely consumed when a reaction goes to completion. It comes into the picture when reaction involves two ore more reactants. For solving such reactions, first step is to calculate Limiting Reagent.

Calculation of Limiting Reagent:

Method-I : By calculating the required amount by the equation and comparing it with given amount. [Useful when only two reactant are there]

Method-II : 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*.

Method-III : 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.]

Illustration

If 20gm of $CaCO_3$ is treated with 20gm of HCl, how many grams of CO_2 can be generated according to following reaction?

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

Sol. Mole of $CaCO_3 = \dfrac{20}{100} = 0.2$

Mole of HCl $= \dfrac{20}{36.5} = 0.548$

$$\left[\frac{Mole}{Stoichiometric\ co\text{-}efficient}\right] \text{ for } CaCO_3 = \frac{0.2}{1} = 0.2$$

$$\left[\frac{Mole}{Stoichiometric\ co\text{-}efficient}\right] \text{ for HCl} = \frac{0.548}{2} = 0.274$$

So $CaCO_3$ is limiting reagent

According to reaction :

100 gm of $CaCO_3$ gives 44gm of CO_2

20 gm $CaCO_3$ will give $\dfrac{44}{100} \times 20 = 8.8$ gm CO_2

Exercise

Calculate the mass of carbon tetrachloride can be produced by the reaction of 144gm of carbon with 71 gm of Chlorine.

Ans. 77 gm

6.2 PROBLEMS RELATED WITH MIXTURE

Illustration

4 gram of a mixture of $CaCO_3$ and Sand (SiO_2) is treated with an excess of HCl and 0.88 gm of CO_2 is produced. What is the percentage of $CaCO_3$ in the original mixture?

Ans. $CaCO_3 + 2HCl \rightarrow CaCl_2 + H_2O + CO_2$

$SiO_2 + HCl \rightarrow$ No reaction

$CaCO_3 = x$ gm

100 gm $CaCO_3$ gives $\longrightarrow$ 44 gm CO_2

x gm $CaCO_3$ gives $\longrightarrow$ 0.88 gm CO_2

$$\Rightarrow \quad \frac{100}{x} = \frac{44}{0.88} \quad \Rightarrow \quad x = 2 \text{ gram}$$

$$\% \ CaCO_3 = \frac{2}{4} \times 100 = 50\%$$

Exercise

44 gram sample of a natural gas, consisting of methane [CH_4] and ethylene [C_2H_4] was burned in excess of oxygen yielding 132 gm CO_2 and some H_2O as products. What is the mole % of ethylene in the sample?

Ans. 50%

6.3 PERCENTAGE YIELD

In gener59al, when a reaction is carried out in the laboratory we do not obtain the theoretical amount of product. The amount of product that is actually obtained is called the actual yield. Knowing the actual yield and theoretical yield, the % yield can be calculated by the following formula–

$$\text{Percentage yield} = \frac{\text{Actual yield}}{\text{Theoritical yield}} \times 100\ \%$$

SOLVED EXAMPLES

Q.1 Naturally occurring chlorine is 75.53% Cl^{35} which has an atomic mass of 34.969 amu and 24.47% Cl^{37} which has a mass of 36.966 amu. Calculate the average atomic mass of chlorine-
(A) 35.5 amu (B) 36.5 amu (C) 71 amu (D) 72 amu

Ans. (A)

Sol. Average atomic mass = $\dfrac{\%\text{ of I isotope} \times \text{its atomic mass} + \%\text{ of II isotope} \times \text{its atomic mass}}{100}$

$= \dfrac{75.53 \text{ x } 34.969 + 24.47 \text{ x } 36.96}{100}$

= 35.5 amu.

Q.2 How many carbon atoms are present in 0.35 mol of $C_6H_{12}O_6$ -
(A) 6.023×10^{23} carbon atoms (B) 1.26×10^{23} carbon atoms
(C) 1.26×10^{24} carbon atoms (D) 6.023×10^{24} carbon atoms

Ans. (C)

Sol. $\therefore$ 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
= $2.1 \times 6.022 \times 10^{23}$ **= 1.26×10^{24} carbon atoms**

Q.3 Calculate the mass in gm of $2N_A$ molecules of CO_2 -
(A) 22 gm (B) 44 gm (C) 88 gm (D) None of these.

Ans. (C)

Sol. $\because$ N_A molecules of CO_2 has molecular mass = 44 gm
$\therefore$ $2N_A$ molecules of CO_2 has molecular mass = 44 × 2 **= 88 gm.**

Q.4 How many years it would take to spend Avogadro's number of rupees at the rate of 1 million rupees in one second -
(A) 19.098×10^{19} years (B) 19.098 years
(C) 19.098×10^{9} years (D) None of these

Ans. (C)

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

$\therefore$ 6.022×10^{23} rupees are spent in = $\dfrac{1 \times 6.022 \times 10^{23}}{10^6}$ sec

$= \dfrac{1 \times 6.023 \times 10^{23}}{10^6 \times 60 \times 60 \times 24 \times 365}$ years **= 19.098×10^9 year**

Q.5 Calculate the number of Cl^- and Ca^{+2} ions in 222 g anhydrous $CaCl_2$.
(A) $2N_A$ ions of Ca^{+2} 4 N ions of Cl^- (B) $2N_A$ ions of Cl^- & 4N ions of Ca^{+2}
(C) $1N_A$ ions of Ca^{+2} & 1N ions of Cl^- (D) None of these.

Ans. (A)

Sol. $\because$ mol. wt. of $CaCl_2$ = 111 g
$\because$ 111 g $CaCl_2$ has = N_A ions of Ca^{+2}
$\therefore$ 222g of $CaCl_2$ has $\dfrac{N_A \times 222}{111}$ = $2N_A$ ions of Ca^{+2}

Also $\because$ 111 g $CaCl_2$ has = $2N_A$ ions of Cl^-

$\therefore$ 222 g $CaCl_2$ has = $\frac{2N_A \times 222}{111}$ ions of Cl^- **= $4N_A$ ions of Cl^- .**

Q.6 What is the molecular mass of a substance, each molecule of which contains 9 carbon atoms, 13 hydrogen atoms and 2.33×10^{-23} g of other component?

Ans. 135.04

Sol. The molecule has C, H and other component.

Mass of 9 C atoms = 12 × 9 = 108 amu

Mass of 13 H atoms = 13 × 1 = 13 amu

Mass of other component = $\frac{2.33 \times 10^{-23}}{1.66 \times 10^{-24}} = 14.04 \text{amu}$

$\therefore$ Total mass of one molecule = 108 + 13 + 14.04 = 135.04 amu

$\therefore$ Mol. mass of substance **= 135.04**

Q.7 The density of O_2 at 0ºC and 1 atm is 1.429g / litre. The molar volume of gas is -

(A) 22.4 lit. (B) 11.2 lit (C) 33.6 lit (D) 5.6 lit.

Ans. (A)

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.**

Q.8 How many molecules are 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

Ans. (B)

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**

Q.9 How many g of S are required to produce 10 moles and 10g of H_2SO_4 respectively?

Ans. 320 g, 3.265 g

Sol. $\because$ 1 mole of H_2SO_4 has = 32g S

$\therefore$ 10 mole of H_2SO_4 has = 32 × 10 = **320 g S**

Also, 98g of H_2SO_4 has = 32 g S

$\therefore$ 10 g of H_2SO_4 has = (32 × 10)/98 **= 3.265 g S**

Q.10 P and Q are two elements which form P_2Q_3 and PQ_2 molecules. If 0.15 mole of P_2Q_3 and PQ_2 weighs 15.9 g and 9.3g, respectively, what are atomic mass of P and Q?

Ans. P = 26, Q = 18

Sol. Let at. mass of P and Q be a and b respectively,

$\therefore$ Mol. mass of P_2Q_3 = 2a + 3b

and Mol. mass of PQ_2 = a + 2b

$\therefore$ (2a + 3b) × 0.15 = 15.9

and (a + 2b) × 0.15 = 9.3

a = 26, b = 18

atomic mass of **P = 26**

atomic mass of **Q = 18**

EXERCISE-1 (Exercise for JEE Mains)

[SINGLE CORRECT CHOICE TYPE]

Q.1 Which is heaviest :
(A) 25 g of Hg (B) 2 mole of H_2O (C) 2 mole of CO_2 (D) 4 g-atom of O
[2020112299]

Q.2 16 g of SO_x occupies 5.6 litre at STP. Assuming ideal gas nature, The value of x is :
(A) 1 (B) 2 (C) 3 (D) None of these
[2020110849]

Q.3 The density of liquid (mol. wt. = 70) is 1.2 g mL^{-1}. If 2 mL of liquid contains 35 drops, the number of molecules of liquid in one drop are :
(A) $\frac{1.2}{3.5} \times N_A$ (B) $\frac{1}{35} \times N_A$ (C) $\frac{1.2}{35^2} \times N_A$ (D) 1.2 N_A
[2020110582]

Q.4 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}
[2020110100]

Q.5 Rearrange the following (I to IV) in the order of increasing masses.
(I) 0.5 mole of O_3 (II) 0.5 gm molecule of Nitrogen
(III) 3.011×10^{23} molecules of O_2 (IV) 11.35 L of CO_2 at STP.
(A) IV < III < II < I (B) II < III < IV < I (C) III < II < I < IV (D) I < II < III < IV
[2020110110]

Q.6 A mixture of gas "X" (mol. wt. 16) and gas Y (mol. wt. 28) in the mole ratio a : b has a mean molecular weight 20. What would be mean molecular weight if the gases are mixed in the ratio b : a under identical conditions (gases are non reacting).
(A) 24 (B) 20 (C) 26 (D) 40
[2020111599]

Q.7 The percentage by mole of NO_2 in a mixture of NO_2(g) and NO(g) having average molecular mass 34 is :
(A) 25% (B) 20% (C) 40% (D) 75%
[2020111450]

Q.8 An iodized salt contains 0.5 % of NaI. A person consumes 3 gm of salt everyday. The number of iodide ions going into his body everyday is
(A) 10^{-4} (B) 6.02×10^{-4} (C) 6.02×10^{19} (D) 6.02×10^{23}
[2020111898]

Q.9 The number of carbon atoms present in a signature, if a signature written by carbon pencil weights 1.2×10^{-3} g is
(A) 12.04×10^{20} (B) 6.02×10^{19} (C) 3.01×10^{19} (D) 6.02×10^{20}
[2020110919]

EXERCISE-2 (Exercise for JEE Advanced)

[PARAGRAPH TYPE]

Paragraph for Question Nos. 1 to 2

$FeSO_4$ undergoes decomposition as

$$2FeSO_4\,(s) \longrightarrow Fe_2O_3(s) + SO_2(g) + SO_3(g)$$

At 1 atm & 273 K if (7.6gm) $FeSO_4$ is taken then **[2020110028]**

Q.1 The volume occupied by the gases at 1 atm & 273 K

(A) 22.4 lit (B) 11.2 lit (C) 1.12 lit (D) 2.24 lit

Q.2 The average molar mass of the gaseous mixture.

(A) 72 (B) 36 (C) 48 (D) 60

Paragraph for Question Nos. 3 to 5

NaBr, used to produce AgBr for use in photography can be self prepared as follows :

$$Fe + Br_2 \longrightarrow FeBr_2 \quad ....(i)$$
$$3FeBr_2 + Br_2 \longrightarrow Fe_3Br_8 \quad ....(ii) \quad \text{(not balanced)}$$
$$Fe_3Br_8 + Na_2CO_3 \longrightarrow 3NaBr + CO_2 + Fe_3O_4 \quad ....(iii) \quad \text{(not balanced)}$$

[2020110049]

Q.3 Mass of iron required to produce 2.06×10^3 kg NaBr

(A) 420 g (B) 420 kg (C) 4.2×10^5 kg (D) 4.2×10^8 g

Q.4 If the yield of (ii) is 60% & (iii) reaction is 70% then mass of iron required to produce 2.06×10^3 kg NaBr

(A) 10^5 kg (B) 10^5 g (C) 10^3 kg (D) None

Q.5 If yield of (iii) reaction is 90% then mole of CO_2 formed when 2.06×10^3 gm NaBr is formed

(A) 20 (B) 10 (C) 40 (D) None

Paragraph for Question Nos. 6 to 9

A 10 ml mixture of N_2, a alkane & O_2 undergo combustion in Eudiometry tube. There was contraction of 2 ml, when residual gases are passed through KOH. To the remaining mixture comprising of only one gas excess H_2 was added & after combustion the gas produced is absorbed by water, causing a reduction in volume of 8 ml. **[20202120210]**

Q.6 Gas produced after introduction of H_2 in the mixture?

(A) H_2O (B) CH_4 (C) CO_2 (D) NH_3

Q.7 Volume of N_2 present in the mixture?

(A) 2 ml (B) 4 ml (C) 6 ml (D) 8 ml

Q.8 Volume of O_2 remained after the first combustion?

(A) 4 ml (B) 2 ml (C) 0 (D) 8 ml

Q.9 Identify the hydrocarbon.

(A) CH_4 (B) C_2H_6 (C) C_3H_8 (D) C_4H_{10}

EXERCISE-3 (Miscellaneous Exercise)

Q.1 Find the number of g-molecules of oxygen in 6.023×10^{24} CO molecules.
[2020112647]

Q.2 On heating 1.763 g of hydrated barium chloride $[BaCl_2.x\ H_2O]$ to dryness, 1.505 g of anhydrous salt remained. Find the value of x. **[2020110598]**

Q.3 The abundance of three isotopes of oxygen are as follows
% of O^{16} = 90%
% of O^{17} + % of O^{18} = 10%
Assume at. mass same as mass no. Find out % of O^{17} and O^{18}, if the isotopic mass is 16.12.
[2020111246]

Q.4 1.44 gram of Titanium (Ti) reacted with excess of O_2 and produced x gram of non-stoichiometric compound $Ti_{1.44}O$. Calculate The value of x be **[2020110146]**

Q.5 How many g of HCl is needed for complete reaction with 69.6 g MnO_2 ?
$$HCl + MnO_2 \longrightarrow MnCl_2 + H_2O + Cl_2$$ **[2020111201]**

Q.6 Flourine reacts with uranium to produce uranium hexafluoride, UF_6, as represented by this equation
$$U(s) + 3F_2(g) \rightarrow UF_6(g)$$
How many fluorine molecules are required to produce 2.0 mg of uranium hexafluoride, UF_6, from an excess of uranium ? The molar mass of UF_6 is 352 gm/mol. **[2020111576]**

Q.7 What total volume, in litre at 600°C and 1 atm, could be formed by the decomposition of 16 gm of NH_4NO_3 ? Reaction : $2\ NH_4NO_3 \rightarrow 2N_2 + O_2 + 4H_2O_{(g)}$. **[2020110801]**

Q.8 Calculate mass of phosphoric acid required to obtain 53.4g pyrophosphoric acid.
[2020110500]

Q.9 Calculate the amount of H_2SO_4 produced (in g) when 40 ml H_2O (d = 0.9 gm/ml) reacts with 50 *l* SO_3 at 1 atm. and 300 K, according to the following reaction ?
$$H_2O + SO_3 \rightarrow H_2SO_4$$ **[2020111926]**

Q.10 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
$$n(CH_3)_2SiCl_2 + 2nOH^- \longrightarrow 2nCl^- + nH_2O + [(CH_3)_2SiO]_n$$
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 $(CH_3)_2\ SiCl_2$ is needed to waterproof one side of a piece of fabric, 1.00 m by 3.00 m, with a film 300 layers thick ? The density of the film is 1.0 g/cm^3. **[2020111550]**

EXERCISE-4

SECTION-A
(IIT JEE Previous Year's Questions)

Q.1 Which has the maximum number of atoms : **[IIT-JEE 2003]**
(A) 24 g C (12) (B) 56 g Fe (56) (C) 27 g Al (27) (D) 108 g Ag (108)
[2020110647]

Q.2 Calculate the molarity of pure water using its density to be 1000 kg m^{-3}. **[JEE'2003]**
[2020211198]

Q.3 One gm of charcoal absorbs 100 ml 0.5 M CH_3COOH to form a monolayer, and thereby the molarity of CH_3COOH reduces to 0.49. Calculate the surface area of the charcoal adsorbed by each molecule of acetic acid. Surface area of charcoal = 3.01×10^2 m^2/gm. **[JEE'2003]**
[2020212244]

Q.4 Calculate the amount of calcium oxide required when it reacts with 852 g of P_4O_{10}.
[IIT-JEE 2005]
[2020111000]

Q.5 20% surface sites have adsorbed N_2. On heating N_2 gas evolved from sites and were collected at 0.001 atm and 298 K in a container of volume is 2.46 cm^3. Density of surface sites is $6.023\times10^{14}/cm^2$ and surface area is 1000 cm^2, find out the no. of surface sites occupied per molecule of N_2.
[JEE 2005]
[2020212593]

Q.6 Dissolving 120 g of urea (mol. wt. 60) in 1000 g of water gave a solution of density 1.15 g/mL. The molarity of the solution is **[JEE 2011]**
(A) 1.78 M (B) 2.00 M (C) 2.05 M (D) 2.22 M
[2020210589]

Q.7 The volume (in ml) of 0.1 M $AgNO_3$ required for complete precipitation of chloride ions present in 30 ml of 0.01 M solution of $[Cr(H_2O)_5Cl]Cl_2$, as silver chloride is close to **[JEE 2011]**
[2020210539]

SECTION-B
(AIEEE Previous Year's Questions)

Q.8 A solution containing 2.675 g of $CoCl_3.6\,NH_3$ (molar mass = 267.5 g mol^{-1}) is passed through a cation exchanger. The chloride ions obtained in solution were treated with excess of $AgNO_3$ to give 4.78 g of AgCl (molar mass = 143.5 g mol^{-1}). The formula of the complex is
(At. mass of Ag = 108 u) **[AIEEE-2010]**
(A) $[CoCl_3(NH_3)_3]$ (B) $[CoCl(NH_3)_5]Cl_2$ (C) $[Co(NH_3)_6Cl_3$ (D) $[CoCl_2(NH_3)_4]Cl$
[2020114017]

Q.9 29.5 mg of an organic compound containing nitrogen was digested according to Kjeldahl's method and the evolved ammonia was absorbed in 20 mL of 0.1 M HCl solution. The excess of the acid required 15 mL of 0.1 M NaOH solution for complete neutralization. The percentage of nitrogen in the compound is:
(A) 23.7 (B) 29.5 (C) 59.0 (D) 47.4
[AIEEE-2011]
[2020113966]

Q.10 A 5.2 molal aqueous solution of methyl alcohol, CH_3OH, is supplied. What is the mole fraction of methyl alcohol in the solution ? **[AIEEE-2011]**
(A) 0.100 (B) 0.190 (C) 0.086 (D) 0.050
[2020113915]

Q.11 The molarity of a solution obtained by mixing 750 mL of 0.5 (M) HCl with 250 mL of 2 (M) HCl will be:
(A) 1.00 M (B) 1.75 M (C) 0.975 M (D) 0.875 M
[JEE MAIN-2013]
[2020114119]

Q.12 A gaseous hydrocarbon gives upon combustion 0.72 g of water and 3.08 g of CO_2. The empirical formula of the hydrocarbon is:
(A) C_3H_4 (B) C_6H_5 (C) C_7H_8 (D) C_2H_4
[JEE MAIN-2013]
[2020114170]

ANSWER KEY

EXERCISE-1

Q.1	(C)	**Q.2**	(B)	**Q.3**	(C)	**Q.4**	(B)
Q.5	(B)	**Q.6**	(A)	**Q.7**	(A)	**Q.8**	(C)
Q.9	(B)	**Q.10**	(C)	**Q.11**	(C)	**Q.12**	(D)
Q.13	(C)	**Q.14**	(A)	**Q.15**	(A)	**Q.16**	(A)
Q.17	(A)	**Q.18**	(C)	**Q.19**	(A)	**Q.20**	(D)
Q.21	(A)	**Q.22**	(D)	**Q.23**	(B)	**Q.24**	(A)
Q.25	(C)	**Q.26**	(B)	**Q.27**	(A)	**Q.28**	(C)
Q.29	(B)	**Q.30**	(C)	**Q.31**	(A)	**Q.32**	(B)
Q.33	(B)	**Q.34**	(C)	**Q.35**	(C)	**Q.36**	(B)
Q.37	(A)	**Q.38**	(D)	**Q.39**	(C)	**Q.40**	(A)
Q.41	(A)	**Q.42**	(C)	**Q.43**	(C)	**Q.44**	(A)
Q.45	(A)	**Q.46**	(B)	**Q.47**	(D)	**Q.48**	(A)
Q.49	(B)	**Q.50**	(A)				

EXERCISE-2

Q.1	(C)	**Q.2**	(A)	**Q.3**	(B)	**Q.4**	(C)
Q.5	(B)	**Q.6**	(D)	**Q.7**	(B)	**Q.8**	(C)
Q.9	(A)	**Q.10**	(A)	**Q.11**	(A)	**Q.12**	(A), (C)
Q.13	(A)	**Q.14**	(C)	**Q.15**	(C)	**Q.16**	(B)
Q.17	(C)	**Q.18**	(D)	**Q.19**	(A)	**Q.20**	(A)
Q.21	(B)	**Q.22**	(D)	**Q.23**	(A)	**Q.24**	(B), (D)
Q.25	(A), (B), (D)	**Q.26**	(A), (C)	**Q.27**	(A), (B)	**Q.28**	(A), (C)
Q.29	(A), (C)	**Q.30**	(A), (C)	**Q.31**	(B), (D)	**Q.32**	(B), (D)

Q.33 (A), (C)
Q.34 [(A) R, (B) P, (C) Q]
Q.35 [(A) R, (B) Q, (C) P]
Q.36 [A-Q ; B-P, R ; C-P,R; D-P]
Q.37 [A-Q, B-R, C-P, D-T]
Q.38 [(A) P; (B) P,Q ; (C) S; (D) R]
Q.39 [(A) Q; (B) P; (C) S; (D) R]
Q.40 [(A) –R, (B) – S, (C) – P, (D)–Q]

EXERCISE-3

Q.1 [5 g-mole]
Q.2 [2]
Q.3 [16.12]
Q.4 [1.77 g]
Q.5 [116.8 g]
Q.6 [1.0×10^{19}]
Q.7 [50.14 litre]
Q.8 [58.8 g]
Q.9 [0196]
Q.10 [0.9413 g]
Q.11 [9.12]
Q.12 [0.25 mole]
Q.13 [1.1458 g]
Q.14 [Al = 66.6%]
Q.15 [$CaCO_3$ = 28.4%; $MgCO_3$ = 71.6%]
Q.16 [$NaHCO_3$ = 14.9 %; Na_2CO_3 = 85.1 %]
Q.17 [45%]
Q.18 [12.3]
Q.19 [39.18]
Q.20 [61.5 g]
Q.21 [320.3 g]
Q.22 [(i) $Fe_2O_3 + 2Al \longrightarrow Al_2O_3 + 2Fe$; (ii) 80 : 27; (iii)10,000 units]
Q.23 [19.4 g]
Q.24 [12.15g, N_2 = 14.28 % H_2 = 42.86%, NH_3 = 42.86 %]
Q.25 [470.4 g]
Q.26 [(a)59.17 g (b) 61.97 g]
Q.27 [92.70 g/mol]
Q.28 [0.532 : 1.00]
Q.29 [.(i) 0.5 , 0.5 ; (ii) 2, 1 (iii) 1, 2]
Q.30 [59.72%]

Q.31 [10 ml]
Q.32 [NO = 44 ml; N_2O = 16 ml]
Q.33 [C_2H_2 = 6 ml, CO = 14 ml]
Q.34 [CH_4 = 4.5 ml, CO_2 = 1.5 ml]
Q.35 [C_2H_2 = 16 ml, CO = 24 ml]
Q.36 [(a) CO_2, H_2O and O_2 ; (b) $n_{CO_2} = 3$, $n_{H_2O} = 4$; (c) C_2H_4 and CH_4 are the H.C; (d) $n_{O_2} = 8$]
Q.37 [(a) 40 ml, (b) 20%, (c) 72 ml]
Q.38 [0.2,0.2,0.3,0.3]
Q.39 [NH_3]
Q.40 [13.15]
Q.41 [16.67%]
Q.42 [1.288]
Q.43 [0.15 M]
Q.44 [0.06 M]
Q.45 [45.45%]
Q.46 [3×10^{-3} M]
Q.47 [16.8 g]
Q.48 [0.6667, 0.6667]
Q.49 [1.736 litre]
Q.50 [2 M]
Q.51 [1.5 ml]
Q.52 [0.05]
Q.53 [5.56 ml]
Q.54 [250]
Q.55 [(i) 20 gm H_2SO_4 ; (ii) 35.4 gm H_2SO_4; (iii) H_2SO_4= 35.4 gm, H_2O = 34.6gm]
Q.56 [44.8 V]
Q.57 [24.51 ml]
Q.58 [(a) 0.2; (b) 0.4 moles; (c) 0.45; (d) 50.4 'V']
Q.59 [0.05]
Q.60 [0.331g, 2.25×10^{-4}, 2.81, 0.0482, 321, 5.72]

EXERCISE-4

SECTION-A

Q.1 (A)
Q.2 [55.5 mol L^{-1}]
Q.3 [5×10^{-19} m^2]
Q.4 [1008 g]
Q.5 [2]
Q.6 (C)
Q.7 [6]

SECTION-B

Q.8 (C)
Q.9 (A)
Q.10 (C)
Q.11 (D)
Q.12 (C)

HINTS / SOLUTION

EXERCISE-1

Q.1 (a) wt of Hg = 25 g
(b) wt. of $H_2O = 2 \times 18 = 36$ g
(c) wt of $CO_2 = 2 \times 44 = 88$ g
(d) wt. of O = $4 \times 16 = 64$ g

Q.2 One mole of a gas occupies 22.4 litre at STP
gram mol wt. of $SO_x = 32 + 16x$ g

gram mol wt. of $SO_x = \dfrac{16\times 22.4}{5.6} = 32 + 16x$ g

$x = 2$

Q.3 wt. of one drop of liquid = $\dfrac{1.2\times 2}{35}$ gram

70 gram of liquid contain N_A molecules

$\dfrac{1.2\times 2}{35}$ gram of liquid contain $\dfrac{N_A}{70}\times\dfrac{1.2\times 2}{35} = \dfrac{1.2}{(35)^2}\times N_A$

Q.4 Moles of $Mg_3(PO_4)_2 = \dfrac{1}{8}\times 0.25 = 3.125 \times 10^{-2}$

Q.5 Convert all the value in mass and the increasing order is (II < III < IV < I)

Q.6 $\dfrac{a\times 16 + b\times 28}{a+b} = 20$

$16a + 28b = 20a + 20b$

$4a = 8b \Rightarrow a = 2b \Rightarrow a/b = 2$

Now $\dfrac{16b+28a}{b+a} = \dfrac{16+28a/b}{1+a/b} = \dfrac{16+28\times 2}{1+2} = 24$

Q.7 $\text{Mavg} = \dfrac{x.M_{NO_2} + (100-x)M_{NO}}{100}$

$34 = \dfrac{x\times 46 + (100-x)30}{100}$

$x = 25\%$

Q.8 Moles of I^- = moles of NaI

$= \dfrac{\text{wt. of NaI}}{\text{Mol. mass of NaI}} = \left(\dfrac{0.5\times 3}{100}\right)\times\dfrac{1}{150}$

$= 10^{-4}$ moles

No. of Iodine ions = moles of I^- $\times N_A$

$= 6.02 \times 10^{19}$

Q.9 No. of carbon atoms = $\dfrac{1.2 \times 10^{-3}}{12} \times N_A = 6.02 \times 10^{19}$

Q.10 $M_{avg} = 24.31 = \dfrac{79 \times 24 + (21 - x) \times 25 + x \times 26}{100}$

$x = 10$

Q.11 (a) 8 g sulphur is present in 100 g of the compound
(For minimum molecular mass, one mole of compound should contain at least one mole of sulphur)

Hence 32 g S (1 mole) will be present $= \dfrac{100}{8} \times 32 = 400$ g

So minimum molecular weight = 400

(b) Molecular weight when four atoms are present $= \dfrac{400}{8} \times 4$

$= 1600$

Q.12 $\dfrac{18n}{142 + 18n} \times 100 = 55.9$

$n = 10$

Q.13 Wt of iron $= \dfrac{0.33}{100} \times 67200 = 222.76$ amu.

Atoms of iron $= \dfrac{222.76}{56} = 3.98 \approx 4$

Q.14 Atomic wt. of S = 32 amu

Minimum molecular weight of insulin $= \dfrac{100 \times 32}{3.4} = 914.176$

Q.15 $Ag_2CO_3 \xrightarrow{\Delta} 2Ag + CO_2 + 1/2\ O_2$

276 g 216g

wt. of Ag $= \dfrac{216}{276} \times 2.76 = 2.16$ g

Q.16 $NaHCO_3 + HCl \longrightarrow NaCl + CO_2 + H_2O$

1 1 1 1 1

Vol. = 22.4 litre at STP