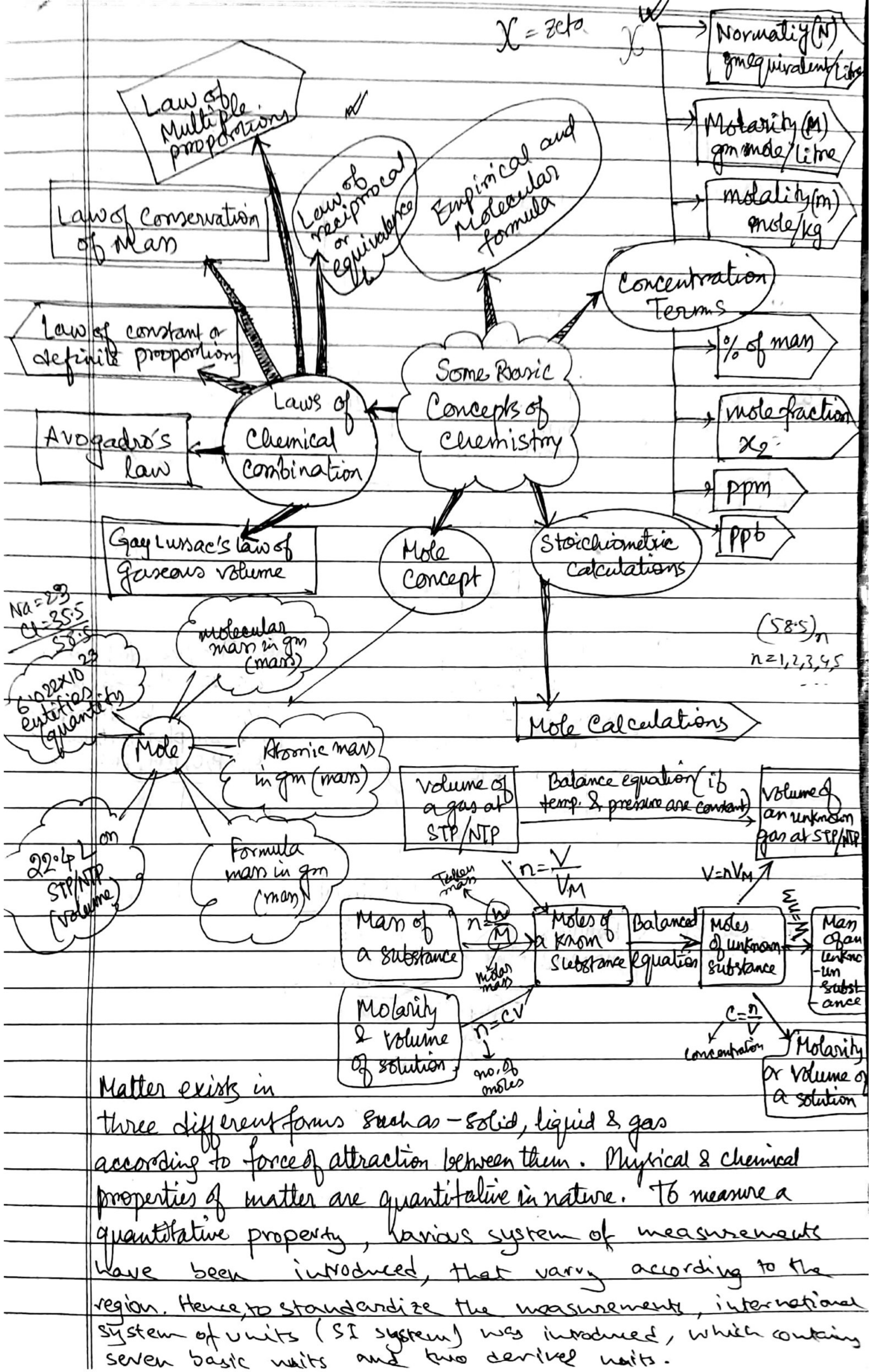

Matter exists in three different forms such as – solid, liquid & gas according to force of attraction between them. Physical & chemical properties of matter are quantitative in nature. To measure a quantitative property, various system of measurements have been introduced, that vary according to the region. Hence, to standardize the measurements, international system of units (SI system) was introduced, which contains seven basic units and two derived units.

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Matter

Physical classification

- **Solid** — has definite shape & volume
- **Liquid** — has no specific shape but has definite volume
- **Gas** — has no fixed shape & vol

Chemical classification

- **Mixtures** — variable composition
  - **Homogeneous mixture** — composition of substances is uniform throughout the mixture. exa: Solutions, and well stirred fluid
  - **Heterogenous Mixture** — Multiphase mixtures, poorly stirred fluids eg:- ores, colloids
  - **Colloids** — smoke, cloud, emulsions
  - **Composite materials** — Inorganic – rock & salt; Organic – Wood; Biological – yest
- **Pure substances** — have constant composition
  - **Elements** — They contain only one type of atom or molecule, can't be decomposed into simpler substances such as – C, N_2, H_2, fe etc.
    - **Metals** — Good conductor of heat & electricity
    - **Nonmetals** — Brittle & nonconductive. exceptional – Graphite, gas Carbon etc.
    - **Metalloids** — Intermediate between metals & non metals
  - **Compounds** — Two/more different atoms combine to form a compd which can be decomposed into simpler substances eg: H_2O, CH_4, NH_3, etc.
    - **Organic compounds** — whose molecules containing Carbon
    - **Inorganic compounds** — The elements other than C-atom are combined

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Separation of Mixtures

(i) **Filteration** can separate those mixtures whose one component is soluble in a particular solvent & other is not.

(ii) **Fractional Distillation** can be used to separate constituents of mixtures having different boiling points

(iii) **Extraction** dissolves one out of several components of mixture.

(iv) **Crystallisation** is a process of separating solids having different solubilities in a particular solvent.

(v) **Sublimation** separates volatile solids which sublime on heating from non-volatile solids.

(vi) **Chromatography** is the technique of separating constituents of a mixture which utilises the property of difference of adsorption on a particular adsorbent.

(vii) **Gravity separation** can separate magnetic components from nonmagnetic ones.

What is mole? Mole is a unit in S.I used to indicate such amount of ~~species~~ matter in which Avogadro's number (N_A) of species (ions/atoms/molecules) present which is numerically equal to 6.022×10^{23}.

1 gm-mole CO_2 →
- 44 gm of CO_2 (gm molecular mass of CO_2)
- Contains N_A no. of CO_2 molecules
- At STP occupies 22.4 Litre volume

Find the no. of Oxygen atoms in 1 mole of CO_2?

No. O-atoms present in 1 molecule of CO_2 is 2

1 mole CO_2 = N_A no. of CO_2 molecules, contain $2 \times N_A$ no. of O-atoms

Find no. of gm atoms of Oxygen present 1 gmole of CO_2?

1 gm atom O = 16 g O_2

1 gm mole CO_2 = N_A no. of CO_2 molecules contain $2N_A$ no. O-atoms

$= 2 \times N_A \times 16$ gm

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1 gm mole CO_2 contains = 1 gm mole O_2 = 32 gm

16 gm O = 1 gm atom of O

32 g O = 2 gm atoms of O = 1 gm mole O_2

∴ 2 ~~Number~~ gmatom of oxygen presents in 1 gm mole CO_2.

(Relative) Atomic mass of a substance (in H-scale) = $\frac{\text{Mass of one atom}}{\text{Mass of one H-atom}}$

(in O-scale) = $\frac{\text{Mass of one atom}}{\text{Mass of one } {}_8O^{16}\text{-isotope}} \times 16$

isotopes of oxygen ${}_8O^{16}$, ${}_8O^{17}$, ${}_8O^{18}$

(in C-scale) = $\frac{\text{Mass of one atom}}{\text{Mass of one } {}_6C^{12} \text{ isotope}} \times 12$

${}_6C^{12}$ ${}_6C^{13}$ ${}_6C^{14}$

Similarly

Molecular mass of a substance = $\frac{\text{Mass of one molecule}}{\text{Mass of one H-atom}}$.

- Atoms are so tiny that even the smallest speck of dust visible to the naked eye contains about 10^{19} atoms. Thus the mass of single atom in gram is much too small a number for convenience and chemists therefore use a unit called atomic mass unit (a.m.u), also known as dalton (Da) → Unified mass (u)

One amu can be defined as – "It is the exactly $\frac{1}{12}$th part of the mass of one atom of ${}_6C^{12}$ and is equal to 1.66054×10^{-24} gm".

12 gm is the mass of 1 gmatom C i.e. N_A no. of C

On reverse, N_A no. of C-atoms weigh 12 gm

1 no. of C atom has mass $\frac{12}{N_A}$

∴ 1 a.m.u = $\frac{1}{12} \times \frac{12}{N_A} = \frac{1}{6.022 \times 10^{23}}$ gm

$= 1.66057 \times 10^{-24}$ gm

Express the true atomic mass of one Nitrogen atom in gm?

Mass of one N-atom = 14 u

$= (14 \times 1.66057 \times 10^{-24})$ gm

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R.

$_{11}Na^{23}$ $p = 11$
$n = 12$
(mass no.) $A = 23$

Average atomic mass = $\frac{R.A(1) \times \text{Atomic mass}(1) + R.A.(2) \times \text{Atomic mass}(2)}{R.A(1) + R.A(2)}$

R.A = Relative abundance

~~Say~~ Chlorine has avg. atomic mass 35.5, say x% is the relative abundance of its 1st isotope Cl^{35} ∴ The % relative abundance of its 2nd isotope $_{17}Cl^{37}$, $(100 - x)$

$$35.5 = \frac{x \times 35 + (100 - x) \times 37}{x + 100 - x}$$

(A→V→E.)

$$3550 = 35x + 3700 - 37x$$

$$(3700 - 3550) = (37 - 35)x$$

$$2x = 150$$

$$x = 75$$

∴ % $_{17}Cl^{35}$ = 75% & % $_{17}Cl^{37}$ = 25%

22/04/19

Equivalent mass

The equivalent mass of a metal = $\frac{\text{Mass of the metal}}{\text{Mass of } H_2 \text{ replaced by the metal}} \times 1.008$

In H-scale

or.

$Zn + H_2SO_4 \rightarrow ZnSO_4 + H_2$
65 gm. 2 gm
$65/2 \times 1.008$

Equiv. mass = $\frac{\text{Mass of the metal}}{\text{Volume of } H_2 \text{ replaced by metal at (g)}} \times 11200$ ml

STP

At STP, 1 gm mole = 2.016 gm H_2 has volume 22400 ml

atoms

1.008 g " " $\frac{22400 \times 1.008}{2.016}$ = 11200 ml

Equivalent mass is the no. of parts by weight of the substance that combines or displaces directly or indirectly, 1.008 parts by mass of H_2 or 8 parts by mass of O_2 or 35.5 parts by mass of chloride. It can be calculated as equivalent mass for

It is independent of temp. and pressure

V.D or relative density, Molar volume

→ $$V.D \text{ or } (R.D) = \frac{\text{Mass of definite volume of a gas}}{\text{Mass of same volume of } H_2}$$ [Both gases are measured at same Temp & pressure]

$$= \frac{\text{Mass of V volume of the gas}}{\text{Mass of V volume of } H_2}$$ [" " "]

According to Avogadro's hypothesis, under same T & P equal volume of all gases contain same number of molecules since if we assume that n no. of molecules be present in V volume of every gas then –

$$V.D = \frac{\text{Mass n no. of molecules gas}}{\text{Mass n no. of } H_2 \text{ molecules}}$$

$$\text{or } V.D = \frac{\text{Mass of 1 molecule of the gas}}{2 \times \text{Mass of 1 H atom}}$$

[∵ H_2 is a diatomic molecule]

$$V.D \times 2 = \frac{\text{Mass of 1 molecule of gas}}{\text{Mass of 1 H atom}}$$

molecular mass of gas ← $\boxed{M = V.D \times 2}$ proved.

From the definition of vapour density we may write –

$$V.D = \frac{\text{Mass of V Litre of gas}}{\text{Mas of V litre of } H_2}$$ [Both gases are measured at same T & P]

$$V.D = \frac{\text{Mass of 1 litre of gas at STP}}{\text{Mass of 1 litre of } H_2 \text{ at STP}}$$

[After a series of experiments it was found that mass of 1 litre H_2 gas at STP, 0.0891 gm]

$$V.D = \frac{\text{Mass of 1 litre of gas at STP}}{0.0891 \text{ gm}}$$

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$Z = (8)O^{16}$ ① H^1 = at mass 1.008

If 'M' g be the molecular mass of the gas then $V.D = \frac{M}{2}$
= g/mole

$$\frac{M}{2} = \frac{\text{mass of 1 litre of gas at STP}}{0.0891}$$

At STP, $\frac{M}{2} \times 0.0891$ g is the mass of 1 litre of gas

1 gm " " $\frac{2}{M \times 0.0891}$ litre of gas

M gm " " $\frac{2 \times M}{M \times 0.0891}$ Litre

$= 22.4$ litre

H_2O 16g O, 89 O, 2g, 1g

∴ At STP 1 gmmole of any gas has volume 22.4 litre, since this is known molar volume.

In O-scale $2Zn + O_2 \rightarrow 2ZnO$

$$\text{Equiv. mass of metal} = \frac{\text{Mass of metal}}{\text{Mass of Oxygen combined with the metal}} \times 8$$

or $$\text{Equiv. mass of metal} = \frac{\text{mass of metal}}{\text{Volume of Oxygen combined with the metal (at STP)}} \times 5600 \text{ ml}$$

At STP 1 gmmole = 32g Oxygen has volume 22400 ml

8 g " " " $\frac{22400 \times 8}{32} = 5600$ ml

In Cl-scale

$$\text{Equiv. mass of metal} = \frac{\text{Mass of metal}}{\text{Mass of Chlorine combined}} \times 35.5$$

$$= \frac{\text{Mass of metal}}{\text{Volume of Chlorine combined (at STP)}} \times 11200 \text{ ml}$$

Hcl
$A = V \times E$
$35.5 = 1 \times E$

Equivalent mass of an acid = $\frac{\text{Molecular mass of the acid}}{\text{No. of basicity of the acid}}$

H = 1
S = 32
O = 16

Say for, H_2SO_4 acid $\rightleftharpoons 2H^{\oplus} + SO_4^{2\ominus}$

molecular mass = $2 \times 1 + 32 + 4 \times 16$
= 98

Equiv mass of H_2SO_4 = $\frac{98}{2} = 49$

∴ To prepare 1 gm-equiv. Sulphuric acid soln we have to add 49 gm H_2SO_4 in solution.

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SO_4^{2-}

$A = V \times \theta$

Oil Rig

Oxidan is losing of e → Reduction is gaining of $\bar{e}$

Equivalent mass of the base = $\frac{\text{Molecular mass of the base}}{\text{No. of acidity of the base}}$

Say for $Ca(OH)_2 \rightleftharpoons Ca^{++} + 2OH^{\ominus}$ (no. of acidity)

Ca = 40
O = 16
H = 1

molecular mass of $Ca(OH)_2$ = 74

Equiv. mass of Calcium hydroxide = $\frac{74}{2} = 37$

1 gmequiv. calcium hydroxide soln = 37 g $Ca(OH)_2$

Equivalent mass of a salt = $\frac{\text{Molecular (Formula) mass of the salt}}{\text{Total No. of +ve charges in the salt}}$

say for washing soda, i.e. $Na_2CO_3 \cdot 10H_2O$

Na = 23
C = 12
O = 16
H = 1

Molar mass of this salt = $23 \times 2 + 12 + 16 \times 3 + 10 \times 18$
$= 46 + 12 + 48 + 180$
$= 106 + 180$
$= 286$

$Na_2CO_3 \rightleftharpoons 2Na^{\oplus} + CO_3^{2-}$ (radical)

Equiv. mass of washing soda = $\frac{286}{2 \times 1}$
$= 143$

Equiv. oxidant/reductant = $\frac{\text{Formular mass of oxidant/reductant}}{\text{No. of electrons lost/gaind by reductant/oxidant}}$

Equiv. (base) = $\frac{\text{formula mass of base}}{\text{Acidity}}$

Gram Equivalent Mass (GEM)

Equiv. element = $\frac{\text{Atomic of element}}{\text{Valency}}$

Equiv. (ion) = $\frac{\text{Formula mass of ion}}{\text{Charge on ion}}$

Equiv. (salt) = $\frac{\text{Formula mass of salt}}{\text{Total +ve/-ve charge of cation/anion}}$

Equiv. = $\frac{M_{(acid)}}{\text{Basicity}}$

Equiv. (acid salt) = $\frac{\text{Formula mass of acid salt}}{\text{Replaceable H-atom(s) in the salt}}$

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$_8O$ $2\ 6 \xleftarrow{2e}$ 8 NaCl : 23+35.5 = 58.5 Na 2 8 1

$\frac{1s}{2}\ \frac{2s\ 2p}{8}\ \frac{3s}{1}$

Say we take a metallic oxide of a metal M, having atomic mass "a" and valency "v" of the metal is M_2O_v

In M_2O_v, 16V parts by mass of oxygen is combined with 2a parts by mass of metal

1 parts by mass of " " " - $\frac{2a}{16V}$ parts by mass of metal

8 parts " " " $\frac{2a \times 8}{16V} = \frac{a}{V}$

Equiv. mass of metal $= \frac{a}{V}$

$\boxed{A = V \times E}$ proved

$+6$ H_2SO_4 x

$\underset{H}{2x(+1)} + \underset{S}{x} + \underset{Oxygen}{4(-2)} = 0$

$2 + x - 8 = 0 \Rightarrow x - 6 = 0$

$x = +6$

6.022×10^{23}

- Number of atoms in 1 gm-atom of any element
- Number of molecules in 22.4 litre of any gaseous substance
- No. of molecules in 1 gm mole of an element/compound
- Number of ions in 1 gm-ion of any substance

■ Equivalent mass for oxidising agents =

$\frac{\text{Formula mass of the oxidising agents}}{\text{No. of electrons gained per molecule}}$

in acidic medium $\overset{+1}{K}\overset{+7}{Mn}\overset{-8}{O_4} \longrightarrow K^{\oplus} + MnO_4^{\ominus}$ / Mn^{2+}

permanganate ion

permanganate (purple colour)

manganous salt (colourless)

$$\boxed{\overset{+7}{MnO_4^{\ominus}} + 5e + 8H^{\oplus} \rightleftharpoons Mn^{2+} + 4H_2O}$$

acidic medium

Equiv. mass of $KMnO_4$ in acidic medium $= \frac{158}{5}$

$= 31.6$

K = 39

Mn = 55

O = 16

formula mass of potassium permanganate = 39 + 55 + 64 = 158

$x + 4 \times (-2) = -1$

$x - 8 = -1$

$x = 8 - 1 = +7$

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$n = \frac{V}{22.4L}$ (given volume) (no. of moles) $n = \frac{W}{M}$ (Taken or given mass / Molecular mass)

Equiv. mass of $KMnO_4$ in alkaline medium.

$KMnO_4$ potassium manganate

$KMnO_4$ potassium permanganate

$$\overset{+7}{MnO_4^{\ominus}} + e \rightleftharpoons \overset{+6}{MnO_4^{2-}}$$

permanganate ion (purple colour) — Manganate ion (green colour)

Equiv. mass of $KMnO_4$ in basic medium $= \frac{158}{1}$

Equiv. mass of $KMnO_4$ in neutral medium $= \frac{158}{3}$

$$\overset{+7}{MnO_4^{\ominus}} + 3e + 4H^{\oplus} \rightleftharpoons \overset{+4}{MnO_2} + 2H_2O$$

manganese dioxide

(VI) Equivalent mass for reducing agents $= \frac{\text{Formula mass}}{\text{No. of electrons lost}}$

(VII) Equivalent weight of radical $= \frac{\text{Formula mass of radical}}{\text{No. of units of charge}}$

29/04/19 **Methods of determining Equivalent masses**

Metal displacement method — utilises the fact that one GEM of a more electro+ve metal displaces one GEM of a less electro+ve metal from its salt.

Faraday's 1st law & 2nd law electrolysis :-

If 'W' g be deposited for Q Coulomb passage of electricity then by Faraday's 1st law

$$W \propto Q$$

or $W = ZQ$, where Z, the proportionality constant, known as Electrochemical equivalent (E.C.E) which can be defined as — Mass of electrolyte be deposited when 1 Coulomb electricity is made to pass through its solution.

When Q = 1 Coulomb then W = Z

$$\overset{+1}{Ag^{\oplus}} + e \xrightarrow{\text{reduction}} \overset{0}{Ag}\downarrow$$

1 mole — 1 mole of electron — 1 mole

$$Z = \frac{\text{Atomic mass of substance}}{\text{No. of electrons exchanged during rxn}} \times \text{Faraday}$$

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$MnO_4^{\ominus}$
$MnO_4^{2\ominus}$

1 Faraday is the total charge of 1 moles of electrons.

$\therefore$ Charge of 1 electron $= 1.602 \times 10^{-19}$ C

Charge of 1 mole i.e. N_A no. of electron $= 1.602 \times 10^{-19} \times 6.022 \times 10^{23}$ C

$= 96472.44$ C

$\simeq 96500$ C.

$$\boxed{1e = \frac{F}{N_A}}$$

$\Rightarrow$ or $Z = \dfrac{\text{Equivalent Mass}}{\text{Faraday}}$

Faraday's 2nd law of electrolysis for A & B (two different cells) are connected in series if Q coulomb current is made to pass through them then

$$W_A = Z_A Q \quad \& \quad W_B = Z_B Q$$

$$\frac{W_A}{Z_A} = \frac{W_B}{Z_B} \Rightarrow \frac{W_A}{W_B} = \frac{Z_A}{Z_B} = \frac{\frac{E_A}{F}}{\frac{E_B}{F}} = \frac{E_A}{E_B}$$

Conversion method When one compd of a metal is converted to another compd of similar metal:

$$\frac{\text{Weight of 1st compd}}{\text{Weight of 2nd compd}} = \frac{\text{Equ. mass of metal} + \text{Equiv. mass of 1st radical}}{\text{Equ. mass of metal} + \text{Equiv. mass of 2nd radical}}$$

29 g $\Leftarrow A = Na_2CO_3$ Equiv. mass of Na = ?

40 $\Leftarrow B = Na_2SO_4$

$$\frac{29}{40} = \frac{E_{Na} + 30}{E_{Na} + 48}$$

$$E \times 29 + 1392 = 40 E_{Na} + 1200$$

$$(40 - 29) E_{Na} = 1392 - 1200$$

$$\frac{192}{11}$$

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Equiv. ...)

- Electrolytic method states that the quantity of substance that reacts at electrode when 1 Faraday of electricity is passed is equal to GEM = electrochemical (z) equivalent × 96500 and ratio of weights deposited by equal amount of electricity is in ratio of their equivalent masses.

- **Double decomposition method**

$$AB + CD \rightarrow AD\downarrow + CB$$

$$\frac{\text{weight of Compound } AB}{\text{weight of } AD} = \frac{\text{Equiv. mass of } A + \text{Equiv. mass of } B}{\text{Equiv. mass of } A + \text{Equiv. mass of } D}$$

$$AgNO_3 + NaCl \rightarrow AgCl + NaNO_3$$

$$\frac{W_{AgNO_3}}{W_{AgCl}} = \frac{\text{Equiv. mass}(Ag) + \text{Equiv. mass}(NO_3^-)}{\text{Equiv mass}(Ag) + \text{Equiv. mass}(Cl^-)}$$

- **Neutralisation method is for acids & bases**

$$\text{Equiv. mass of acid/base} = \frac{\text{Weight of acid/base}}{\text{Volume of acid/(base) in 1 litre required for neutralisation} \times \text{Normality of acid/(base)}}$$

- **Silver salt method** · commonly used for organic acid

$$\text{Equiv. mass of an acid} = \frac{108 \times \text{Mass of Ag-salt}}{\text{Mass of Ag metal}} - 107$$

Molar mass of the acid = Equiv. mass of acid × Basicity.

$$CH_3COOH + Ag\text{-}salt \rightarrow CH_3COO^-Ag^+ + HNO_3$$

M

- **Volatile chloride method**

$$\text{valency of metal} = \frac{2 \times \text{V.D of chloride}}{\text{Equiv. mass of metal chloride}}$$

$$= \frac{2 \times \text{V.D}}{\ldots}$$

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$H_2 + \frac{1}{2}O_2 \rightarrow H_2O$

2 16 18

$\Rightarrow \frac{2 \times V.D \text{ of chloride}}{\text{Valency}} - 35.3$

Limiting Reagent (L.R) A + B → Product

It is the reactant which is totally consumed during the course of rxn and when it is consumed rxn stops.

For a balanced rxn : $A + B \rightarrow C + D$

B would be L.R if $\frac{n_B}{n_A} < \frac{n_A}{n_B}$

Similarly A would be L.R if $\frac{n_A}{n_B} < \frac{n_B}{n_A}$

Q. In the reaction, $2A + 4B \rightarrow 3C + 4D$, When 5 moles of A react with 6 moles of B, then – (a) Which is the limiting reagent? (b) Calculate the amount of C formed.

Solution $2A + 4B \rightarrow 3C + 4D$

2 moles of A requires → 4 moles of B, from the rxn

5 moles of A " $\frac{4}{2} \times 5$

= 10 moles of B

But only 6 moles of B is provided here ∴ B is the limiting reagent. (a)

From the given eqn.

4 moles of B produces 3 moles of C

6 moles of B " $\frac{3 \times 6}{4}$

$\frac{3}{2}$

= 4.5 moles of C formed

Calculation of Atomic mass

According to Dulong & Petit's law for solids (except Be, B, Si, C)

At ordinary temp., Atomic mass × Specific heat ≈ 6.4 (approx) → atomic heat.

∴ (approximate) atomic mass = $\frac{6.4}{\text{Given value of Sp. heat}}$

(approximate) valency after rounding off = $\frac{\text{approx. atomic mass}}{\text{Equiv. mass}}$

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$E = mc^2$ $\boxed{\frac{E}{m} = c^2}$ $\frac{E}{M} \neq c$

Na (280) $1s^2 2s^2 2p^6 3s^1$ / M

rounded up valency × Equiv. mass = ~~true~~ atomic mass

Specific heat method is for gases, $\gamma = \frac{C_p}{C_v}$ where C_p = specific heat at constant pressure. and C_v = specific heat at constant volume.

for monoatomic, $\gamma = 1.66$
for diatomic, $\gamma = 1.40$
for triatomic, $\gamma = 1.33$

∴ atomic mass of gaseous element $= \frac{\text{Molecular mass}}{\text{atomicity}}$

$= \frac{\text{Molecular mass}}{\gamma}$

Mitscherlich's law of isomorphism states that isomorphous substances having similar chemical constitution, isomorphous substances form crystals of same shape and valencies of elements forming isomorphous salts are also same. eg: $ZnSO_4 \cdot 7H_2O$ (white vitriol), $MgSO_4 \cdot 7H_2O$ (epsom salt) and $FeSO_4 \cdot 7H_2O$ (green vitriol) are isomophous.

Laws of chemical combinations in terms of their statements

(i) Law of conservation of mass (Lavoisier, 1774)
(ii) Law of constant (or definite) proportions (Proust, 1799)
(iii) Law of multiple proportions (Dalton, 1803)
(iv) Law of reciprocal proportions (Richter, 1799)

The law of conservation of mass in the light of interconversion of mass and energy — the law of conservation of mass isn't absolutely true.
According to modern theory of radiations, the law of conservation of mass

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mass & energy law of equivalence

$\Delta E = mc^2$

$\Delta E = 1\,gm \times (3\times10^{10}\,cm)^2$

$= 9\times10^{20}$ ergs

$= \frac{9\times10^{20}}{10^7} = 9\times10^{13}\,J = \frac{9\times10^{13}}{4'184} = 2'15\times10^{13}$ Calorie

Nuclear fission $_{92}U^{238} + {}_0n^1 \longrightarrow {}_{56}Ba^{141} + {}_{36}Kr^{92} + 3\,{}_0n^1$ + Huge energy

Slow neutron

238

fusion $_1H^1 + {}_1H^2 \longrightarrow {}_2He^3$

proton deuterium Helium isotopes

Law of definite proportion The same compd always contains the same elements combine together in the same fixed proportions by weight & its composition is independent of the methods by which it is prepared.

$MgCO_3 \xrightarrow{\Delta} MgO + CO_2$

$Mg(OH)_2 \xrightarrow{\Delta} MgO + H_2O\uparrow$

$2Mg(NO_3)_2 \xrightarrow{\Delta} 2MgO + 2NO_2$

Mg:O remains same.

$\overset{+2}{Sn}O$	$\overset{+4}{Sn}O_2$
Stannous oxide	Stannic oxide
Sn:O = 1:1	Sn:O = 1:2

Limitations

- Sometimes union of elements may give rise to more than one compd. It happens in the case of elements having variable valency. Thus Cu and Cl_2 on combination may give Cuprous Chloride ($\overset{+1}{Cu}Cl$) and Cupric chloride ($\overset{+2}{Cu}Cl_2$)
  1:1 1:2

variable valency NH_3 NCl_3 NF_3
PH_3 PCl_3 PF_3
PCl_5

- In case of isotopic composition Law of definite proportion doesn't hold true.

$_1H^1$ $_1H^2$ $_1H^3$

$_8O^{16}$ $_8O^{17}$

H_2O 2:16

H:O = 1:8 2:4 3:8
H_2O 2:17 4:17 6:17

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Law of Multiple proportions

The law state that " When two elements combine to form two or more compounds, the different weights of one of the elements which combine with a fixed weight of the other element, bear a simple ratio of whole numbers to one another.

$H + O$

H_2O — 1 : 8

H_2O_2 — 1 : 16

8 : 16 = 1 : 2

Compds	weights of C	weights of H	Fixed weight of C	weights of H_2 which combine with a fixed wt of C	Ratio of weights of Hydrogen
Methane (CH_4)	12	4	12	4	
Ethane (C_2H_6)	24	6	12	3	4 : 3 : 2 : 1
Ethylene (C_2H_4)	24	4	12	2	is a simple whole no. ratio
Acetylene (C_2H_2)	24	2	12	1	

Limitations of multiple proportions

- This law doesn't apply to such compds eg in

it is found that 12 parts by mass of C in each case combine with 2.5, 2.4, 2.33 parts by mass of H - respectively.

- butane (C_4H_{10}) C : H = 1 : 2.5
- Pentane (C_5H_{12}) C : H = 1 : 2.4
- Hexane (C_6H_{14}) C : H = 1 : 2.33

The weight ratio of H i.e. 2.5 : 2.4 : 2.33 is not definitely a simple ratio.

- As a result of catenation, carbon can form a wide range of compounds through $-\overset{|}{C}-\overset{|}{C}-$ (single), $>C=C<$ (double) and $-C\equiv C-$ (triple) bonds. Boron & Silicon also display this property to a lesser extent.
- Furthermore slight variation in the results will be observed if the isotopic constitution of the atom of the combining elements differ.

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EMCET

The law of Reciporal or Equivalent Proportions

The weights of 2 or more different elements which separately combine with a fixed weight of another element, are either the same as or simple multiples or submultiples of the weights of these different elements when they combine among themselves.

$H \xrightarrow{O} H_2O$ H : O = 1 : 8

$H \xrightarrow{C} CH_4$ C : H = 3 : 1

$C + O_2 \rightarrow CO_2$

12 : 32

3 : 8

$C \xrightarrow{O_2} CO_2$ C : O = 3 : 8

$C \xrightarrow{S} CS_2$ C : S = 3 : 16

SO_2

= 32 : 32

= 1 : 1

16 : 8

~~Law of Combustion~~

1Q. 1.5 g C_2H_6 on complete combustion give 4.4 g of CO_2 and 2.7 g of H_2O. Show that the rxn obeys law of conservation of mass.

$$C_xH_y + \left(x + \frac{y}{4}\right)O_2 \rightarrow xCO_2 + \frac{y}{2}H_2O$$

$$C_2H_6 + \left(2 + \frac{6}{4}\right)O_2 \rightarrow 2CO_2 + 3H_2O$$

7 : 1

$\frac{1.5}{5.6}$

$$C_2H_6 + \frac{7}{2}O_2 \rightarrow 2CO_2 + 3H_2O$$

4.4

2.7

7.1 g

$$2C_2H_6 + 7O_2 \rightarrow 4CO_2 + 6H_2O$$

2 mole 7 moles of O_2 from the rxn 2 moles of ethane needs 7 moles of O_2

$n = \frac{W}{M}$, no. of moles of ethane $= \frac{1.5}{30} = 0.05$ moles of ethane

0.05 " " " $\frac{7 \times 0.05}{2}$

= 0.175 moles of Oxygen

(32×0.175) gm = 5.6 gm. O_2

∴ The rxn obeys law of conservation of mass.

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Q2. In an experiment 0.243 gm of Mg on burning with oxygen yields 0.4030 gm of MgO. In another experiment 0.182 gm of Mg on burning with Oxygen yields 0.302 gm MgO. Now prove that the above given data follows the law of definite proportion.

In 1st experiment,

0.243 gm of Mg combines with

	0.4030 g (MgO)
−	0.2430 g
	0.1600 g
	= 0.160 g of oxygen

$Mg : O = \frac{0.243}{0.160} = 1.5 : 1 = 3 : 2$

In 2nd experiment,

0.182 g Mg combines with

	0.302 g (MgO)
−	0.182 g Mg
	0.120 g Mg

$Mg : O = \frac{0.182}{0.120} = 1.5 : 1$

$= 3 : 2$

∴ The above given data follows the law of definite proportions.

Q3 Elements A and B give three different compounds X, Y and Z with the following weight ratios :-

Substance	X	Y	Z
weight of A (g)	0.5831	0.01800	0.3600
weight of B (g)	0.4200	0.0200	0.5200

Use these weight ratios to illustrate a law of chemical combination. State the law in words.

In X,

weight ratio of $A : B = \frac{0.5831}{0.4200}$

$= 1 : 0.72$

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Normality – is defined as the no. of gm equivalents (equiv. wt. in grams) of a solute present per litre of the solution. Units of Normality are ~~gm~~ gm. equiv. litre^{-1}. Normality changes with temp. When a solu. is diluted n times, its normality decreases by n times.

i) $N = \frac{\text{No. of geq. of solute}}{\text{Vol. of solution in litres}}$

ii) $N = \frac{\text{wt. of solute per litre of solution}}{\text{geq. wt. of solute}}$

iii) $N = \frac{\text{wt. of solute}}{\text{geq. wt of solute}} \times \frac{1000}{\text{vol. of solution in ml}}$

iv) $N = \frac{\text{No. of meq. of solute}}{\text{vol. of solution in ml}}$

v) $N = \frac{\text{Percent of solute} \times 10}{\text{geq. wt. of solute}}$

vi) $N = \frac{\text{Strength in of solution}}{\text{geq. wt. of solute}}$

vii) $N = \frac{10 \times \text{Sp. gravity of the solution} \times \text{wt. \% of the solu}}{\text{geq. wt. of the solute}}$

viii) $N_1V_1 = N_2V_2$ or No. of gmequiv. of one substance = No. of gequiv of another subst

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ix) When two solutions of the same solute are mixed then normality of the mixture (N) is

$$N = \frac{V_1N_1 + V_2N_2}{V_1 + V_2}$$

x) Vol. of water to be added i.e $(V_2 - V_1)$ to get V_2 ml. of solution of normality N_2 from V_1 ml of normality N_1.

$$V_2 - V_1 = \left(\frac{N_1 - N_2}{N_2}\right) V_1$$

xi) If W gm of an acid is completely neutralized by V ml of base of normality N.

$$\frac{\text{wt. of acid}}{\text{gm equiv. wt. of acid}} = \frac{VN}{1000}$$

Similarly, $\frac{\text{wt. of base}}{\text{gequiv. wt of base}} = \frac{\text{vol. of acid} \times N \text{ of acid}}{1000}$

xii) When V_a ml of acid of normality N_a is mixed with V_b ml of base of normality N_b.

a) if $V_aN_a = N_bV_b$ (solution is neutral)
b) if $V_aN_a > V_bN_b$ (solu. is acidic)
c) if $V_bN_b = V_aN_a$ (solution is basic)

xiii) Normality of the basic mixture

$$= \frac{V_bN_b - V_aN_a}{(V_a + V_b)}$$, Normality of the acidic mixture

$$= \frac{V_aN_a - V_bN_b}{(V_a + V_b)}$$

Also remember, Normality = $\frac{\text{strength in g/litre}}{\text{g eq. wt. of the compound}}$

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Molal solutions are less concentrated than molar solutions:

i) $m = \frac{\text{No. of gm moles of solute}}{\text{Wt. of solvent in kg}}$

ii) $m = \frac{\text{wt. of solute} \times 1000}{\text{Mol. wt. of solute} \times \text{wt. of solvent in g}}$

iii) $m = \frac{\text{No. of millimetres of solute}}{\text{wt. of solvent in g}}$

iv) $m = \frac{10 \times \text{Solubility}}{\text{mol. wt. of solute}}$

v) $m = \frac{1000 \times \text{wt. \% of solute } (x)}{(100 - x) \times \text{Mol. wt. of solute}}$

vi) $m = \frac{1000 \times \text{Molarity}}{(1000 \times \text{Sp. gravity}) - (\text{Molarity} \times \text{mol. wt. of solute})}$

Mole fraction: It is the ratio of the number of moles of one component (i.e solute or solvent) to the total no. of moles of the solution (ie both the components). It is usually represented by the letters x.

Thus in solution containing n_2 moles of solute an n_1 moles of solvent, the mole fraction of the solute (x_2) and solvent (x_1) respectively would be

$$x_1 = \frac{n_1}{n_1 + n_2}, \quad x_2 = \frac{n_2}{n_1 + n_2} \rightarrow \text{for solute}$$

For example, in a solution containing 1 mole

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$\frac{P_1V_1}{T_1} =$ 22.4 L 2.24 L 28 $\frac{28 \times 2.24}{22.4} = \frac{28 \times 10}{100} = 2.8$

of alcohol and 4 moles of H_2O, the mole fraction of alcohol is 1/5 and that of water is 4/5. $\therefore x_1 + x_2 = 1$

Relation between molality of solution (m) and mole fraction of the solute (x_2)

$$x_2 = \frac{m}{55.5 + m}$$

Molality and mole fraction are independent of temp. variation of the solution.

Grams per litre: This is the no. of grams of solute in one millimetre (cm^3) of solution. The no. of grams per litre (dm^3) of solution is also used.

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Additional Useful Information and Objective Questions

ADDITIONAL USEFUL INFORMATION

Relation between molarity (M) and molality (m)

Molarity (M) means that M moles of the solute are present in 1000 mL of the solution. If density of the solution is ρ g cm^{-3}, then

Mass of solution = $1000\ \rho$

Mass of solute = MM_2 (M_2 is the molar mass of solute)

∴ Mass of solvent = $1000\ \rho - MM_2$

∴ $$\text{Molality} = \frac{M}{1000\rho - MM_2} \times 1000 = \frac{1000\ M}{1000\rho - MM_2}$$

or $$m = \frac{M}{\rho - \frac{MM_2}{1000}}$$

or $$\frac{1}{m} = \frac{\rho - \frac{MM_2}{1000}}{M}$$

$$\frac{1}{m} = \frac{\rho}{M} - \frac{MM_2}{1000}$$

$$\frac{\rho}{M} = \frac{1}{m} + \frac{MM_2}{1000}$$

Relation between molality (m) and mole fraction(x_2)

Molality means moles of solute in 1000 g of the solvent.

Moles of solvent = $\frac{1000}{M_1}$ (M_1 is molar mass of solvent)

Moles of solute = m

$$\text{Mole fraction } (x_2) = \frac{m}{m + \frac{1000}{M_1}}$$

∴ $$x_2 = \frac{mM_1}{mM_1 + 1000}$$

or $$\frac{1}{x_2} = \frac{mM_1 + 1000}{mM_1} = 1 + \frac{1000}{mM_1}$$

or $$\frac{1000}{mM_1} = \frac{1}{x_2} - 1 = \frac{1 - x_2}{x_2} = \frac{x_1}{x_2}$$

∴ $$m = \frac{1000\ x_2}{x_1 M_1}$$

Relation between molarity (M) and mole fraction(x_2)

Molarity (M) means that M moles of solute are present in 1000 mL of solution. If ρ is the density of the solution, then mass of solution is 1000 ρ. Mass of solute = MM_2 (M_2 is the molar mass of solute).

Mass of solvent = $1000\ \rho - MM_2$

$$\text{Moles of solvent} = \frac{1000\ \rho - MM_2}{M_1}$$

(M_1 is molar mass of solvent)

$$\text{Mole fraction, } x_2 = \frac{M}{\frac{1000\ \rho - MM_2}{M_1} + M}$$

$$= \frac{MM_1}{(1000\ \rho - MM_2) + MM_1}$$

$$= \frac{MM_1}{M(M_1 - M_2) + 1000\ \rho}$$

or $$x_2 = \frac{MM_1}{M(M_1 - M_2) + 1000\ \rho}$$

Rearranging

$$M(M_1 - M_2)x_2 + 1000\ \rho x_2 = MM_1$$

or $$MM_1 - MM_1 x_2 + MM_2 x_2 = 1000\ \rho x_2$$

$$MM_1(1 - x_2) + MM_2 x_2 = 1000\ \rho x_2$$

$$MM_1 x_1 + MM_2 x_2 = 1000\ \rho x_2$$

$$M(M_1 x_1 + M_2 x_2) = 1000\ \rho x_2$$

∴ $$M = \frac{1000\ \rho x_2}{x_1 M_1 + x_2 M_2}$$

Note : If molarity (M) is in mol/litre and density, ρ is in kg/L and molality m is in mol/kg of solvent then 1000 will be replaced by 1 in the above relations.

AZEOTROPES – BOILING POINT DIAGRAMS

Some liquids on mixing form azeotropes which are binary mixtures having same composition in liquid and vapour phase and boil at constant temperature. In such cases, it is not possible to separate the components by fractional distillation. There are two types of azeotropes called *minimum boiling azeotropes and maximum boiling azeotropes*.

(*i*) Minium boiling azeotropes: In case of solutions showing very large positive deviations from Raoult's law, there is a maximum in the vapour pressure curve which is above the vapour pressure of either of the pure components. For one of the intermediate composition, the total vapour pressure of such a solution will be the highest and the boiling point will be the lowest (because higher the vapour pressure, lower is the boiling point). At this point, the composition of liquid and vapour phase is same and the liquid mixture boils at constant temperature and remains unchanged in composition. Therefore, this liquid mixture distils over as if it is a *pure liquid*. The solution acquires the the property of boiling at constant temperature and remains unchanged in composition. These types of solutions are called **minimum boiling azeotropes.**

For example, ethanol and water form minimum

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Additional Useful Information and Objective Questions

ADDITIONAL USEFUL INFORMATION

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Molarity (M) means that M moles of the solute are present in 1000 mL of the solution. If density of the solution is ρ g cm^{-3}, then

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Mass of solute = MM_2 (M_2 is the molar mass of solute)

∴ Mass of solvent = 1000 ρ − MM_2

∴ $$\text{Molality} = \frac{M}{1000\rho - MM_2} \times 1000 = \frac{1000\,M}{1000\rho - MM_2}$$

or $$m = \frac{M}{\rho - \frac{MM_2}{1000}}$$

or $$\frac{1}{m} = \frac{\rho - \frac{MM_2}{1000}}{M}$$

$$\frac{1}{m} = \frac{\rho}{M}\frac{MM_2}{1000}$$

$$\frac{\rho}{M} = \frac{1}{m} + \frac{MM_2}{1000}$$

Relation between molality (m) and mole fraction(x_2)

Molality means moles of solute in 1000 g of the solvent.

Moles of solvent = $\frac{1000}{M_1}$ (M_1 is molar mass of solvent)

Moles of solute = m

Mole fraction (x_2) $$= \frac{m}{m + \frac{1000}{M_1}}$$

∴ $$x_2 = \frac{mM_1}{mM_1 + 1000}$$

or $$\frac{1}{x_2} = \frac{mM_1 + 1000}{mM_1} = 1 + \frac{1000}{mM_1}$$

or $$\frac{1000}{mM_1} = \frac{1}{x_2} - 1 = \frac{1 - x_2}{x_2} = \frac{x_1}{x_2}$$

∴ $$m = \frac{1000\,x_2}{x_1 M_1}$$

Relation between molarity (M) and mole fraction(x_2)

Molarity (M) means that M moles of solute are present in 1000 mL of solution. If ρ is the density of the solution, then mass of solution is 1000 ρ. Mass of solute = MM_2 (M_2 is the molar mass of solute).

Mass of solvent = 1000 ρ − MM_2

Moles of solvent $$= \frac{1000\,\rho - MM_2}{M_1}$$

(M_1 is molar mass of solvent)

Mole fraction, x_2 $$= \frac{M}{\frac{1000\,\rho - MM_2}{M_1} + M}$$

$$= \frac{MM_1}{(1000\,\rho - MM_2) + MM_1}$$

$$= \frac{MM_1}{M(M_1 - M_2) + 1000\,\rho}$$

or $$x_2 = \frac{MM_1}{M(M_1 - M_2) + 1000\,\rho}$$

Rearranging

$$M(M_1 - M_2)x_2 + 1000\,\rho x_2 = MM_1$$

or $$MM_1 - MM_1x_2 + MM_2x_2 = 1000\,\rho x_2$$

$$MM_1(1 - x_2) + MM_2x_2 = 1000\,\rho x_2$$

$$MM_1x_1 + MM_2x_2 = 1000\,\rho x_2$$

$$M(M_1x_1 + M_2x_2) = 1000\,\rho x_2$$

∴ $$M = \frac{1000\,\rho x_2}{x_1M_1 + x_2M_2}$$

Note : If molarity (M) is in mol/litre and density, ρ is in kg/L and molality m is in mol/kg of solvent then 1000 will be replaced by 1 in the above relations.

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For example, ethanol and water form minimum

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boiling azeotrope. In this boiling point diagram (Fig. 1), the indicate the composition of the vapour phase by the upper curve and composition of the liquid phase by the lower curve. As shown in Fig. 1, the boiling point diagram shows an azeotropic composition at $x(H_2O) = 0.056$ and $x(C_2H_5OH) = 0.944$ at a temperature of 351 K (or 78°C) which is lower than that of pure ethanol 351.5 K (or 78.5°C) and water 373 K (or 100°C).

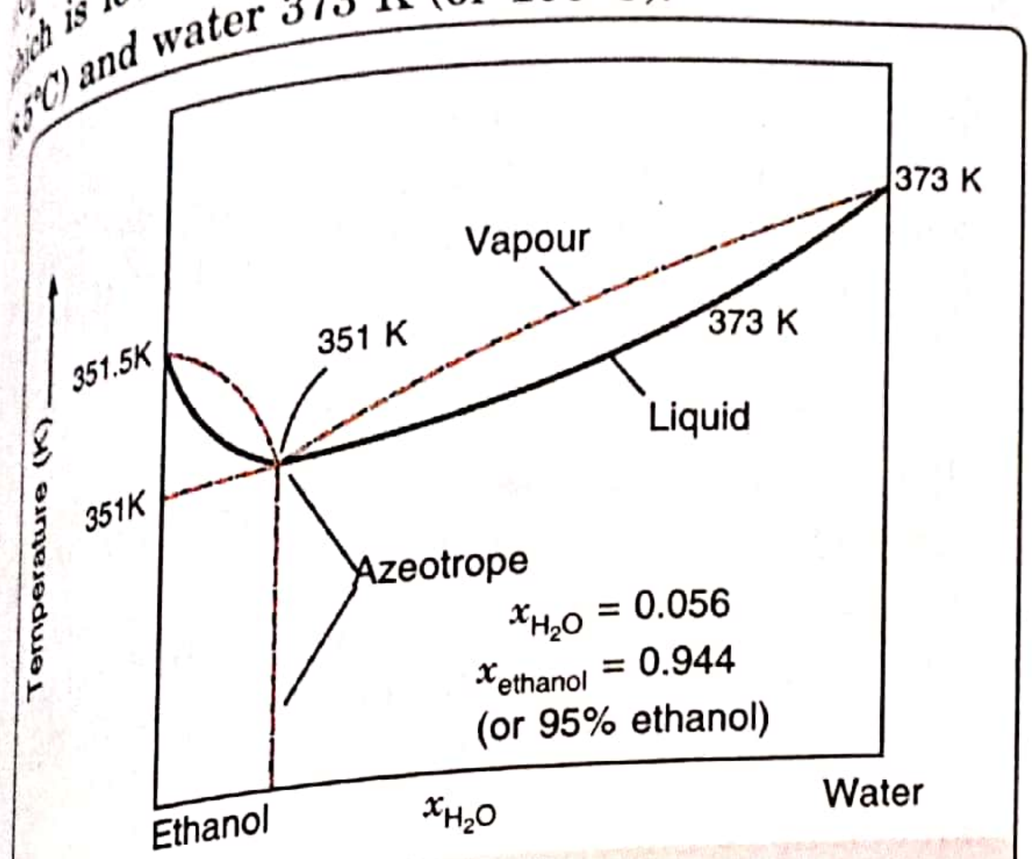


Fig. 1. Boiling point diagram for ethanol-water mixtures showing azeotrope.

(*ii*) **Maximum boiling azeotropes:** In the case of solutions showing negative deviations, total vapour pressure becomes less than the corresponding ideal solution of same composition (because lower the vapour pressure, higher is the boiling point). The boiling points of such solutions are increased because lower the vapour pressure, higher is the boiling point). For one of the intermediate composition, the total vapour pressure will be the least and the boiling point will be the highest (Fig. 2). At this composition, the solution also boils at constant temperature without a change in composition. These types of solution are called **maximum boiling azeotropes.**

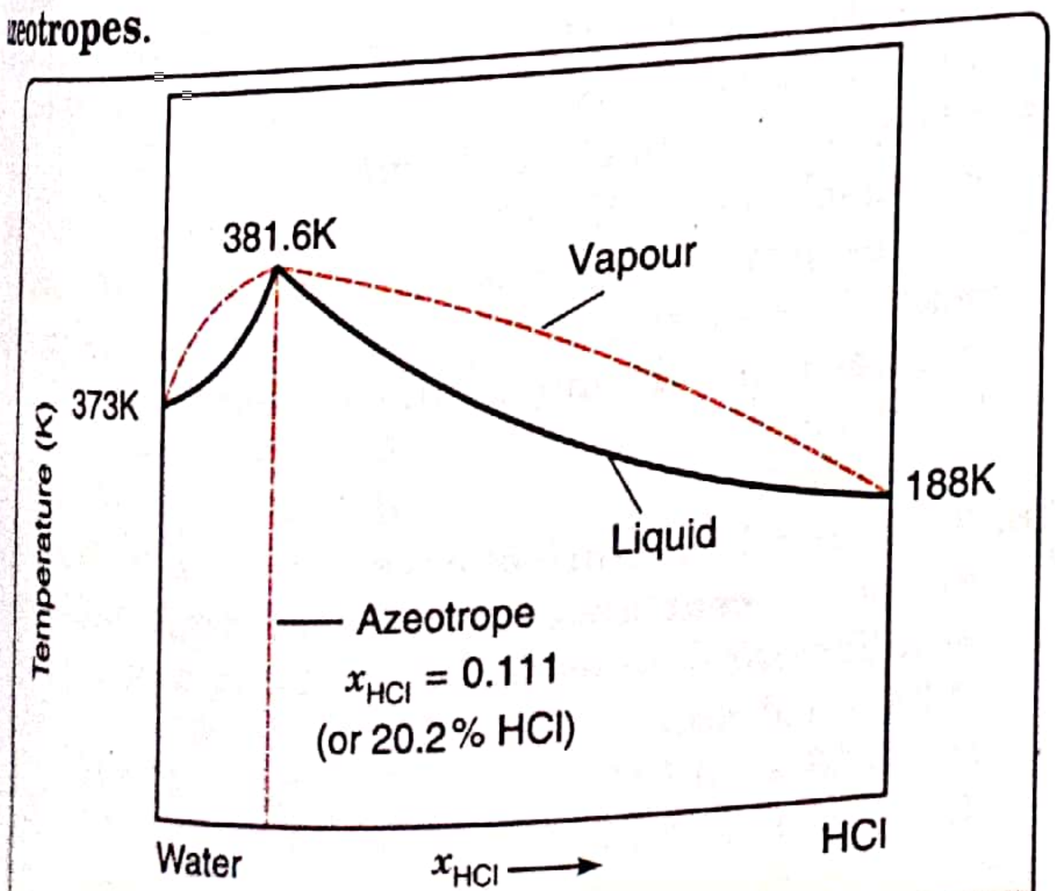


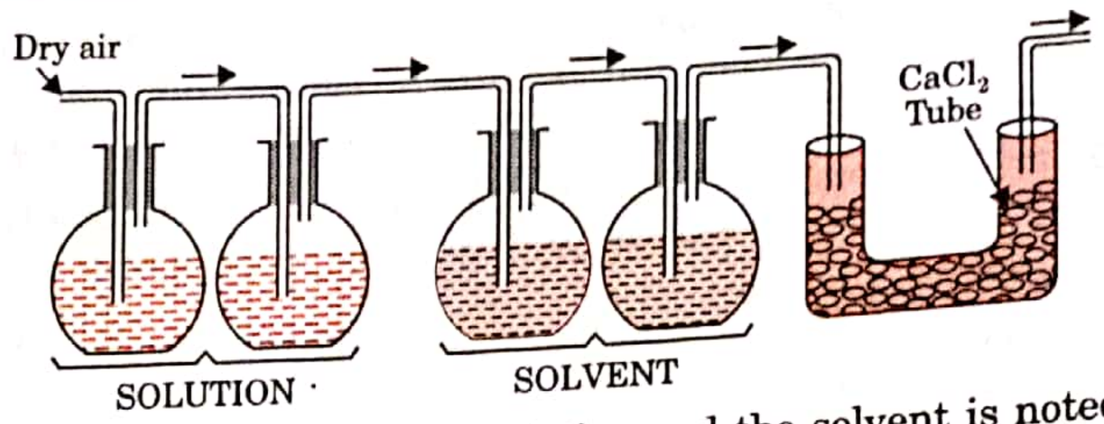
Fig. 2. Boiling point diagram for HCl water mixture.

For example, hydrochloric acid and water form maximum boiling point azeotrope at the composition $x(H_2O) = 0.889$ and $x(HCl) = 0.111$ (or 20.2% HCl) which boils at 381.6 K (or 108.6°C) which has higher value than that of pure water and HCl as shown in Fig. 2.

MEASUREMENT OF RELATIVE LOWERING IN VAPOUR PRESSURE

In this method, a stream of dry and pure air is passed through bulbs containing solution and then through bulbs containing pure solvent and finally through U-tubes containing calcium chloride (if solvent is water).

As the dry air passes through the solution, it becomes saturated upto the vapour pressure of the solution or the solvent. The actual loss of vapours from the bulbs is obtained by weighing them before and after the air has been passed through them.



The loss of water from the solution and the solvent is noted. These are proportional to p_A and $p_A^\circ - p_A$ respectively. *i.e.*,

Loss in weight of solution bulb ∝ vap. pressure of the solution (p_A).

Loss in weight of solvent bulb ∝ vap. pressure of solvent –vap. pressure of solution ($p_A^\circ - p_A$).

From this relative lowering in vapour pressure can be calculated. This method is known as **Ostwald Walker dynamic method.**

Illustration: A current of dry air was passed through a solution of 13.4 g of non-volatile substance 'S' in 100 g of water and then through water alone. The loss in weight of the former was 1.02 g and that of the latter was 0.05 g. Calculate

(*i*) mole fraction of the solute in the solution

(*ii*) molecular mass of the solute.

Solution: Loss in weight of solution ∝ p_A = 1.02 g

Loss in weight of solvent (water) ∝ $p_A^\circ - p_A$

$$= 0.05 \text{ g}$$

$$p_A^\circ = (p_A^\circ - p_A) + p_A = 0.05 + 1.02$$

$$= 1.07 \text{ g}$$

$$\frac{p_A^\circ - p_A}{p_A^\circ} = \frac{0.05}{1.07} = 0.0467$$

$$\therefore \quad x_2 = 0.0467$$

Now $$\frac{p_A^\circ - p_A}{p_A^\circ} = \frac{n_2}{n_1} = \frac{w_2/M_2}{w_1/M_1}$$

$$= 0.0467$$

or $$\frac{13.4/M_2}{100/18} = 0.0467$$

or $$M_2 = \frac{13.4 \times 18}{100 \times 0.0467}$$

$$= \mathbf{51.65\ g\ mol^{-1}}.$$

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OBJECTIVE TYPE QUESTIONS

Multiple Choice Questions *M. C. Q.*

A Topicwise MULTIPLE CHOICE QUESTIONS *with only one correct answer*

Types of Solutions and Expressing their Concentrations

A1. An aqueous solution containing 6 g of urea in 500 mL of solution has a density equal to 1.05. If the molar mass of urea is 60, then the molality of solution is :
(*a*) 0.20 (*b*) 0.19 (*c*) 0.10 (*d*) 1.2.

A2. 2.5 litre of 1 M NaOH solution are mixed with another 3 litre of 0.5 M NaOH solution. Then the molarity of the resulting solution is
(*a*) 0.80 M (*b*) 0.1 M
(*c*) 0.73 M (*d*) 0.50 M

A3. The volume of 4N HCl and 10 N HCl required to make 1 litre of 6N HCl are
(*a*) 0.75 litre of 4 N HCl and 0.25 litre of 10 N HCl
(*b*) 0.25 litre of 4 N HCl and 0.75 litre of 10 N HCl
(*c*) 0.67 litre of 4 N HCl and 0.33 litre of 10 N HCl
(*d*) 0.50 litre of 4 N HCl and 0.20 litre of 10 N HCl

A4. The mole fraction of methanol in its 4.5 molal aqueous solution is
(*a*) 0.250 (*b*) 0.125
(*c*) 0.100 (*d*) 0.075

A5. Density of 3M NaCl solution is 1.28 g/cc. The molality of the solution is
(*a*) 2.79 molal (*b*) 0.279 molal
(*c*) 1.279 molal (*d*) 3.85 molal

A6. The mole fraction of solute in 2.5 m aqueous solution is
(*a*) 0.045 (*b*) 0.043
(*c*) 0.86 (*d*) 0.25

A7. Battery acid is 4.27M H_2SO_4 (*aq*) and has the density of 1.25 g mL^{-1}. The molality of H_2SO_4 in the solution is
(*a*) 3.416 m (*b*) 3.342 m
(*c*) 5.135 m (*d*) 2.135 m

A8. A 7M solution of potassium hydroxide (KOH) in water contains 40% by weight of KOH. The density of the solution is
(*a*) 1.96 (*b*) 1.28
(*c*) 0.49 (*d*) 0.98

A9. What volume of 12M and 4M HCl must be mixed to prepare 1000 mL of 6M HCl?
(*a*) 200, 800 (*b*) 700, 300
(*c*) 250, 750 (*d*) 400, 600

A10. The volume of 80% sulphuric acid (H_2SO_4) by weight (density = 1.80 g mL^{-1}) required to prepare 1L of 0.2 M H_2SO_4 is
(*a*) 14.7 mL (*b*) 29.4 mL
(*c*) 6.8 mL (*d*) 13.60 mL

Solubility, Vapour Pressure of Liquid Solutions, Ideal and Non-ideal Solutions

A11. The vapour pressure pure liquid 'A' is 70 torr at 27°C. It forms an ideal solution with another liquid B. The mole fraction of B in the solution is 0.2 and total pressure of solution is 84 torr at 27°C. The vapour pressure of pure liquid B at 27°C is :
(*a*) 14 torr (*b*) 56 torr (*c*) 140 torr (*d*) 70 torr.

A12. Which of the following plots represents the behaviour of an ideal binary liquid solution?
(*a*) plot of $1/p_{total}$ vs y_A is linear (mol fraction of A in vapour phase)
(*b*) plot of p_{total} vs y_B is linear
(*c*) plot of p_{total} vs y_A is linear
(*d*) plot of $1/p_{total}$ vs y_B is non-linear

A13. The vapour pressure of a solution prepared by dissolving 1 mol of liquid A and 2 mol of liquid B has been found to be 38 torr. The vapour pressure of pure A and pure B are 45 and 36 torr respectively. The solution
(*a*) shows negative deviation
(*b*) is a minimum boiling azeotrope
(*c*) is an ideal solution
(*d*) has ΔH_{mixing} positive

A14. Which pair will not form an ideal solution ?
(*a*) C_2H_5Br and C_2H_5I (*b*) C_6H_5Br and C_6H_5I
(*c*) C_6H_6 and $C_6H_5CH_3$ (*d*) C_2H_5I and C_2H_5OH

A15. When a gas is bubbled through water at 298 K, a very dilute solution of the gas is obtained. Henry's law constant for the gas at 298 K is 100 kbar. If the gas exerts a partial pressure of 1 bar, the number of millimoles of the gas dissolved in one litre of water is
(*a*) 0.555 (*b*) 5.55
(*c*) 0.0555 (*d*) 55.5

A16. The partial pressure of oxygen in air is 0.2 atm. What is the concentration of dissolved oxygen in water in equilibrium with air at 25°C? (K_H for oxygen at 25°C is 4.34×10^4 atm)
(*a*) 2.56×10^{-4} M (*b*) 3.68×10^{-6} M
(*c*) 4.26×10^{-4} M (*d*) 2.96×10^{-6} M

Answers

A1. (*b*) A2. (*c*) A3. (*c*) A4. (*d*) A5. (*a*) A6. (*b*) A7. (*c*) A8. (*d*) A9. (*c*) A10. (*d*)
A11. (*c*) A12. (*a*) A13. (*a*) A14. (*d*) A15. (*a*) A16. (*a*)

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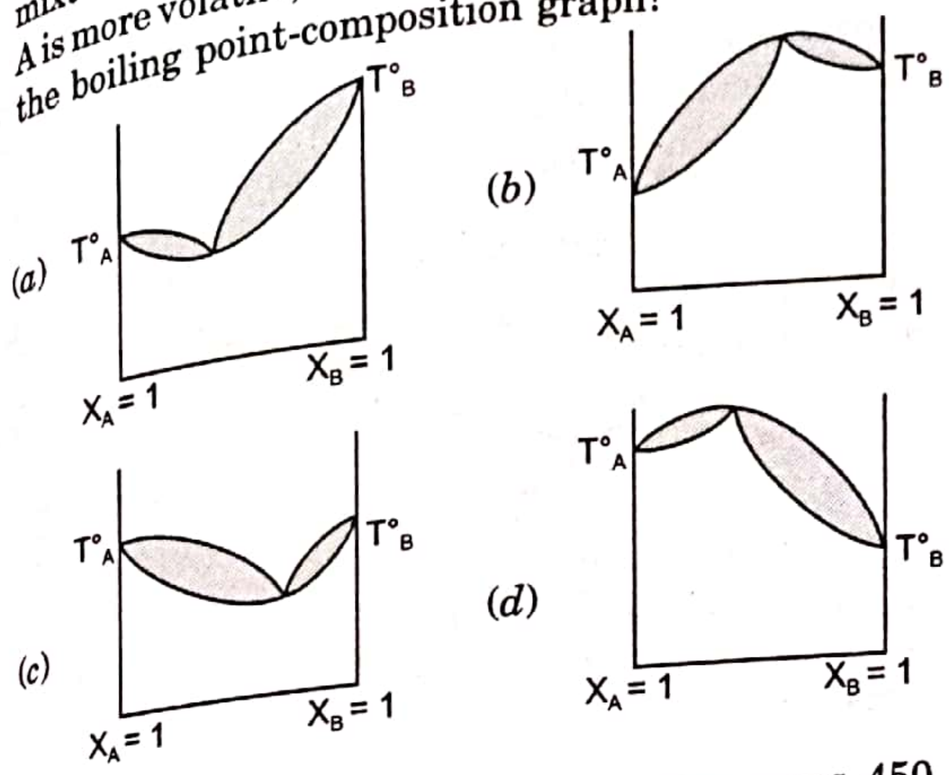
A17. The vapour pressure of pure components X and Y are 200 torr and 100 torr respectively. Assuming a solution of these components obeys Raoult's law, the mole fraction of component X in the vapour phase in equilibrium with a solution containing equimoles of X and Y is
(a) 0.22 (b) 0.33
(c) 0.50 (d) 0.67

A18. If the ratio of vapour pressure of pure liquids A and B is 1 : 2 and their mole fraction in solution is 1:2, then mole fraction of B in vapours is
(a) 0.25 (b) 0.80
(c) 0.56 (d) 0.20

A19. Two completely miscible liquids A and B form an azeotropic mixture having maximum vapour pressure. If the liquid A is more volatile, then which of the following respresents the boiling point-composition graph?



A20. Two liquids P and Q have vapour pressures 450 and 200 torr respectively at certain temperature. In an ideal solution of the two, the mole fraction of P at which two liquids have equal partial pressures is
(a) 0.80 (b) 0.308
(c) 0.444 (d) 0.154

Colligative Properties

A21. A solution of solute X in benzene boils at 0.126°C higher than benzene. What is the molality of the solution ? (K_b for benzene = 2.52 K/m)
(a) 0.05 (b) 2 (c) 1 (d) 20.

A22. The osmotic pressure of 0.2 molar solution of urea at 27°C (R = 0.082 litre atm mol^{-1} K^{-1}) is :
(a) 4.92 atm (b) 1 atm (c) 0.2 atm (d) 27 atm.

A23. A 5% solution of glucose (molar mass = 180) is isotonic with a 2.5% solution of a substance X at the same temperature. The molar mass of X is
(a) 360 (b) 180
(c) 90 (d) 45

A24. An aqueous solution containing 1 g of urea boils at 100.25°C. The aqueous solution containing 3 g of glucose in the same volume will boil at
(a) 100.75°C (b) 100.5°C
(c) 100°C (d) 100.25°C.

A25. An aqueous solution of sucrose boils at 100.01°C. The number of dextrose molecules in 100 g solution are (K_b of water = 0.50°K kg mol^{-1})
(a) 1.2×10^{21} (b) 2.0×10^{22}
(c) 3.0×10^{23} (d) 6.0×10^{11}

A26. The vapour pressure of the solvent decreased by 10 mm of Hg when a non-volatile solute was added to the solvent. The mole fraction of the solute in the solution is 0.2. What should be the mole fraction of the solvent if a decrease in vapour pressure of 20 mm of Hg is desired :
(a) 0.6 (b) 0.8 (c) 0.4 (d) 0.2

A27. Which of the following colligative property can provide molar mass of proteins (or polymers or colloids) with greater precision ?
(a) Relative lowering of vapour pressure ?
(b) Elevation of boiling point
(c) Depression in freezing point
(d) Osmotic pressure

A28. An aqueous solution of a substance X boils at 100. 512°C. The freezing point of the solution is (K_f = 1.86 Km^{-1} and K_b = 0.512 Km^{-1})
(a) 0.93°C (b) –0.93°C
(c) 1.86°C (d) –1.86°C

A29. When a non-volatile solute (A) is added to solvent (B), its vapour pressure is reduced by 10%. If molar mass of B is 30% of molar mass of A, the mass ratio of B and A is
(a) 0.33 (b) 6.0
(c) 3.0 (d) 0.66

A30. When 0.6 g of urea is dissolved in 100 g water, the solution will boil at (K_b for water = 0.52 K m^{-1} and normal boiling point of water = 100°C):
(a) 372.48 K (b) 273.52 K
(c) 373.052 K (d) 273.052 K.

Colligative Properties of Electrolytic Solutions : Abnormal Molar Masses

A31. The osmotic pressure of equimolar solutions of glucose, sodium chloride and barium chloride will be in the order :
(a) $BaCl_2$ > NaCl > glucose (b) $BaCl_2$ > glucose > NaCl
(c) Glucose > $BaCl_2$ > NaCl (d) NaCl > $BaCl_2$ > glucose.

A32. Equal weights of *m* gram of the following substances were dissolved in equal amount of water. Which of these will have highest boiling points ?
(a) Urea (NH_2CONH_2)
(b) Glucose ($C_6H_{12}O_6$)
(c) Sodium chloride (NaCl)
(d) Calcium chloride ($CaCl_2$)

Answers

A17. (d) A18. (b) A19. (a) A20. (b) A21. (a) A22. (a) A23. (c) A24. (d) A25. (a) A26. (a)
A27. (d) A28. (d) A29. (c) A30. (c) A31. (a) A32. (c)

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A33. Which one of the following pairs of solutions can be expected to be isotonic at the same temperature ?
(*a*) 0.1 M urea and 0.1 M NaCl
(*b*) 0.1 M urea and 0.1 M $MgCl_2$
(*c*) 0.1 M NaCl and 0.1 M Na_2SO_4
(*d*) 0.1 M $Ca(NO_3)_2$ and 0.1 M Na_2SO_4

A34. The Van't Hoff factor for 0.1 M $Ba(NO_3)_2$ solution is 2.74. The degree of dissociation is
(*a*) 91.3% (*b*) 87% (*c*) 100% (*d*) 74%

A35. A 0.2 molal aqueous solution of weak acid (HX) is 20% ionized. The freezing point of this solution is :
(K_f = 1.86 K kg mol^{-1} for water)
(*a*) – 0.45°C (*b*) – 0.90°C
(*c*) – 0.31°C (*d*) – 0.53°C

A36. Electrolyte A gives 3 ions and B is a non-electrolyte. If 0.1 molar solution of solute B produces an osmotic pressure *p*, then 0.05 molar solution of A will produce an osmotic pressure equal to
(*a*) *p* (*b*) 1.5 *p* (*c*) 0.5 *p* (*d*) 0.75 *p*

A37. 0.01 M solution each of urea, common salt and sodium sulphate are taken, the ratio of depression in freezing point of these solutions is
(*a*) 1 : 1 : 1 (*b*) 1 : 2 : 1
(*c*) 1 : 2 : 3 (*d*) 2 : 2 : 3

A38. Which of the following 0.10 m aqueous solution will have the lowest freezing point ?
(*a*) $Al_2(SO_4)_3$ (*b*) $C_6H_{12}O_6$
(*c*) $C_{12}H_{22}O_{11}$ (*d*) KI

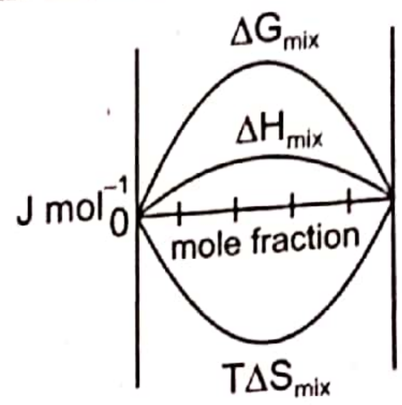
A39. In a 0.2 molal aqueous solution of a weak acid, HX, the degree of dissociation is 0.3. Taking K_f for water as 1.86, the freezing point of the solution will be nearest to
(*a*) – 0.360°C (*b*) – 0.206°C
(*c*) + 0.480°C (*d*) – 0.480°C

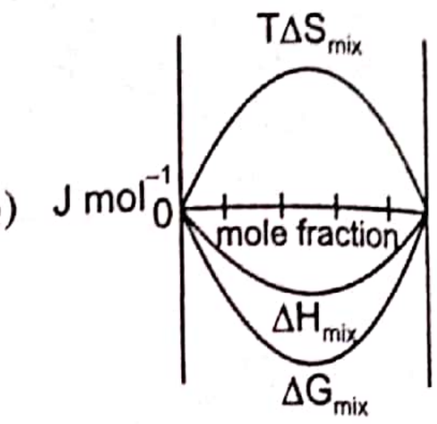
A40. Which of the following solutions are isotonic with one another ?
(1) 0.15 M urea (2) 0.05 M $CaCl_2$
(3) 0.1 M $MgSO_4$ (4) 0.15 M glucose
Select the correct answer using the codes given below :
(*a*) 1 and 4 (*b*) 2 and 3
(*c*) 1, 2 and 4 (*d*) 2, 3 and 4

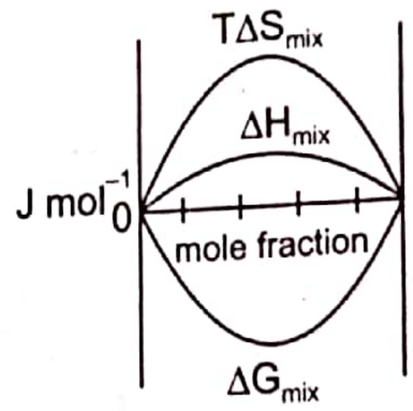
Advanced Level

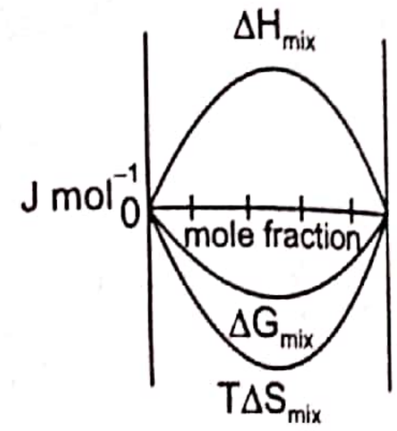
A41. Two volatile liquids A and B having vapour pressures p_A^o and p^o_B respectively form an ideal solution. If x_A and x_B are the mole fractons in the solution and y_A and y_B are the mole fractions in vapour phase of A and B respectively, then a plot of $1/y_A$ along *y*-axis against $1/x_A$ along *x*-axis gives a straight line. The slope of the straight line is
(*a*) p_A^o/p_B^o (*b*) p_B^o/p_A^o
(*c*) $p_A^o - p_B^o$ (*d*) $p_B^o - p_A^o$

A42. Which of the following graph represents correctly the variation in thermodynamic functions during the formation of a binary solution showing positive deviations from ideal behaviour?

(*a*)


(*b*)


(*c*)


(*d*)


A43. Dry air was passed successively through a solution of 5 g of a solute in 80 g of water and then through pure water. The loss in weight of the solution was 2.5 g and that of pure water 0.05 g. The molar mass of solute is
(*a*) 48 (*b*) 32
(*c*) 40 (*d*) 35

Answers

A33. (*d*) **A34.** (*b*) **A35.** (*a*) **A36.** (*b*) **A37.** (*c*) **A38.** (*a*) **A39.** (*d*) **A40.** (*c*) **A41.** (*b*) **A42.** (*c*) **A43.** (*a*)

B MULTIPLE CHOICE QUESTIONS *from Competitive Examinations*

AIPMT & Other State Boards' Medical Entrance

B1. Concentrated aqueous sulphuric acid is 98% H_2SO_4 by mass and has a density of 1.80 g mL^{-1}. Volume of acid required to make one litre of 0.1 M H_2SO_4 is
(*a*) 5.55 mL (*b*) 11.10 mL
(*c*) 16.65 mL (*d*) 22.20 mL
(C.B.S.E. PMT. 2007)

B2. 0.5 molal aqueous solution of a weak acid is 20% ionized. If K_f for water is 1.86 K kg mol^{-1}, the lowering in freezing point of the solution is
(*a*) – 0.56 K (*b*) – 1.12 K
(*c*) 0.56 K (*d*) 1.12 K *(C.B.S.E. PMT. 2007)*

Answers

A 0.0020 m aqueous solution of an ionic compound $Co(NH_3)_5(NO_2)Cl$ freezes at –0.00732°C. Number of moles of ions which 1 mol of ionic compound produces on being dissolved in water will be (K_f = 1.86°C/m)

(a) 3 (b) 4
(c) 1 (d) 2 *(C.B.S.E. PMT 2009)*

25.3 g of sodium carbonate, Na_2CO_3 is dissolved in enough water to make 250 ml of solution. If sodium carbonate dissociates completely, molar concentration of sodium ion, Na^+ and carbonate ions, CO_3^{2-} are respectively (Molar mass of Na_2CO_3 = 106 g mol^{-1}):

(a) 1.90 M and 1.910 M (b) 0.477 M and 0.0477 M
(c) 0.955 M and 1.910 M (d) 1.910 M and 0.955 M
(C.B.S.E. Med 2010)

An aqueous solution is 1.00 molal in KI. Which change will cause the vapour pressure of the solution to increase ?

(a) addition of 1.00 molal KI (b) addition of water
(c) addition of NaCl (d) addition of Na_2SO_4
(C.B.S.E. Med 2010)

A solution of sucrose (molar mass = 342 g mol^{-1}) has been prepared by dissolving 68.5 g of sucrose in 100 g of water. The freezing point of the solution obtained will be (K_f for water = 1.86 K kg mol^{-1}).

(a) + 0.372°C (b) – 0.570°C
(c) – 0.372°C (d) – 0.520°C
(C.B.S.E. Med. 2010)

The van't Hoff factor i for a compound which undergoes dissociation in one solvent and association in other solvent is respectively

(a) less than one and greater than one
(b) less than one and less than one
(c) greater than one and less than one
(d) greater than one and greater than one
(C.B.S.E. P.M.T. 2011)

p_A and p_B are the vapour pressure of pure liquid components, A and B, respectively of an ideal binary solution. If x_A represents the mole fraction of component A, the total pressure of the solution will be

(a) $p_A + x_A(p_B - p_A)$ (b) $p_A + x_A(p_A - p_B)$
(c) $p_B + x_A(p_B - p_A)$ (d) $p_B + x_A(p_A - p_B)$
(A.I.P.M.T. 2012)

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

(a) 0.001 M (b) 0.1 M
(c) 0.02 M (d) 0.01 M *(NEET 2013)*

How many grams of concentrated nitric acid solution should be used to prepare 250 mL of 2.0 M HNO_3? The concentrated acid is 70% HNO_3.

(a) 90.0 g conc. HNO_3 (b) 70.0 g conc. HNO_3
(c) 54.0 g conc. HNO_3 (d) 45.0 g conc. HNO_3
(NEET 2013)

B11. Of the following 0.10 m aqueous solutions, which one will exhibit the largest freezing point depression?

(a) KCl (b) $C_6H_{12}O_6$
(c) $Al_2(SO_4)_3$ (d) K_2SO_4
(A.I.P.M.T. 2014)

B12. The boiling point of 0.2 mol kg^{-1} solution of X in water is greater than equimolal solution of Y in water. Which one of the following statements is true in this case?

(a) Molecular mass of X is less than the molecular mass of Y.
(b) Y is undergoing dissociation in water while X undergoes no change.
(c) X is undergoing dissociation in water.
(d) Molecular mass of X is greater than the molecular mass of Y. *(A.I.P.M.T. 2015)*

B13. Which one of the following electrolytes has the same value of van't Hoff factor (i) as that of $Al_2(SO_4)_3$ (if all are 100% ionised)?

(a) $Al(NO_3)_3$ (b) $K_4[Fe(CN)_6]$
(c) K_2SO_4 (d) $K_3[Fe(CN)_6]$ *(A.I.P.M.T. 2015)*

B14. What is the mole fraction of the solute in a 1.00 m aqueous solution?

(a) 0.0354 (b) 0.0177
(c) 0.177 (d) 1.770 *(A.I.P.M.T. 2015)*

B15. Which of the following statement about the composition of the vapour over an ideal 1 : 1 molar mixture of benzene and toluene is correct? Assume that the temperature is constant at 25°C. (Given, vapour pressure data at 25°C, benzene = 12.8 kPa, toluene = 3.85 kPa)

(a) The vapour will contain equal amounts of benzene and toluene.
(b) Not enough information is given to make a prediction.
(c) The vapour will contain a higher percentage of benzene.
(d) The vapour will contain a higher percentage of toluene.
(NEET 2016)

B16. At 100°C the vapour pressure of a solution of 6.5 g of a solute in 100 g water is 732 mm. If K_b = 0.52 Km^{-1} the boiling point of this solution will be

(a) 102°C (b) 103C°
(c) 101°C (d) 100°C *(NEET 2016)*

B17. Which one of the following is incorrect for an ideal solution?

(a) $\Delta H_{mix} = 0$
(b) $\Delta V_{mix} = 0$
(c) $\Delta P = P_{obs} - P_{calculated\ by\ Raoult's\ law} = 0$
(d) $\Delta G_{mix} = 0$ *(NEET 2016)*

B18. The van't Hoff factor (i) for a dilute aqueous solution of the strong electrolyte barium hydroxide is

(a) 0 (b) 1
(c) 2 (d) 3 *(NEET 2016)*

Answers

B3. (d) B4. (d) B5. (b) B6. (c) B7. (c) B8. (d) B9. (d) B10. (d) B11. (c) B12. (c) B13. (b)
B14. (b) B15. (c) B16. (c) B17. (d) B18. (d)

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B19. If molality of the dilute solution is doubled, the value of molal depression constant (K_f) will be
(a) halved (b) tripled
(c) unchanged (d) doubled *(NEET 2017)*

B20. Consider the following aqueous solutions and assume 100% ionization of electrolytes
(I) 0.1 m urea (II) 0.04 m $Al_2(SO_4)_3$
(III) 0.05 m $CaCl_2$ (IV) 0.005 m NaCl
The correct statement regarding the above solutions is
(a) freezing point will be lowest for solution I
(b) freezing point will be highest for solution IV
(c) vapour pressure will be highest for solution II
(d) osmotic pressure will be highest for solution III
(Kerala P.M.T. 2007)

B21. The temperature at which 10% aqueous solution (w/v) of glucose will exhibit the osmotic pressure of 16.4 atm is ($R = 0.082\ dm^3\ atm\ K^{-1}\ mol^{-1}$).
(a) 360°C (b) 180 K
(c) 90 K (d) 300 K
(e) 360 K *(Kerala P.M.T. 2008)*

B22. At 300 K the vapour pressure of an ideal solution containing 1 mole of liquid A and 2 moles of liquid B is 500 mm of Hg. The vapour pressure of the solution increases by 25 mm of Hg if one more mole of B is added to the above ideal solution at 300 K. Then vapour pressure of A in its pure state is
(a) 300 mm of Hg (b) 40 mm of Hg
(c) 500 mm of Hg (d) 600 mm of Hg
(e) 200 mm of Hg *(Kerala PMT 2009)*

B23. Henry's law constant of oxygen is 1.4×10^{-3} mol L^{-1} atm^{-1} at 298 K. How much of oxygen is dissolved in 100 mL at 298 K when the partial pressure of oxygen is 0.5 atm ?
(a) 1.4 g (b) 3.2 g
(c) 22.4 mg (d) 2.24 mg
(e) 3.2 mg *(Kerala PMT 2009)*

B24. The solubility of a gas in water at 300 K under a pressure of 100 atmospheres is 4×10^{-3} kg L^{-1}. Therefore, the mass of the gas in kg dissolved in 250 mL of water under a pressure of 250 atmospheres at 300 K is
(a) 2.5×10^{-3} (b) 2.0×10^{-3}
(c) 1.25×10^{-3} (d) 5.0×10^{-3}
(e) 3×10^{-3} *(Kerala PMT 2010)*

B25. Which one of the following statements is false?
(a) Raoult's law states that the vapour pressure of a component over a binary solution of volatile liquids is directly proportional to its mole fraction.
(b) Two sucrose solutions of the same molality prepared in different solvents will have the same depression of freezing point.
(c) The correct order of osmotic pressures of 0.01 M solution of each compound is $BaCl_2 > KCl > CH_3COOH$ > glucose.
(d) In the equation osmotic pressure $p = MRT$, M is the molarity of the solution.
(e) The molecular weight of NaCl determined by colligative property measurement is less than its theoretical molecular weight. *(Kerala P.M.T. 2011)*

B26. Equimolal aqueous solutions of NaCl and $BaCl_2$ are prepared. If the freezing point of NaCl is –2°C, the freezing point of $BaCl_2$ solution is expected to be
(a) –2°C (b) –3°C
(c) –1.5°C (d) – 1.66°C *(A.M.U. Med. 2013)*

B27. The degree of ionization of HF in 0.100 m aqueous solution is (freezing point of the solution = – 0.197°C and K_f for water = 1.86 °C)
(a) 6% (b) 12%
(c) 3% (d) 9%

B28. The partial pressure of nitrogen in air is 0.76 atm. and its Henry's law constant is 7.6×10^4 atm at 300 K. What is the mole fraction of N_2 in the solution obtained when air is bubbled through water at 300 K?
(a) 1×10^{-4} (b) 2×10^{-4}
(c) 1×10^{-5} (d) 2×10^{-5}
(e) 1×10^{-6} *(Kerala PMT 2014)*

B29. The experimental and calculated elevation in boiling points of an electrolyte AB in its aqueous solution at a given concentration are 0.81 K and 0.54 K respectively. The percentage ionization of the electrolyte at this concentration is
(a) 20 (b) 40
(c) 50 (d) 60
(e) 80 *(Kerala PMT 2014)*

B30. An electrolyte (AB) is 100% ionized in 10% aqueous solution. What is the osmotic pressure (atm) of a 10% solution of the electrolyte at 300 K, if molecular weight of AB is 200 g mol^{-1} ?
(a) 200 (b) 100
(c) 246 (d) 24.6

B31. The density of 2.0 M solution of a solute is 1.2 g mL^{-1}. If the molecular mass of the solute is 100 g mol^{-1}, then the molality of the solution is
(a) 2.0 m (b) 1.2 m
(c) 1.0 m (d) 0.6 m
(e) 2.4 m *(Kerala PMT 2015)*

Answers

B19. (c) **B20.** (b) **B21.** (e) **B22.** (a) **B23.** (d) **B24.** (a) **B25.** (b) **B26.** (b) **B27.** (a) **B28.** (c)
B29. (c) **B30.** (d) **B31.** (a)

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B32. The correct equation for the degree of association 'α' of an associating solute, 'n' molecules of which undergoes association in solution, is

(a) $\alpha = \frac{n(i-1)}{1-n}$ (b) $\alpha = \frac{i(n-1)}{1+n}$

(c) $\alpha = \frac{i(n+1)}{1-n}$ (d) $\alpha = \frac{i(n+1)}{n-1}$

(e) $\alpha = \frac{n(1-i)}{1-n}$ (*Kerala PMT 2015*)

B33. The vapour pressure of a solvent at 293 K is 100 mm Hg. Then the vapour pressure of a solution containing 1 mole of a strong electrolyte (AB_2) in 99 moles of the solvent at 293 K is (assume complete dissociation of solute)

(a) 103 mm Hg (b) 99 mm Hg

(c) 97 mm Hg (d) 101 mm Hg

(e) 98 mm Hg (*Kerala PMT 2015*)

B34. The correct order of osmotic pressure of 0.01 M aqueous solution of the following is

(a) Sucrose > CH_3COOH > KCl

(b) CH_3COOH > Sucrose > KCl

(c) Sucrose > KCl > CH_3COOH

(d) KCl > Sucrose > CH_3COOH

(e) KCl > CH_3COOH > Sucrose (*Kerala PMT 2015*)

JEE (Main) & Other State Boards' Engineering Entrance

B35. A 5.25% solution of a substance is isotonic with a 1.5% solution of urea (molar mass = 60 g mol^{-1}) in the same solvent. If the densities of both the solutions are assumed to be equal to 1.0 g cm^{-3}, molar mass of the substance will be

(a) 90.0 g mol^{-1} (b) 115.0 g mol^{-1}

(c) 105.0 g mol^{-1} (d) 210.0 g mol^{-1} (*A.I.E.E.E. 2007*)

B36. The density (in g mL^{-1}) of a 3.60 M sulphuric acid solution that is 29% H_2SO_4 (molar mass = 98 g mol^{-1}) by mass will be

(a) 1.64 (b) 1.88

(c) 1.22 (d) 1.95 (*A.I.E.E.E. 2007*)

B37. At 80°C, the vapour pressure of pure liquid 'A' is 520 mm Hg and that of pure liquid 'B' is 1000 mm Hg. If a mixture of solution of 'A' and 'B' boils at 80° C and 1 atm pressure, the amount of 'A' in the mixture is (1atm = 760 mm Hg):

(a) 50 mol percent (b) 52 mol percent

(c) 34 mol percent (d) 48 mol percent (*A.I.E.E.E. 2008*)

B38. The vapour pressure of pure water at 20°C is 17.5 mm Hg. If 18 g of glucose ($C_6H_{12}O_6$) is added to 178.2 g of water at 20°C, the vapour pressure of resulting solution will be

(a) 17.325 mm Hg (b) 17.675 mm Hg

(c) 15.750 mm Hg (d) 16.500 mm Hg (*A.I.E.E.E. 2008*)

B39. Two liquids X and Y form an ideal solution. At 300 K, vapour pressure of the solution containing 1 mole of X and 3 mole of Y is 550 mm Hg. At the same temperature, if 1 mole of Y is further added to this solution, vapour pressure of the solution increases by 10 mm Hg. Vapour pressure (in mm Hg) of X and Y in their pure states will be, respectively

(a) 200 and 300 (b) 300 and 400

(c) 400 and 600 (d) 500 and 300 (*A.I.E.E.E. 2009*)

B40. If sodium sulphate is considered to be completely dissociated into cations and anions in aqueous solution, the change in freezing point of water (ΔT_f), when 0.01 mol of sodium sulphate is dissolved in 1 kg of water is (K_f = 1.86 K kg mol^{-1})

(a) 0.0744 K (b) 0.0186 K

(c) 0.0372 K (d) 0.0558 K (*A.I.E.E.E. 2010*)

B41. On mixing, heptane and octane form an ideal solution. At 373 K, the vapour pressures of the two liquid components (heptane and octane) are 105 kPa and 45 kPa respectively. Vapour pressure of the solution obtained by mixing 25.0 g of heptane and 35 g of octane will be (molar mass of heptane = 100 g mol^{-1} and of octane = 114 g mol^{-1}) :

(a) 96.2 kPa (b) 144.5 kPa

(c) 72.0 kPa (d) 36.1 kPa (*A.I.E.E.E. 2010*)

B42. A 5.2 molal aqueous solution of methyl alcohol, CH_3OH, is supplied. What is the mole fraction of methyl alcohol in the solution?

(a) 0.086 (b) 0.050

(c) 0.100 (d) 0.190 (*A.I.E.E.E. 2011*)

B43. Ethylene glycol is used as an antifreeze in a cold climate. Mass of ethylene glycol which should be added to 4 kg of water to prevent it from freezing at – 6 °C will be (K for water = 1.86 K kg mol^{-1}, and molar mass of ethylene glycol = 62 g mol^{-1})

(a) 400.00 g (b) 304.60 g

(c) 804.32 g (d) 204.30 g (*A.I.E.E.E. 2011*)

B44. The degree of dissociation (α) of a weak electrolyte, A_xB_y is related to Van't Hoff factor (i) by the expression :

(a) $\alpha = \frac{x+y-1}{i-1}$ (b) $\alpha = \frac{x+y+1}{i-1}$

(c) $\alpha = \frac{i-1}{(x+y-1)}$ (d) $\alpha = \frac{i-1}{x+y+1}$ (*A.I.E.E.E. 2011*)

Answers

B32. (a) B33. (c) B34. (e) B35. (d) B36. (c) B37. (a) B38. (a) B39. (c) B40. (d) B41. (c)
B42. (a) B43. (c) B44. (c)

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B45. The molality of a urea solution in which 0.0100 g of urea, $[(NH_2)_2CO]$ is added to 0.3000 dm^3 of water at STP is :

(*a*) 5.55×10^{-4} m (*b*) 33.3 m
(*c*) 3.33×10^{-2} m (*d*) 0.555 m *(A.I.E.E.E. 2011)*

B46. A 5% solution of cane sugar (molar mass 342) is isotonic with 1% of a solution of an unknown solute. The molar mass of unknown solute in g/mol is

(*a*) 171.2 (*b*) 68.4
(*c*) 34.2 (*d*) 136.2 *(A.I.E.E.E. 2011)*

B47. The density of a solution prepared by dissolving 120 g of urea (mol. mass = 60 u) in 1000 g of water is 1.15 g/mL. The molarity of this solution is

(*a*) 1.78 M (*b*) 1.02 M
(*c*) 2.05 M (*d*) 0.50 M *(A.I.E.E.E. 2012)*

B48. K_f for water is 1.86 K kg mol^{-1}. If your automobile radiator holds 1.0 kg of water, how many grams of ethylene glycol ($C_2H_6O_2$) must you add to get the freezing point of the solution lowered to – 2.8°C ?

(*a*) 93 g (*b*) 39 g
(*c*) 27 g (*d*) 72 g *(A.I.E.E.E. 2012)*

B49. The molarity of a solution obtained by mixing 750 mL of 0.5 M HCl with 250 mL of 2M HCl will be

(*a*) 0.875 M (*b*) 1.00 M
(*c*) 1.75 M (*d*) 0.975 M *(JEE Main 2013)*

B50. Consider separate solutions of 0.500M $C_2H_5OH_{(aq)}$, 0.100 M $Mg_3(PO_4)_{2(aq)}$, 0.250 M $KBr_{(aq)}$ and 0.125 M $Na_3PO_{4(aq)}$ at 25 °C. Which statement is true about these solutions, assuming all salts to be strong electrolytes ?

(*a*) 0.500 M $C_2H_5OH_{(aq)}$ has the highest osmotic pressure.
(*b*) They all have the same osmotic pressure.
(*c*) 0.100 M $Mg_3(PO_4)_{2(aq)}$ has the highest osmotic pressure.
(*d*) 0.125 M $Na_3PO_{4(aq)}$ has the highest osmotic pressure. *(JEE Main 2014)*

B51. The vapour pressure of acetone at 20°C is 185 torr. When 1.2 g of a non-volatile substance was dissolved in 100 g of acetone at 20°C, its vapour pressure was 183 torr. The molar mass (g mol^{-1}) of the substance is

(*a*) 128 (*b*) 488
(*c*) 32 (*d*) 64 *(JEE Main 2015)*

B52. 18 g glucose ($C_6H_{12}O_6$) is added to 178.2 g water. The vapour pressure of water (in torr) for this aqueous solution is

(*a*) 7.6 (*b*) 76.0
(*c*) 752.4 (*d*) 759.0 *(JEE Main 2016)*

B53. The freezing point of benzene decreases by 0.45°C when 0.2 g of acetic acid is added to 20 g of benzene. If acetic acid associates to form a dimer in benzene, percentage association of acetic acid in benzene will be: (K_f for benzene = 5.12 K kg mol^{-1})

(*a*) 64.6% (*b*) 80.4%
(*c*) 74.6% (*d*) 94.6% *(JEE Main 2017)*

B54. For 1 molal aqueous solution of the following compounds, which one will show the highest freezing point?

(*a*) $[Co(H_2O)_6]Cl_3$
(*b*) $[Co(H_2O)_5Cl]Cl_2.H_2O$
(*c*) $[Co(H_2O)_4Cl_2]Cl.2H_2O$
(*d*) $[Co(H_2O)_3Cl_3.]3H_2O$ *(JEE Main 2018)*

B55. Two liquids X and Y form an ideal solution. The mixture has a vapour pressure of 400 mm at 300 K when mixed in the molar ratio of 1:1 and a vapour pressure of 350 mm when mixed in the molar ratio of 1:2 at the same temperature. The vapour pressures of the two pure liquids X and Y respectively are

(*a*) 250 mm, 550 mm
(*b*) 350 mm, 450 mm
(*c*) 350 mm, 700 mm
(*d*) 500 mm, 500 mm
(*e*) 550 mm, 250 mm *(Kerala P.E.T. 2008)*

B56. A 6% solution of urea is isotonic with

(*a*) 0.05 M solution of glucose
(*b*) 6% solution of glucose
(*c*) 25% solution of glucose
(*d*) 1 M solution of glucose *(Karnataka C.E.T. 2009)*

B57. The difference between the boiling point and freezing point of an aqueous solution containing sucrose (molecular wt. = 342 g mol^{-1}) in 100 g of water is 105°C. If K_f and K_b of water are 1.86 and 0.51 K kg mol^{-1} respectively, the weight of sucrose in solution is about

(*a*) 34.2 g (*b*) 342 g
(*c*) 7.2 g (*d*) 72 g
(*e*) 68.4 g *(Kerala PET 2009)*

B58. The amount of solute (molar mass 60 g mol^{-1}) that must be added to 180 g of water so that the vapour pressure of water is lowered by 10% is

(*a*) 30 g (*b*) 60 g
(*c*) 120 g (*d*) 12 g
(*e*) 24 g *(Kerala PET 2010)*

59. A solution containing 1.8 g of a compound (empirical formula CH_2O) in 40 g of water is observed to freeze at – 0.465°C. The molecular formula of the compound is (K_f of water = 1.86 kg K mol^{-1})

(*a*) $C_2H_4O_2$ (*b*) $C_3H_6O_3$
(*c*) $C_4H_8O_4$ (*d*) $C_5H_{10}O_5$
(*e*) $C_6H_{12}O_6$ *(Kerala P.E.T. 2011)*

Answers

B45. (*a*) **B46.** (*b*) **B47.** (*c*) **B48.** (*a*) **B49.** (*a*) **B50.** (*b*) **B51.** (*d*) **B52.** (*c*) **B53.** (*d*) **B54.** (*d*)
B55. (*e*) **B56.** (*d*) **B57.** (*d*) **B58.** (*b*) **B59.** (*e*)

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8.5 g of NaCl and 180 g of glucose were separately dissolved in 1000 mL of water. Identify the correct statement regarding the elevation of boiling point (b.pt.) of the resulting solutions.

(a) NaCl solution will show higher elevation of b.pt.
(b) Glucose solution will show higher elevation of b.pt.
(c) Both the solutions will show equal elevation of b.pt.
(d) The b.pt. of elevation will be shown by neither of the solutions. *(W.B.J.E.E. 2012)*

Freezing point of an aqueous solution is – 0.186°C. If the values of K_b and K_f of water are respectively 0.52 K kg mol^{-1} and 1.86 K kg mol^{-1}, then the elevation of boiling point of the solution in K is

(a) 0.52 (b) 1.04
(c) 1.34 (d) 0.134
(e) 0.052 *(Kerala P.E.T. 2012)*

The mass of a non-volatile solute of molar mass 40 g mol^{-1} that should be dissolved in 114 g of octane to lower its vapour pressure by 20% is

(a) 8 g (b) 11.4 g
(c) 9.8 g (d) 12.8 g *(Karnataka C.E.T. 2012)*

The vapour pressures of two liquids A and B in their pure states are in ratio of 1 : 2. A binary solution of A and B contains A and B in the mole proportion of 1 : 2. The mole fraction of A in the vapour phase of the solution will be

(a) 0.33 (b) 0.2
(c) 0.25 (d) 0.52 *(Karnataka C.E.T. 2012)*

The measured freezing point depression for a 0.1 m aqueous CH_3COOH solution is 0.19°C. The acid dissociation constant K_a at this concentration will be (Given K_f, the molal cryoscopic constant = 1.86 K kg mol^{-1})

(a) 4.76×10^{-5} (b) 4×10^{-5}
(c) 8×10^{-5} (d) 2×10^{-5} *(W.B. JEE 2013)*

The vapour pressure of pure benzene and toluene at a particular temperature are 100 mm and 50 mm respectively. Then the mole fraction of benzene in vapour phase in contact with equimolar solution of benzene and toluene is

(a) 0.67 (b) 0.75
(c) 0.33 (d) 0.50
(e) 0.20 *(Kerala P.E.T. 2013)*

An aqueous solution containing 3 g of a solute of molar mass 111.6 g mol^{-1} in a certain mass of water freezes at –0.125 °C. The mass of water in grams present in the solution is (K_f = 1.86 K kg mol^{-1})

(a) 300 (b) 600
(c) 500 (d) 400
(e) 250 *(Kerala PET 2014)*

B67. A solution of 1.25 g of P in 50 g of water lowers freezing point by 0.3 °C. Molar mass of P is 94 and K_f (water) = 1.86 K kg mol^{-1}. The degree of association of P if it forms dimers in water is

(a) 80% (b) 60%
(c) 65% (d) 75% *(Karnataka CET 2014)*

B68. Van't Hoff factor of centimolal solution of $K_3[Fe(CN)_6]$ is 3.333. Calculate the per cent dissociation of $K_3[Fe(CN)_6]$.

(a) 33.33 (b) 0.78
(c) 78 (d) 23.33 *(MH-CET 2015)*

B69. After adding non-volatile solute freezing point of water decreases to –0.186°C. Calculate ΔT_b if K_f = 1.86 K kg mol^{-1} and K_b = 0.521 K kg mol^{-1}

(a) 0.0521 K (b) 0.0186 K
(c) 0.521 K (d) 1.86 K *(Karnataka CET 2015)*

B70. 0.06% (w/v) aqueous solution of urea is isotonic with

(a) 0.6% glucose solution (b) 0.1 M glucose solution
(c) 0.06% glucose solution (d) 0.01 M glucose solution *(Karnataka CET 2015)*

B71. Which of the following aqueous solutions has the highest freezing point?

(a) 0.01 m NaCl (b) 0.01 m Na_2SO_4
(c) 0.1 m Sucrose (d) 0.1 m NaCl *(Karnataka CET 2015)*

B72. A solution containing 2.44 g of solute dissolved in 75 g of water boiled at 100.413°C. What will be the molar mass of the solute? (K_b for water = 0.52 K kg mol^{-1})

(a) 40.96 g mol^{-1} (b) 20.48 g mol^{-1}
(c) 81.92 g mol^{-1} (d) None of these *(A.M.U. 2015)*

B73. If P° and P are the vapour pressures of the pure solvent and solution and n_1 and n_2 are the moles of solute and solvent respectively in the solution, then the correct relation between P and P° is

(a) $P° = P\left[\frac{n_1}{n_1+n_2}\right]$ (b) $P° = P\left[\frac{n_2}{n_1+n_2}\right]$

(c) $P = P°\left[\frac{n_2}{n_1+n_2}\right]$ (d) $P = P°\left[\frac{n_1}{n_1+n_2}\right]$ *(WB JEE 2016)*

B74. Calculate the molality of a solution that contains 51.2 g of naphthalene, ($C_{10}H_8$) in 500 mL of carbon tetrachloride. The density of CCl_4 is 1.60 g/mL.

(a) 0.250 m (b) 0.500 m
(c) 0.750 m (d) 0.840 m
(e) 1.69 m *(Kerala PET 2016)*

B75. 31 g of ethylene glycol ($C_2H_6O_2$) is mixed with 500 g of solvent (K_f of the solvent is 2 K kg mol^{-1}). What is the freezing point of the solution in K? (freezing point of solvent = 273 K).

(a) 272 (b) 271
(c) 270 (d) 274
(e) 275 *(Kerala PET 2016)*

Answers

B60. (a) B61. (e) B62. (a) B63. (b) B64. (b) B65. (a) B66. (d) B67. (a) B68. (b) B69. (a)
B70. (d) B71. (a) B72. (a) B73. (c) B74. (b) B75. (b)

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B76. Osmotic pressure of the solution can be increased by
(a) increasing the temperature of the solution
(b) decreasing the temperature of the solution
(c) increasing the volume of the vessel
(d) diluting the solution. *(Karnatka C.E.T. 2016)*

B77. The molarity of 3 M solution of methanol if the density of the solution is 0.9 g cm^{-3} is
(a) 3.73 (b) 3.0
(c) 3.33 (d) 3.1
(e) 3.2 *(Kerala PET 2017)*

B78. The freezing point of equimolal aqueous solutions will be highest for
(a) $C_6H_5NH_3Cl$ (b) $AgNO_3$
(c) $Ca(NO_3)_2$ (d) $La(NO_3)_3$
(e) D-fructose *(Kerala PET 2017)*

B79. Assuming the compounds to be completely dissociated in aqueous solution, identify the pair of the solutions that can be expected to be isotonic at the same temperature.
(a) 0.01 M Urea and 0.01 M NaCl
(b) 0.02 M NaCl and 0.01 M Na_2SO_4
(c) 0.03 M NaCl and 0.02 M $MgCl_2$
(d) 0.01 M Sucrose and 0.02 M glucose *(WB JEE 2017)*

B80. The Van't Hoff factor '*i*' accounts for
(a) extent of dissolution of solute
(b) extent of dissociation of solute
(c) extent of mobility of solute
(d) extent of solubility of solute *(Karnataka CET 2017)*

B81. What will be the percentage of dimerization of 61 g of benzoic acid in 1000 g of a solvent and producing a depression in freezing point of 2°C? Consider K_f to be 6.
(a) 72% (b) 67%
(c) 43% (d) 28% *(J.K. CET 2018)*

B82. Calculate the molarity of a solution of 30 g of $Co(NO_3)_2.6H_2O$ in 4.3 L of solution. Consider atomic mass of Co = 59u, N = 14u, O = 16u, H = 1u
(a) 0.023 M (b) 0.23 M
(c) 0.046 M (d) 0.46 M *(J.K. CET 2018)*

B83. Which of the following aqueous solution should have the highest boiling point?
(a) 1.0 M NaOH (b) 1.0 M Na_2SO_4
(c) 1.0 M NH_4NO_3 (d) 1.0 M KNO_3
(Karnataka CET 2018)

B84. Isotonic solutions are having the same
(a) surface tension (b) vapour pressure
(c) osmotic pressure (d) viscosity.
(Karnataka CET 2018)

B85. If 1 mol of NaCl solute is dissolved into 1 kg of water, at what temperature will water boil at 1.013 bar? (K_b of water is 0.52 K kg mol^{-1}).
(a) 373.15 K (b) 373.67 K
(c) 374.19 K (d) 373.19 K
(e) 375 K
(Kerala PET 2018)

JEE (Advance) for IIT Entrance

B86. The elevation in boiling point of a solution of 13.44 g of $CuCl_2$ in 1 kg of water using following information will be (molecular wt. of $CuCl_2$ = 134.4, K_b = 0.52 K $molal^{-1}$).
(a) 0.16 (b) 0.05
(c) 0.1 (d) 0.2 *(I.I.T. 2005)*

B87. When 20 g of naphthoic acid ($C_{11}H_8O_2$) is dissolved in 50 g of benzene (K = 1.72 K kg mol^{-1}) a freezing point depression of 2 K is observed. The Van't Hoff factor '*i*' is
(a) 0.5 (b) 1
(c) 2 (d) 3 *(I.I.T. 2007)*

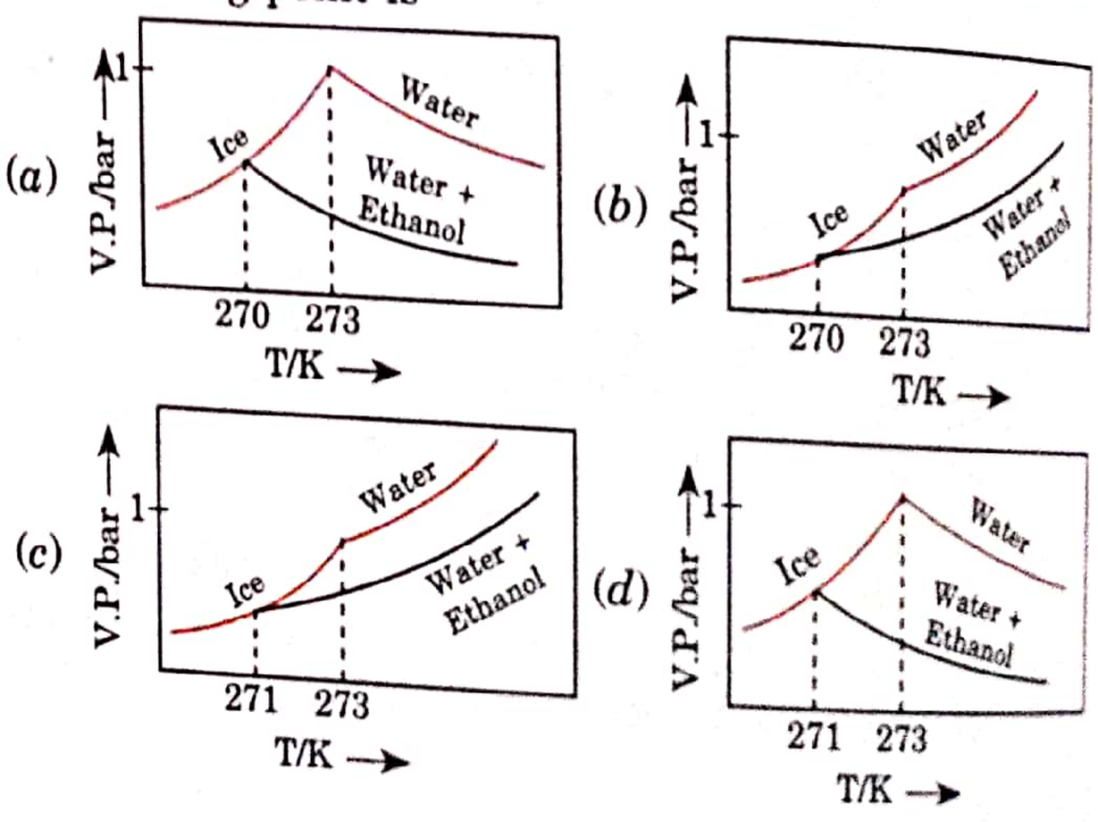
B88. The Henry's law constant for the solubility of N_2 gas in water at 298 K is 1.0×10^5 atm. The mole fraction of N_2 in air is 0.8. The number of moles of N_2 from air dissolved in 10 moles of water at 298 K and 5 atm pressure is
(a) 4.0×10^{-4} (b) 4.0×10^{-5}
(c) 5.0×10^{-4} (d) 4.0×10^{-6} *(IIT-JEE 2009)*

B89. Dissolving 120g 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
(a) 1.78 M (b) 2.00 M
(c) 2.05 M (d) 2.22 M *(I.I.T. 2011)*

B90. The freezing point (in °C) of a solution containing 0.1 g of $K_3[Fe(CN)_6]$ (mol. wt. 329) in 100 g of water (K_f = 1.86 K kg mol^{-1}) is
(a) -2.3×10^{-2} (b) -5.7×10^{-2}
(c) -5.7×10^{-3} (d) -1.2×10^{-2} *(I.I.T. 2011)*

B91. For a dilute solution containing 2.5 g of a non-volatile non-electrolyte solution in 100 g of water, the elevation in boiling point at 1 atm pressure is 2°C. Assuming concentration of solute is much lower than the concentration of solvent, the vapour pressure (mm of Hg) of the solution is (take K_b = 0.76 K kg mol^{-1})
(a) 724 (b) 740
(c) 736 (d) 718 *(I.I.T. J.E.E. 2012)*

B92. Pure water freezes at 273 K and 1 bar. The addition of 34.5 g of ethanol to 500 g of water changes the freezing point of the solution. Use the freezing point depression constant of water as 2 K kg mol^{-1}. The figures shown below represent plots of vapour pressure (V.P.) versus temperature (T).
(Molecular weight of ethanol is 46 g mol^{-1})
Among the following, the option representing change in the freezing point is



(JEE Advance 2017)

Answers

B76. (a) **B77.** (a) **B78.** (e) **B79.** (c) **B80.** (b) **B81.** (b) **B82.** (a) **B83.** (b) **B84.** (c) **B85.** (c)
B86. (a) **B87.** (a) **B88.** (a) **B89.** (c) **B90.** (a) **B91.** (a) **B92.** (b)

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Competition File

Matrix Match Type Questions

Each question contains statements given in two columns. Match the statements in column I with statements in column II.

Each question contains statements given in two columns, which have to be matched. Statements in Column I are labelled as A, B, C and D whereas statements in Column II are labelled as *p*, *q*, *r* are *s*. Match the entries of Column I with appropriate entries of Column II. Each entry in Column I may have one or more than one correct option from Column II. The answers to these questions have to be appropritate bubbled as illustrated in the following example.

If the correct matches are A-*q*, A-*r*, B-*p*, B-*s*, C-*r*, C-*s* and D-*q*, then the correctly bubbled matrix will look like the following:

	p	q	r	s
A	(p)	(q)	(r)	(s)
B	(p)	(q)	(r)	(s)
C	(p)	(q)	(r)	(s)
D	(p)	(q)	(r)	(s)

1. Match the behaviour of solutions in Column I with the examples listed in Column II.

Column I	Column II
(A) Show ideal behaviour	(*p*) Water + Nitric acid
(B) Show –ve deviation from ideal behaviour.	(*q*) Benzene + Acetone
(C) Show +ve deviation from ideal behaviour	(*r*) *n*-hexane + *n*-heptane
(D) Non-ideal solution	(*s*) Carbon tetrachloride + chloroform

2. Match the type of solutions in Column I with the characteristic property mentioned in Column II.

Column I	Column II
(A) Solution in which solute undergoes association	(*p*) Van't Hoff factor will be less than 1 observed
(B) Solution in which solute dissociation	(*q*) observed molecular mass will be more than normal value
(C) Solution containing non-electrolyte	(*r*) colligative property will be more than normal value
(D) 0.1M solution of benzoic acid in benzene	(*s*) Van't Hoff factor will be equal to 1.

Answers

(1) : (A) – (*r*) (B) – (*p*) (C) – (*q*) (*s*) (D) – (*p*) (*q*) (*s*)

(2) : (A) – (*p*) (*q*) (B) – (*r*) (C) – (*s*) (D) – (*p*) (*q*)

Integer type or Numerical Value Type Questions

Integer Type: The answer to each of the following question is a **single-digit**-integer ranging from 0 to 9.

1. How many of the following solutions show negative deviation from ideal behaviour ?

   Chloroform + diethyl ether, acetone + aniline, water + nitric acid, acetone + ethyl alcohol, acetone + carbon disulphide, chloroform + nitric acid.

2. The depression in freezing point for 1 M urea, 0.5 M glucose, 1 M NaCl, and 1M K_2SO_4 are in the ratio $x : 1 : y : z$, The value of $x + z$ is

3. At a certain temperature, the vapour pressure (in mm Hg) of CH_3OH and C_2H_5OH solution is represented as:

$$p = 126\,x + 142$$

where x is the mole fraction of CH_3OH. The vapour of solution containing equimoles of CH_3OH and C_2H_5OH is $y + 200$ mm Hg. The value of y is

4. An electrolyte A_2B_3 ionizes in water upto 75%. The van't Hoff factor for it is

5. The depression in freezing point expected for 0.6 m $Al_2(SO_4)_3$ solution will be 'n' times compared with 0.2 m Na_2SO_4 solution. The value of n is

6. 29.2% (w/w) HCl stock solution has a density of 1.25 g mL^{-1}. The molecular weight of HCl is 36.5 g mol^{-1}. The volume (mL) of stock solution required to prepare 200 mL of 0.4 M HCl is *(I.I.T. 2012)*

7. MX_2 dissociates into M^{2+} and X^- ions in an aqueous solution, with a degree of dissociation (α) of 0.5. The ratio of the observed depression of freezing point of the aqueous solution to the value of the depression of freezing point in the absence of ionic dissociation is.

(JEE Advance 2014)

Answers

1. 4 2. 8 3. 5 4. 4 5. 5 6. 8 7. 2

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Competition File

8. If the freezing point of a 0.01 molal aqueous solution of a cobalt (III) chloride-ammonia complex (which behaves as a strong electrolyte) is – 0.0558°C, the number of chloride (s) in the coordination sphere of the complex is [K_f of water = 1.86 K kg mol^{-1}]

(JEE Advance 2015)

9. The mole fraction of a solute in a solution is 0.1. At 298 K, molarity of this solution is the same as its molality. Density of this solution at 298 K is 2.0 g cm^{-3}. The ratio of the molecular weights of the solute and solvent, $\left(\frac{MW_{solute}}{MW_{solvent}}\right)$, is

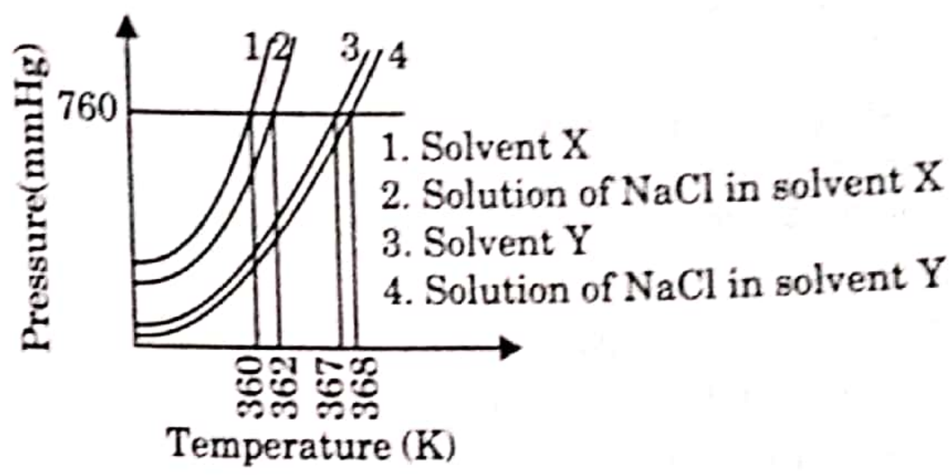
(JEE Advance 2016)

Numerical Value Type: Give the correct numerical value (in decimal notation truncated/rounded off to the second decimal place).

10. Liquids A and B form ideal solution over the entire range of composition. At temperature T, equimolar binary solution of liquids A and B has vapour pressure 45 torr. At the same temperature, a new solution of A and B having mole fractions x_A and x_B respectively has vapour pressure of 22.5 torr. The value of x_A/x_B in the new solution is ..... .
(Given that the vapour pressure of pure liquid A is 20 torr at temperature T.)

(JEE Advance 2018)

11. The plot given below shows P—T curves (where P is the pressure and T is the temperature) for two solvents X and Y and isomolal solutions of NaCl in these solvents. NaCl completely dissociates in both the solvents.



On addition of equal number of moles of a non-volatile solute S in equal amount (in kg) of these solvents, the elevation of boiling point of solvent X is three times that of solvent Y. Solute S is known to undergo dimerization in these solvents. If the degree of dimerization is 0.7 in solvent Y, the degree of dimerization in solvent X is ..... .

(JEE Advance 2018)

Answers

8. 1 9. 9 10. 19.00 11. 0.05

NCERT Exemplar Problems

Objective Questions

Multiple Choice Questions (Type-I)

1. Which of the following units is useful in relating concentration of solution with its vapour pressure?
   (a) mole fraction (b) parts per million
   (c) mass percentage (d) molality

2. On dissolving sugar in water at room temperature solution feels cool to touch. Under which of the following cases dissolution of sugar will be most rapid?
   (a) Sugar crystals in cold water.
   (b) Sugar crystals in hot water.
   (c) Powdered sugar in cold water.
   (d) Powdered sugar in hot water.

3. At equilibrium the rate of dissolution of a solid solute in a volatile liquid solvent is _____.
   (a) less than the rate of crystallisation
   (b) greater than the rate of crystallisation
   (c) equal to the rate of crystallisation
   (d) zero

4. A beaker contains a solution of substance 'A'. Precipitation of substance 'A' takes place when small amount of 'A' is added to the solution. The solution is _____.
   (a) saturated (b) supersaturated
   (c) unsaturated (d) concentrated

Answers

1. (a) 2. (d) 3. (c) 4. (b)

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Competition File

5. Maximum amount of a solid solute that can be dissolved in a specified amount of a given liquid solvent does **not** depend upon _____.
   (a) Temperature (b) Nature of solute
   (c) Pressure (d) Nature of solvent

6. Low concentration of oxygen in the blood and tissues of people living at high altitude is due to _____.
   (a) low temperature
   (b) low atmospheric pressure
   (c) high atmospheric pressure
   (d) both low temperature and high atmospheric pressure

7. Considering the formation, breaking and strength of hydrogen bond, predict which of the following mixtures will show a positive deviation from Raoult's law?
   (a) Methanol and acetone.
   (b) Chloroform and acetone.
   (c) Nitric acid and water.
   (d) Phenol and aniline.

8. Colligative properties depend on _____.
   (a) the nature of the solute particles dissolved in solution.
   (b) the number of solute particles in solution.
   (c) the physical properties of the solute particles dissolved in solution.
   (d) the nature of solvent particles.

9. Which of the following aqueous solutions should have the highest boiling point?
   (a) 1.0 M NaOH (b) 1.0 M Na_2SO_4
   (c) 1.0 M NH_4NO_3 (d) 1.0 M KNO_3

10. The unit of ebullioscopic constant is _____.
   (a) K kg mol^{-1} or K $(molality)^{-1}$
   (b) mol kg K^{-1} or K^{-1}(molality)
   (c) kg mol^{-1} K^{-1} or $K^{-1}(molality)^{-1}$
   (d) K mol kg^{-1} or K (molality)

11. In comparison to a 0.01 M solution of glucose, the depression in freezing point of a 0.01 M $MgCl_2$ solution is _____.
   (a) the same (b) about twice
   (c) about three times (d) about six times

12. An unripe mango placed in a concentrated salt solution to prepare pickle, shrivels because _____.
   (a) it gains water due to osmosis.
   (b) it loses water due to reverse osmosis.
   (c) it gains water due to reverse osmosis.
   (d) it loses water due to osmosis.

13. At a given temperature, osmotic pressure of a concentrated solution of a substance _____.
   (a) is higher than that of a dilute solution.
   (b) is lower than that of a dilute solution.
   (c) is same as that of a dilute solution.
   (d) cannot be compared with osmotic pressure of dilute solution.

14. Which of the following statements is false?
   (a) Two different solutions of sucrose of same molality prepared in different solvents will have the same depression in freezing point.
   (b) The osmotic pressure of a solution is given by the equation $\pi = cRT$ (where c is the molarity of the solution).
   (c) Decreasing order of osmotic pressure for 0.01 M aqueous solutions of barium chloride, potassium chloride, acetic acid and sucrose is $BaCl_2 > KCl > CH_3COOH >$ sucrose.
   (d) According to Raoult's law, the vapour pressure exerted by a volatile component of a solution is directly proportional to its mole fraction in the solution.

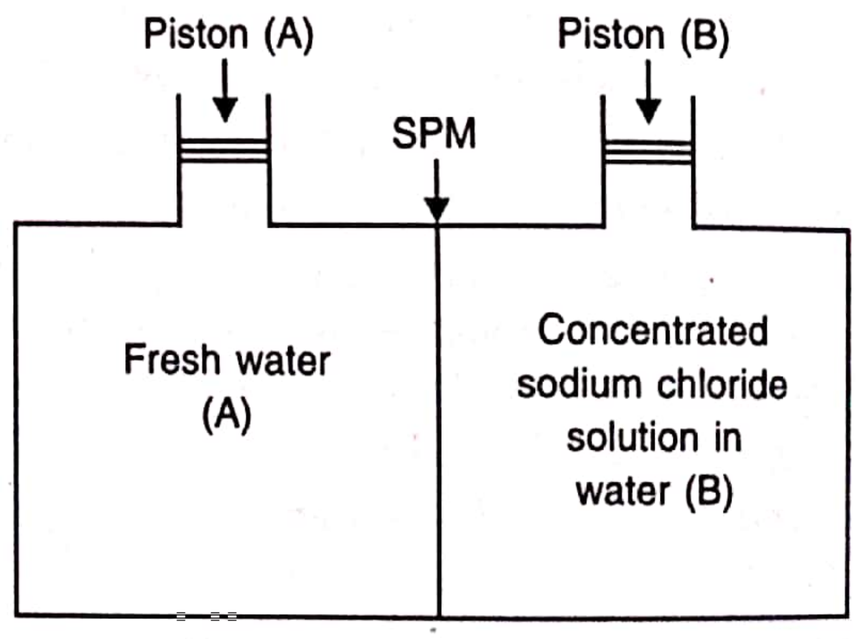
15. The values of Van't Hoff factors for KCl, NaCl and K_2SO_4 respectively, are _____.
   (a) 2, 2 and 2 (b) 2, 2 and 3
   (c) 1, 1 and 2 (d) 1, 1 and 1

16. Which of the following statements is **false**?
   (a) Units of atmospheric pressure and osmotic pressure are the same.
   (b) In reverse osmosis, solvent molecules move through a semipermeable membrane from a region of lower concentration of solute to a region of higher concentration.
   (c) The value of molal depression constant depends on nature of solvent.
   (d) Relative lowering of vapour pressure, is a dimensionless quantity.

17. Value of Henry's constant K_H _____.
   (a) increases with increase in temperature.
   (b) decreases with increase in temperature.
   (c) remains constant.
   (d) first increases then decreases.

18. The value of Henry's constant K_H is _____.
   (a) greater for gases with higher solubility.
   (b) greater for gases with lower solubility.
   (c) constant for all gases.
   (d) not related to the solubility of gases.

19. Consider the figure given below and mark the correct option.



   (a) water will move from side (A) to side (B) if a pressure lower than osmotic pressure is applied on piston (B).
   (b) water will move from side (B) to side (A) if a pressure greater than osmotic pressure is applied on piston (B).

Answers

5. (c)	6. (b)	7. (a)	8. (b)	9. (b)	10. (a)	11. (c)	12. (d)	13. (a)
14. (a)	15. (b)	16. (b)	17. (a)	18. (b)	19. (b)			

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(c) water will move from side (B) to side (A) if a pressure equal to osmotic pressure is applied on piston (B).

(d) water will move from side (A) to side (B) if pressure equal to osmotic pressure is applied on piston (A).

We have three aqueous solutions of NaCl labelled as 'A', 'B' and 'C' with concentrations 0.1M, 0.01M and 0.001M, respectively. The value of van't Hoff factor for these solutions will be in the order_____.

(a) $i_A < i_B < i_C$ (b) $i_A > i_B > i_C$

(c) $i_A = i_B = i_C$ (d) $i_A < i_B > i_C$

On the basis of information given below mark the correct option.

Information:

In bromoethane and chloroethane mixture, intermolecular interactions of A–A and B–B type are nearly same as A–B type interactions.

In ethanol and acetone mixture A–A or B–B type intermolecular interactions are stronger than A–B type interactions.

In chloroform and acetone mixture A–A or B–B type intermolecular interactions are weaker than A–B type interactions.

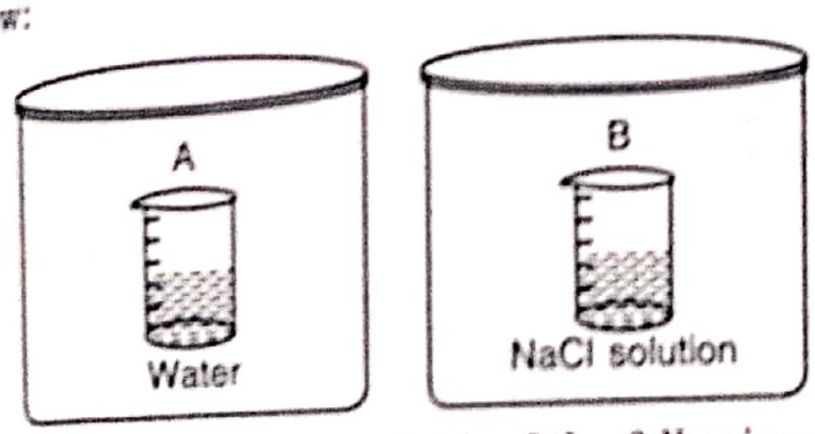
(a) Solution (B) and (C) will follow Raoult's law.

(b) Solution (A) will follow Raoult's law.

(c) Solution (B) will show negative deviation from Raoult's law.

(d) Solution (C) will show positive deviation from Raoult's law.

Two beakers of capacity 500 mL were taken. One of these beakers, labelled as "A", was filled with 400 mL water whereas the beaker labelled "B" was filled with 400 mL of 2 M solution of NaCl. At the same temperature both the beakers were placed in closed containers of same material and same capacity as shown in figure given below:



At a given temperature, which of the following statement is correct about the vapour pressure of pure water and that of NaCl solution.

(a) vapour pressure in container (A) is more than that in container (B).

(b) vapour pressure in container (A) is less than that in container (B).

(c) vapour pressure is equal in both the containers.

(d) vapour pressure in container (B) is twice the vapour pressure in container (A).

23. If two liquids A and B form minimum boiling azeotrope at some specific composition then _____.

(a) A–B interactions are stronger than those between A–A or B–B.

(b) vapour pressure of solution increases because more number of molecules of liquids A and B can escape from the solution.

(c) vapour pressure of solution decreases because less number of molecules of only one of the liquids escape from the solution.

(d) A–B interactions are weaker than those between A–A or B–B.

24. 4L of 0.02 M aqueous solution of NaCl was diluted by adding one litre of water. The molality of the resultant solution is _____.

(a) 0.004 (b) 0.008

(c) 0.012 (d) 0.016

25. On the basis of information given below mark the correct option.

Information : On adding acetone to methanol some of the hydrogen bonds between methanol molecules break.

(a) At specific composition, methanol-acetone mixture will form minimum boiling azeotrope and will show positive deviation from Raoult's law.

(b) At specific composition, methanol-acetone mixture forms maximum boiling azeotrope and will show positive deviation from Raoult's law.

(c) At specific composition, methanol-acetone mixture will form minimum boiling azeotrope and will show negative deviation from Raoult's law.

(d) At specific composition, methanol-acetone mixture will form maximum boiling azeotrope and will show negative deviation from Raoult's law.

26. K_H value for Ar(g), CO_2(g), HCHO (g) and CH_4(g) are 40.39, 1.67, 1.83×10^{-5} and 0.413 respectively.

Arrange these gases in the order of their increasing solubility.

(a) HCHO < CH_4 < CO_2 < Ar

(b) HCHO < CO_2 < CH_4 < Ar

(c) Ar < CO_2 < CH_4 < HCHO

(d) Ar < CH_4 < CO_2 < HCHO

Answers

20. (c) **21.** (b) **22.** (a) **23.** (d) **24.** (d) **25.** (b) **26.** (c)

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Competition File

Multiple Choice Questions (Type-II)

Note : In the following questions two or more options may be correct.

27. Which of the following factor (s) affect the solubility of a gaseous solute in the fixed volume of liquid solvent ?

(*i*) nature of solute (*ii*) temperature (*iii*) pressure

(*a*) (*i*) and (*iii*) at constant T

(*b*) (*i*) and (*ii*) at constant P

(*c*) (*ii*) and (*iii*) only

(*d*) (*iii*) only

28. Intermolecular forces between two benzene molecules are nearly of same strength as those between two toluene molecules. For a mixture of benzene and toluene, which of the following are **not** true?

(*a*) Δ_{mix} H = zero (*b*) Δ_{mix} V = zero

(*c*) These will form minimum boiling azeotrope.

(*d*) These will not form ideal solution.

29. Relative lowering of vapour pressure is a colligative property because _____.

(*a*) It depends on the concentration of a non electrolyte solute in solution and does not depend on the nature of the solute molecules.

(*b*) It depends on number of particles of electrolyte solute in solution and does not depend on the nature of the solute particles.

(*c*) It depends on the concentration of a non electrolyte solute in solution as well as on the nature of the solute molecules.

(*d*) It depends on the concentration of an electrolyte or non electrolyte solute in solution as well as on the nature of solute molecules.

30. Van't Hoff factor '*i*' is given by the expression _____.

(*a*) $i = \dfrac{\text{Normal molar mass}}{\text{Abnormal molar mass}}$

(*b*) $i = \dfrac{\text{Abnormal molar mass}}{\text{Normal molar mass}}$

(*c*) $i = \dfrac{\text{Observed colligative property}}{\text{Calculated colligative property}}$

(*d*) $i = \dfrac{\text{Calculated colligative property}}{\text{Observed colligative property}}$

31. Isotonic solutions must have the same _____.

(*a*) solute

(*b*) density

(*c*) elevation in boiling point

(*d*) depression in freezing point

32. Which of the following binary mixtures will have same composition in liquid and vapour phase?

(*a*) Benzene – Toluene

(*b*) Water – Nitric acid

(*c*) Water – Ethanol

(*d*) *n*-Hexane – *n*-Heptane

33. In isotonic solutions _____.

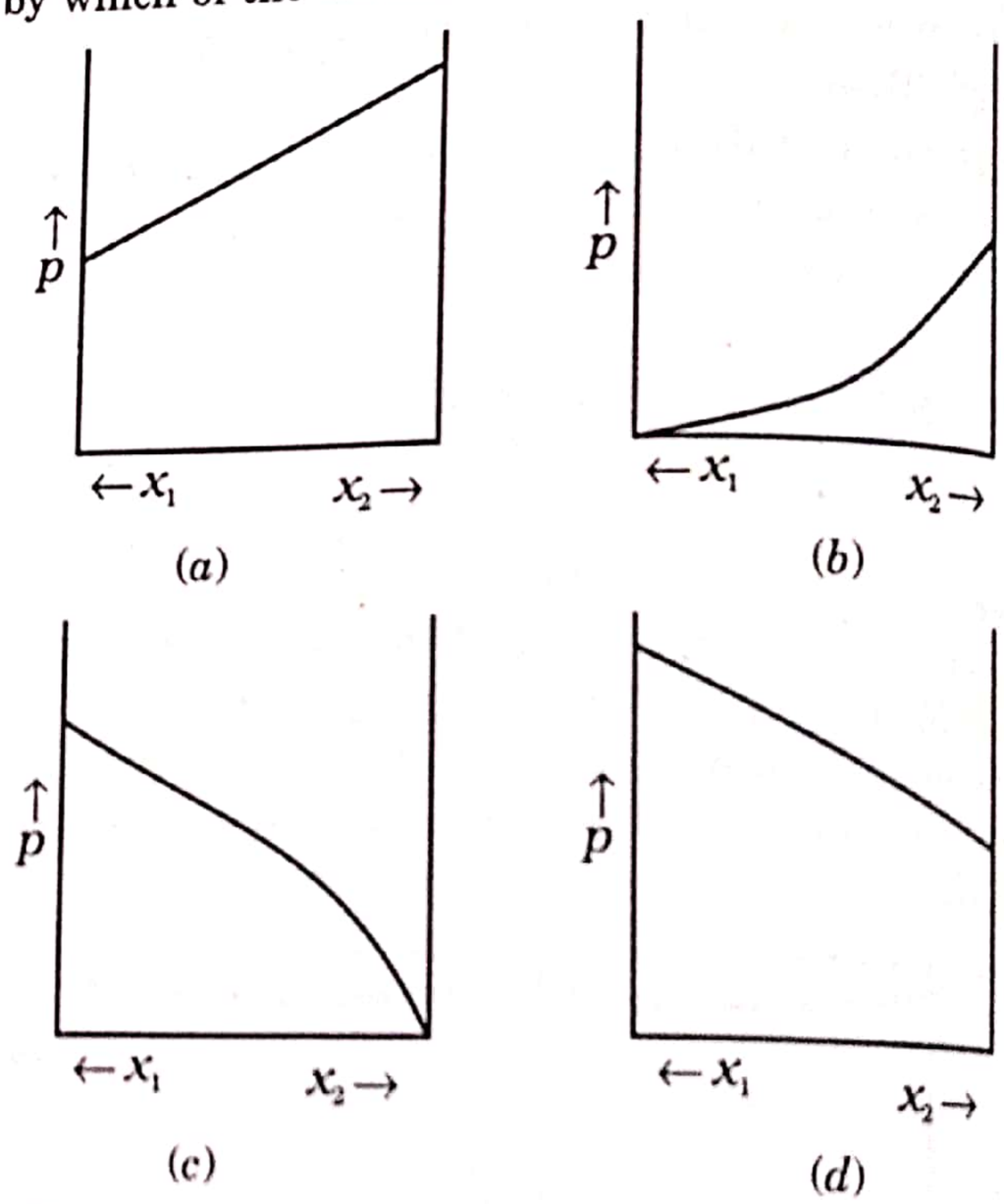
(*a*) solute and solvent both are same.

(*b*) osmotic pressure is same.

(*c*) solute and solvent may or may not be same.

(*d*) solute is always same solvent may be different.

34. For a binary ideal liquid solution, the variation in total vapour pressure versus composition of solution is given by which of the curves?



35. Colligative properties are observed when _____.

(*a*) a non volatile solid is dissolved in a volatile liquid.

(*b*) a non volatile liquid is dissolved in another volatile liquid.

(*c*) a gas is dissolved in non volatile liquid.

(*d*) a volatile liquid is dissolved in another volatile liquid.

Answers

(*a*), (*b*) **28.** (*c*), (*d*) **29.** (*a*),(*b*) **30.** (*a*),(*c*) **31.** (*c*),(*d*) **32.** (*b*),(*c*) **33.** (*b*),(*c*) **34.** (*a*),(*d*) **35.** (*a*),(*b*)

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For example, in a solution containing 1 mole of alcohol and 4 moles of water, the mole fraction of alcohol is 1/5 and that of water is 4/5. Remember that $x_1 + x_2 = 1$

Relation between molality of solution (m) and mole fraction of the solute (x_1).

$$x_1 = \frac{m}{55 \cdot 5 + m}$$

Molality and mole fraction are independent of temperature variation of the solution.

6. **Grams per millilitre.** This is the number of grams of solute in one millilitre (cm^3) of solution. The number of grams per litre (dm^3) of solution is also used.

7. **Demal unit (D).** One demal represents one mole of solute present in one litre of the solution at 0°C.

Example 1. *Calculate the amount of each in the following solutions. (i) 150 ml of N/7 H_2SO_4, (ii) 250 ml of 0·2 M $NaHCO_3$, (iii) 400 ml of N/10 Na_2CO_3, (iv) 1052 g of 1 m KOH.*

Solution. *(i)* Eq. wt. of $H_2SO_4 = \frac{\text{Mol. wt.}}{\text{Basicity}} = \frac{98}{2} = 49$

$\therefore$ Amount of H_2SO_4 per litre (strength) = Normality × Eq. wt.

$= 1/7 \times 49 = 7$ g/litre

$$\text{Amount in 150 ml} = \frac{7 \times 150}{1000} = \mathbf{1 \cdot 05\ g}$$

(ii) Molecular wt. of $NaHCO_3 = 23 + 1 + 12 + 48 = 84$

Amount of $NaHCO_3$ required to produce 1000 c.c. of one molar solution = 84 g

Amount present per litre in 0·2 M solution = 84 × 0·2 = 16·8 g

$$\therefore \text{Amount present in 250 c.c.} = \frac{16 \cdot 8 \times 250}{1000} = \mathbf{4 \cdot 2\ g}$$

(iii) Equivalent weight of $Na_2CO_3 = \frac{\text{Mol. wt.}}{\text{No. of positive valencies}} = \frac{106}{2} = 53$

Amount of Na_2CO_3 = Normality × Eq. wt. $= \frac{1}{10} \times 53 = 5 \cdot 3$ g/litre

$$\therefore \text{Amount present in 400 c.c.} = \frac{5 \cdot 3 \times 400}{1000} = \mathbf{2 \cdot 12\ g}$$

(iv) We know that 1 molal solution of a substance contains 1000 g of solvent.

$\therefore$ Wt. of KOH in 1052 g of 1 m KOH solution = 1052 − 1000 = **52 g**

Example 2. *Calculate the molarity of water in pure water.* **(I.I.T. 1976, C.P.M.T. 1990)**

Solution. Since molarity is the number of moles of water per litre of pure water.

Wt. of 1 litre of pure water = 1000 gm

Mol. wt. of water = 18

$$\therefore \text{Molarity of } H_2O \text{ in pure water} = \frac{1000}{18} = \mathbf{55 \cdot 55}$$

Example 3. *Determine the molarity of the solution containing 6 millimoles of solute in 60 ml. of solution.*

Solution. $M = \frac{\text{No. of mmole of solute}}{\text{Vol. of solution in ml}}$

$$= \frac{6}{60} = \mathbf{0 \cdot 1}$$

Example 4. *How many millimoles of solute is present in 250 ml of 0·4 M HCl solution ?*

Solution. No. of mmole = $M \times V$ (ml)

$= 0 \cdot 4 \times 250 = 100$

Example 5. *Find the molarity of the solution obtained by mixing 200 ml of water with 300 ml of 0 M NaOH.*

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Example 7. *How many ml of water should be added to 300 ml of 0·5 M NaOH solution so as to make it a solution of 0·3 M ?*

Solution. $M_1V_1 = M_2V_2$

(initial) (final)

$0 \cdot 5 \times 300 = 0 \cdot 3 \times V_2$

$V_2 = \frac{0 \cdot 5 \times 300}{0 \cdot 3} = 500$ ml

Vol. of mixture solution = 750 ml.

Vol. of water to be added = 750 − 300 = **450 ml**

Example 8. *How many millilitres of 0·5 M H_2SO_4 are needed to dissolve 0·5 g of copper (II) carbonate ?* **(I.I.T. 1999)**

Solution. No. of meq of H_2SO_4 = No. of meq of $CuCO_3$

$$\text{meq. of } CuCO_3 = \frac{\text{Wt}}{\text{Eq. Wt.}} \times 1000$$

$$= \frac{0 \cdot 5}{61 \cdot 75} \times 1000 \qquad \left[\text{Eq. Wt. of } CuCO_3 = \frac{\text{Mol. Wt.}}{2}\right]$$

$$= 8 \cdot 09$$

$$\text{meq of } H_2SO_4 = N \times V_{(\text{in ml.})}$$

$$= 0 \cdot 5 \times 2 \times V = 1 \times V$$

$$\therefore \quad 1 \times V = 8 \cdot 09$$

$$\therefore \quad V = \mathbf{8 \cdot 09 \text{ ml}}$$

Example 8. *20 ml of 0·02 M $KMnO_4$ was required to completely oxidise 10 ml of oxalic acid solution. What is the molarity of the oxalic acid solution ?*

Solution. The concerned reaction is

$$2KMnO_4 + 3H_2SO_4 + 5(COOH)_2 \longrightarrow K_2SO_4 + 2MnSO_4 + 10CO_2 + 8H_2O$$

[For $KMnO_4$]	[For oxalic acid]
$V_1 = 20$ ml	$V_2 = 10$ ml
$M_1 = 0 \cdot 02$ M	$M_2 = ?$
$n_1 = 2$	$n_2 = 5$

$$\frac{M_1V_1}{n_1} = \frac{M_2V_2}{n_2}$$

$$\frac{0 \cdot 02 \times 20}{2} = \frac{M_2 \times 10}{5}$$

$$M_2 = \frac{0 \cdot 02 \times 20 \times 5}{2 \times 10} = \mathbf{0 \cdot 1 \text{ M}}$$

Example 9. *Determine the amount of NaOH present in 200 ml. of 0·5 N solution.*

Solution. Wt. of solute $= \frac{N \times V \times \text{geq wt.}}{1000}$

$$= \frac{0 \cdot 5 \times 200 \times 40}{1000} = \mathbf{4 \text{ g}}$$

Example 10. *What will be the normality of the solution obtained by mixing 200 ml of pure water to a 100 ml of 0·2 N HCl solution ?*

Solution. $N_1V_1 = N_2V_2$

(Initial) (Final)

$$0 \cdot 2 \times 100 = N_2 \times 300$$

$$N_2 = \frac{0 \cdot 2 \times 100}{300} = 0 \cdot 067 \text{ N}$$

Example 11. *300 ml 0·1 M HCl and 200 ml of 0·3 M H_2SO_4 are mixed. Calculate the normality of the resulting mixture.*

Solution.

For HCl

$V_1 = 300$ ml

$N_1 = M \times$ Basicity

$= 0 \cdot 1 \times 1 = 0 \cdot 1$

For H_2SO_4

$V_2 = 200$ ml

$N_2 = M \times$ Basicity

$= 0 \cdot 3 \times 2 = 0 \cdot 6$

Normality of the mixture,

$$N = \frac{V_1N_1 + V_2N_2}{V_1 + V_2}$$

$$= \frac{300 \times 0 \cdot 1 + 200 \times 0 \cdot 6}{500} = \frac{30 + 120}{500} = 0 \cdot 3 \text{ N}$$

Example 12. *Calculate the molality of a solution of conc HCl containing 36·5% by weight of HCl.*

Solution.

$$m = \frac{1000 \times \text{Wt. of the solute } (x)}{(100 - x) \times \text{Mol. wt.}}$$

$$= \frac{1000 \times 36 \cdot 5}{(100 - 36 \cdot 5) \times 36 \cdot 5} = 15 \cdot 75\%$$

Example 13. *10·6 g of Na_2CO_3 was exactly neutralised by 100 ml of H_2SO_4 solution. What is its normality ?*

Solution. Weight of base $(W) = 10 \cdot 6$ g

geq wt. of base $= 53$

Vol. of acid $(V) = 100$ ml

Normality of acid $(N) = ?$

$$\frac{W}{\text{geq wt.}} = \frac{VN}{1000}$$

$$\frac{10 \cdot 6}{53} = \frac{100 \times N}{1000}$$

$$N = \frac{1000 \times 10 \cdot 6}{100 \times 53} = 2\text{N}$$

Example 14. *100 ml of 0·2 N KOH solution is mixed with 100 ml of 0·1 M H_2SO_4 solution. What is the normality of the resulting solution ?*

Solution.

Acid

$V_a = 100$ ml

$N_a = 0 \cdot 1 \times 2$

$\therefore \quad V_aN_a = 100 \times 0 \cdot 2 = 20$

Base

$V_b = 100$ ml

$N_b = 0 \cdot 2$

$V_bN_b = 100 \times 0 \cdot 2 = 20$

Since $N_aV_a = N_bV_b$; the resulting solution is neutral hence the normality of the mixture is zero.

Example 15. *A solution of ethanol in water is 1·54 molal. How many grams of it are there in 500 gm. of the solvent ? (At. wt. of C = 12, H = 1, O = 16).*

Solution.

$$m = \frac{\text{Wt. of solute}}{\text{Mol. wt. of solute}} \times \frac{1000}{\text{Wt. of solvent in g}}$$

$$1 \cdot 54 = \frac{w}{46} \times \frac{1000}{500}$$

$$w = 35 \cdot 42 \text{ g}$$

Example 16. *The density of a 3 M sodium thiosulphate solution is 1·25 g ml^{-1}. Calculate (i) the % by weight of sodium thiosulphate, (ii) the mole fraction of sodium thiosulphate, and (iii) the molalities of Na^+ and $S_2O_3^{2-}$ ions.* **(I.I.T. 1985)**

Solution. *(i) Calculation of % by weight of $Na_2S_2O_3$*

Density of 3 M $Na_2S_2O_3$ solution=1·25 g/ml

Wt. of 1000 ml of $Na_2S_2O_3$ solution $= \frac{1 \cdot 25 \times 1000}{1} = 1250$ g

Since 1 mole of $Na_2S_2O_3 = 23 \times 2 \times + 32 \times 2 + 16 \times 3 = 158$

Wt. of $Na_2S_2O_3$ in 1000 ml of 3M solution $= 3 \times 158 = 474$ g

1250 g of solution contain = 474 g $Na_2S_2O_3$

100 g of solution contain $= \frac{474 \times 100}{1250} = 37 \cdot 92$ g

∴ % by weight of sod. thiosulphate = **37·92%**

(ii) Calculation of mole fraction of $Na_2S_2O_3$.

100 g of the solution contain = 37·92 g $Na_2S_2O_3$

100 g of the solution contain = 100 − 37·92 = 62·08 g water

No. of moles of $Na_2S_2O_3$ in 37·92 g of $Na_2S_2O_3 = \frac{37 \cdot 92}{158} = 0 \cdot 24$ moles

Similarly,

No. of moles of H_2O in 62·08 g water $= \frac{62 \cdot 08}{18} = 3 \cdot 45$ moles

∴ Total No. of moles = 0·24 + 3·45 = 3·69 moles

∴ Mole fraction of $Na_2S_2O_3 = \frac{0 \cdot 24}{3 \cdot 69} = \mathbf{0 \cdot 065}$

(iii) Calculation of molalities of Na^+ and $S_2O_3^{2-}$ ions.

62·08 g of water contain = 0·24 moles of $Na_2S_2O_3$

1000 g of water contain $= \frac{0 \cdot 24 \times 1000}{62 \cdot 08}$ moles

= 3·865 moles of $Na_2S_2O_3$

Since 1 mole of $Na_2S_2O_3$ contain 2 moles of Na^+ and 1 mole of $S_2O_3^{2-}$

∴ Molality of $Na^+ = 2 \times 3 \cdot 865 = \mathbf{7 \cdot 730}$

Similarly, molality of $S_2O_3^{2-} = 1 \times 3 \cdot 865 = \mathbf{3 \cdot 865}$

Example 17. *Calculate the molality and mole fraction of the solute in aqueous solution containing 3·0 gm of urea per 250 gm of water (Mol. wt. of urea = 60).*

Solution. Wt. of solute (urea) dissolved= 3·0 gm

Wt. of the solvent (water) = 250 gm

Mol. wt. of the solute = 60

Calculation of molality.

3·0 gm of the solute $= \frac{3 \cdot 0}{60}$ moles = 0·05 moles

Thus 250 gm of the solvent contain = 0·05 moles of solute

∴ 1000 gm of the solvent contain $= \frac{0 \cdot 05 \times 1000}{250} = 0 \cdot 2$ moles

Hence molality of the solution = **0·2 m**

In short, Molality = No. of moles of solute/1000 g of solvent

∴ Molality $= \frac{3/60}{250} \times 1000 = \mathbf{0 \cdot 2\ m}$

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Calculation of mole fraction

3·0 gm of solute = 3/60 moles = 0·05 moles

250 gm of water = $\frac{250}{18}$ moles = 13·94 moles

$$\therefore \text{ Mole fraction of the solute} = \frac{0 \cdot 05}{0 \cdot 05 + 13 \cdot 94}$$

$$= \frac{0 \cdot 05}{13 \cdot 99} = 0 \cdot 00357$$

Example 18. *$8 \cdot 0575 \times 10^{-2}$ kg of Glauber's salt is dissolved in water to obtain 1 dm^3 of a solution of density $1077 \cdot 2$ kg m^{-3}. Calculate the molarity, molality and mole fraction of Na_2SO_4 in the solution.* **(I.I.T. 1994)**

Solution. Molar mass of Glauber's salt, $Na_2SO_4 . 10 H_2O = 322 \cdot 3$ g mol^{-1}

No. of moles of Glauber's salt dissolved $(n_2) = \frac{m}{M}$

$$= \frac{8 \cdot 0575 \times 10^{-2} \text{ kg}}{322 \cdot 3 \times 10^{-3} \text{ kg mol}^{-1}} = 0 \cdot 25 \text{ mol.}$$

Mass of 1 dm^3 of solution $= d \times V$

$= 1077 \cdot 2$ kg $m^{-3} \times 10^{-3}$ m^3 $\quad (\because 1 \text{ dm}^3 = 10^{-3} \text{ m}^3)$

$= 1 \cdot 0772$ kg

322·3 g of $Na_2SO_4.10H_2O$ contain 142 g of Na_2SO_4

$8 \cdot 0575 \times 10^{-2}$ g of $Na_2SO_4.10H_2O$ contain $= \frac{142 \times 8 \cdot 0575 \times 10^{-2}}{322 \cdot 3} = 3 \cdot 5525 \times 10^{-2}$ kg

$\therefore$ Mass of Na_2SO_4 in solution $= 3 \cdot 5525 \times 10^{-2}$ kg

Mass of water (solvent) in 1 dm^3 solution $= (1 \cdot 0772 - 3 \cdot 5525 \times 10^{-2})$ kg $= 1 \cdot 041675$ kg

$$\text{Molarity of solution} = \frac{n_2}{V} = \frac{0 \cdot 25 \text{ mol}}{1 \text{ dm}^3} = \mathbf{0 \cdot 25 \text{ mol dm}^{-3}}$$

$$\text{Molality of solution} = \frac{n_2}{m_{\text{solvent}}} = \frac{0 \cdot 25 \text{ mol}}{1 \cdot 0417 \text{ kg}} = \mathbf{0 \cdot 24 \text{ mol kg}^{-1}}$$

$$\text{No. of moles of solvent in 1 dm}^3 \text{ solution } (n_1) = \frac{1 \cdot 0417 \times 10^3}{18 \text{ g mol}^{-1}} = 57 \cdot 87 \text{ mol}$$

$$\text{Mole fraction of } Na_2SO_4 \text{ in solution} = \frac{n_1}{n_1 + n_2} = \frac{0 \cdot 25}{0 \cdot 25 + 57 \cdot 87} = \mathbf{0 \cdot 0043}$$

Example 19. *A solution has 25% of water, 25% ethanol and 50% acetic acid by mass. Calculate the mole fraction of each component.*

Solution. Since 18 g of water = 1 mole

$$25 \text{ g of water} = \frac{25}{18} = 1 \cdot 38 \text{ mole}$$

Similarly, 46 g of ethanol = 1 mole

$$25 \text{ g of ethanol} = \frac{25}{46} = 0 \cdot 55 \text{ moles}$$

Again, 60 g of acetic acid = 1 mole

$$50 \text{ g of acetic acid} = \frac{50}{60} = 0 \cdot 83 \text{ mole}$$

$\therefore$ Mole fraction of water $= \dfrac{1 \cdot 38}{1 \cdot 38 + 0 \cdot 55 + 0 \cdot 83} = 0 \cdot 50$

Similarly, Mole fraction of ethanol $= \dfrac{0 \cdot 55}{1 \cdot 38 + 0 \cdot 55 + 0 \cdot 83} = 0 \cdot 19$

Mole fraction of acetic acid $= \dfrac{0 \cdot 83}{1 \cdot 38 + 0 \cdot 55 + 0 \cdot 83} = 0 \cdot 3$

Example 20. *Calculate the molarity and normality of a solution containing 0·5 gm of NaOH dissolved in 500 ml. solution.*

Solution. Wt. of NaOH dissolved = 0·5 gm

Vol. of NaOH solution = 500 ml

Calculation of molarity.

$0 \cdot 5$ g of NaOH $= \dfrac{0 \cdot 5}{40}$ moles of NaOH [$\because$ Mol. wt of NaOH = 40]

$= 0 \cdot 0125$ moles

Thus 500 ml of the solution contain NaOH= 0·0125 moles

$\therefore$ 1000 ml of the solution contain $= \dfrac{0 \cdot 0125}{500} \times 1000 = 0 \cdot 025$ M

Hence molarity of the solution = **0·025 M**

Calculation of normality.

Since NaOH is monoacidic;

Eq. wt. of NaOH = Mol. wt. of NaOH = 40

$\therefore$ 0·5 gm of NaOH $= \dfrac{0 \cdot 5}{40}$ gm equivalnets

$= 0 \cdot 0125$ gm equivalents

Thus 500 ml of the solution contain NaOH= 0·0125 gm equ.

$\therefore$ 1000 ml of the solution contain $= \dfrac{0 \cdot 0125}{500} \times 1000 = 0 \cdot 025$

Hence normality of the solution = **0·025 N**

Example 21. *Calculate the molality of 1 litre solution of 93% H_2SO_4 (weight/volume). The density of the solution is 1·84 g/ml.*

(I.I.T. 1990, M.L.N.R. 1993)

Solution. Mass of H_2SO_4 in 100 ml of 93% H_2SO_4 solution = 93 g

$\therefore$ Mass of H_2SO_4 in 1000 ml of the H_2SO_4 sol. = 930 g

Mass of 1000 ml H_2SO_4 solution = 1000 × 1·84 = 1840 g

Mass of water in 1000 ml of solution = 1840 − 930 g = 910 g = 0·910 kg

Moles of $H_2SO_4 = \dfrac{\text{Wt. of } H_2SO_4}{\text{Mol. wt. of } H_2SO_4} = \dfrac{930}{98}$

$\therefore$ Moles of H_2SO_4 in 1 kg of water $= \dfrac{930}{98} \times \dfrac{1}{0 \cdot 910} = 10 \cdot 43$ mol

$\therefore$ Molality of 1 litre solution = **10·43**

Example 22. *A 6·90 M solution of KOH in water contains 30% by weight of KOH. Calculate the density of the solution.*

Solution. By definition of molarity,

6·90 M solution contains 6·90 mole of KOH in 1000 ml of solution.

Wt. of 6·90 moles of KOH = 6·90 × 56 g = 386·4 g ($\therefore$ Mol. wt. of KOH = 56 g mol^{-1})

Wt. of KOH in 1000 ml of solution = 386·4 g

Now since, density $= \frac{\text{Weight}}{\text{Volume}} = \frac{1288}{1000} = 1 \cdot 288 \text{ g ml}^{-1}$

Alternatively. Molarity $= \frac{10 \times \text{Sp. gravity of solution} \times \text{Wt. of the solute}}{\text{Mol. wt. of the solute}}$

$$6 \cdot 90 = \frac{10 \times \text{Sp. gravity} \times 30}{56}$$

$$\text{Sp. gravity} = \frac{56 \times 6 \cdot 90}{300} = 1 \cdot 288 \text{ g ml}^{-1}$$

Example 23. *When 10·00 ml of ethanol of density 0·7893 g/ml is mixed with 20·00 ml of water of density 0·9971 g/ml at 25°C, the final solution has a density of 0·9571 g/ml. Calculate the percentage change in total volume on mixing. Also calculate the molarity of the final solution.*

Solution. Masses are additive, hence let us determine the mass of each component.

10 ml of ethanol $\left(0 \cdot 7893 \frac{\text{g}}{\text{ml}}\right) = 7 \cdot 893$ g

20 ml of water $\left(0 \cdot 9971 \frac{\text{g}}{\text{ml}}\right) = 19 \cdot 94$ g

$\therefore$ Total mass $= 7 \cdot 893 + 19 \cdot 94 = 27 \cdot 83$ g

Conversion of 27·83 g of solution (of density 0·9571 g/ml) into volume.

$$V = \frac{m}{d} = \frac{27 \cdot 83}{0 \cdot 9571} = 29 \cdot 08 \text{ ml} = 0 \cdot 02908 \text{ litre}$$

$\therefore$ Change in volume on mixing $= 30 \cdot 00 - 29 \cdot 08 = 0 \cdot 92$ ml

$\therefore$ % Change in total volume $= \frac{0 \cdot 92}{30} \times 100 = \mathbf{3 \cdot 1\% \text{ contraction}}$

Molar concentration of C_2H_5OH in solution $= \frac{\text{Moles of ethanol}}{\text{Volume of solution}}$

$$\text{Moles of ethanol} = \frac{7 \cdot 893 \text{ g}}{46 \cdot 07 \text{ g/mol.}} = 0 \cdot 1713 \text{ mol.}$$

$$\text{Molarity} = \frac{0 \cdot 1713 \text{ mol}}{0 \cdot 02908 \text{ litre}} = \mathbf{5 \cdot 891 \text{ M}}$$

Example 24. *How many kilograms of wet NaOH containing 12% water are required to prepare 60 litres of 0·50 N solution ?*

Solution. One litre of 0·50 N NaOH contains $= 0 \cdot 50 \times 40$ g $= 20$ g $= 0 \cdot 020$ kg

$\therefore$ 60 litres of 0·50 N NaOH contain $= 0 \cdot 020 \times 60$ kg

$= 1 \cdot 20$ kg NaOH

Since the given NaOH contains 12% water, the amount of pure NaOH in 100 kg of the given NaOH $= 100 - 12 = 88$ kg.

Thus 88 kg of pure NaOH is present in 100 kg wet NaOH

$\therefore$ 1·20 kg of pure NaOH is present in $= \frac{100}{88} \times 1 \cdot 20 = \mathbf{1 \cdot 36 \text{ kg wet NaOH}}$

Example 25. *Upon heating a litre of a N/2 HCl solution, 2·675 g hydrogen chloride is lost and the volume of the solution shrinks to 750 ml. Calculate (i) the normality of the resultant solution, and (ii) the number of milliequivaletns of HCl in 100 ml of the original solution.*

Solution. Eq. wt. of HCl = Mol. wt. of HCl = 36·5

Wt. of HCl in 1 litre of N/2 HCl $= 36 \cdot 5 \times 1/2$ g $= 18 \cdot 25$ g

Wt. of HCl lost on heating $= 2 \cdot 675$ g

$\therefore$ Wt. of HCl left in solution $= 18 \cdot 25 - 2 \cdot 675$ g $= 15 \cdot 575$ g

36·5 g of HCl = 1 geq.

$$15 \cdot 575 \text{ g of HCl} = \frac{1}{36 \cdot 5} \times 15 \cdot 575 \text{ geq.}$$

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Vol. of the resultant solution = 750 ml

$$= \frac{750}{1000} \text{ litre} = 3/4 \text{ litre}$$

$$\therefore \quad \text{Normality of solution} = \frac{\text{geq. of solute}}{\text{Vol. of solution in litres}} = \frac{15 \cdot 575/36 \cdot 5}{3/4} = \mathbf{0 \cdot 57}$$

Equivalents of HCl in 1000 ml of the original solution = 1/2

$\therefore$ Millieq. of HCl in 1000 ml = 1/2 × 1000 = 500

$$\therefore \text{ Millieq. of HCl in 100 ml} = \frac{500 \times 100}{1000} = \mathbf{50}$$

Example 26. *A solution of NaOH is prepared by dissolving 2 gm of NaOH in 100 ml of water. If specific gravity of solution is 1·96, calculate normality, molarity, molality and percentage of NaOH in the solution. Also calculate the mole fractions of NaOH and water.*

Solution. We know that,

Mol. wt. of NaOH = Eq. wt. of NaOH = 40

$$\text{Normality} = \text{Molarity} = \frac{2}{40} \times \frac{1000}{100} = \mathbf{0 \cdot 5}$$

Wt. of solution = Volume × Sp. gravity

= 100 × 1·96 = 196 gm

$\therefore$ Wt. of water = 196 − 2 = 194 gm

$$\text{Molality} = \frac{\text{Wt. of solute}}{\text{Mol. wt. of solute}} \times \frac{1000}{\text{Wt. of solvent}}$$

$$= \frac{2}{40} \times \frac{1000}{194} = \mathbf{0 \cdot 26}$$

$$\% \text{ of NaOH} = \frac{\text{Wt. of NaOH} \times 100}{\text{Wt. of solution}}$$

$$= \frac{2 \times 100}{196} = \mathbf{1 \cdot 02\%}$$

Moles of NaOH = 2/40 = 0·05

$$\text{Moles of water} = \frac{194}{18} = 10 \cdot 8$$

$\therefore$ Total number of moles = 0·05 + 10·8 = 10·85

$$\text{Mole fraction of NaOH} = \frac{\text{Moles of NaOH}}{\text{Total number of moles}} = \frac{0 \cdot 05}{10 \cdot 85} = \mathbf{0 \cdot 0046}$$

$\therefore$ Mole fraction of water = 1 − 0·0046 = **0·9954**

Example 27. *An aqueous solution prepared by dissolving 90 g of a monobasic acid (molecular weight = 60) in 1000 ml of solution has a density of 0·99. Calculate the molality, molarity, normality and mole fraction of the solute in this solution.*

Solution. Amount of solute = 90·00 g/litre

Mol. wt. of the solute = 60

$$\therefore \text{ No. of moles } (n_1) \text{ of solute} = \frac{90}{60} = 1 \cdot 5 \text{ moles}$$

$\therefore$ **Molarity of the solution = 1·5 M**

$$\text{Eq. wt. of the solute} = \frac{60}{1} = 60 \qquad (\because \text{ Acidity} = 1)$$

$$\therefore \text{ No. of gm equivalents of solute} = \frac{90}{60} = 1 \cdot 5$$

Hence, normality of the solution = No. of geq/litre = **1·5 N**

Now volume of the solution = 1000 ml

Density of the solution = 0·99

∴ Wt. of solution = 1000 × 0·99 = 990 gm

∴ Wt. of solvent (water) = 990 − 90 gm = 900 gm

No. of moles of water (n_2) in 900 gm of water = $\frac{900}{18}$ = 50

∴ **Mole fraction of the solute** = $\frac{1 \cdot 5}{50 + 1 \cdot 5}$ = **0·0291**

Finally, 900 gm of water contain = 90 gm of solute

∴ 1000 gm of water contain = $\frac{90 \times 1000}{900}$ = 100 gm of solute

Hence no. of moles of solute in 100 gm = $\frac{100}{60}$ = 1·66 moles

∴ **Molality of the solution = 1·66 m**

Example 28. *A bottle of commercial sulphuric acid (density 1·787 gm/ml) is labelled as 86 percent by weight. What is the molarity of the acid ? What volume of the acid has to be used to make 1 litre of 0·2 M H_2SO_4 ?*

Solution. *Calculation of molarity of acid.*

$$\text{Molarity} = \text{No. of moles of solute per litre of the solution}$$

$$= \frac{\text{Wt. of } H_2SO_4 \text{ in one litre of solution}}{\text{Mol. wt. of } H_2SO_4}$$

Wt. of given H_2SO_4 in litre = 1000 × density × strength

$$= 1000 \times 1 \cdot 787 \times \frac{86}{100} = 1536 \cdot 82 \text{ gm}$$

Mol. wt. of H_2SO_4 = 2 × 1 + 32 + 4 × 16 = 98

∴ Molarity of H_2SO_4 = $\frac{1536 \cdot 82}{98}$ = **15·68**

Calculation of the volume of acid for making 1 litre of 0·2 M H_2SO_4.

Applying the formula, $M_1V_1 = M_2V_2$

$$15 \cdot 68 \times V_1 = 0 \cdot 2 \times 1000$$

∴ $V_1 = \frac{0 \cdot 2 \times 1000}{15 \cdot 68}$ ml = **12·75 ml**

Example 29. *A 100 ml solution of sodium carbonate is prepared by dissolving 8·653 g of the salt in water. The density of the solution is 1·0816 g per ml. What are the molality and molarity of the solution ?* [At. wt. of Na = 23, C = 12 and O = 16]

Solution. Wt. of Na_2CO_3 dissolved = 8·653 g

Vol. of the solution = 100 ml

Density of the solution = 1·0816 g/ml

Calculation of molality

Wt. of solution = volume × density

= 100 × 1·0816 = 108·16 g

Since wt. of salt is 8·653 g; Wt. of H_2O = 108·16 − 8·653 = 99·507 g

Mol. wt. of Na_2CO_3 = 46 + 12 + 48 = 106

∴ No. of moles of Na_2CO_3 = $\frac{8 \cdot 653}{106}$ = 0·0816 moles

Thus 99·507 g of solvent contain 0·0816 moles of solute

1000 g solvent contain = $\frac{0 \cdot 0816}{99 \cdot 507} \times 1000$ = 0·820 mole

Hence molality of the solution = **0·820 m**

Calculation of molarity

8·653 gm of Na_2CO_3 = 0·0816 moles of Na_2CO_3

Thus 100 ml of solution contain solute = 0·0816 moles

$$\therefore \quad 1000 \text{ ml of solution contain solute} = \frac{0{\cdot}0816}{100} \times 1000 = 0{\cdot}816 \text{ moles}$$

Hence molarity of the solution = **0·816 M**

Example 30. *Following solutions were prepared in water*

NaOH 12 gm per 250 ml

H_2SO_4 9·8 gm per 250 ml

Calculate the number of moles of the solute, molarity of the solution, gram equivalents in solution and normality of the solution.

Solution.

First case. Wt. of NaOH dissolved= 12 gm

Volume of solution = 250 ml

(i) *Calculation of number of moles of the solute*

Mol. wt. of NaOH = 40

$$\therefore \text{ No. of moles of NaOH} = \frac{\text{Wt. in gm}}{\text{Mol. wt}} = \frac{12}{40} = 0{\cdot}3$$

(ii) *Calculation of molarity*

250 ml of the solution contain NaOH = 0·3 moles

$$\therefore \text{ 1000 ml of the solution contain NaOH} = \frac{0{\cdot}3}{250} \times 1000 = 1{\cdot}2 \text{ moles}$$

Hence molarity of the solution = **1·2 M**

(iii) *Calculation of number of gm equivalents*

$$\text{Eq. wt. of NaOH} = \frac{\text{Mol. wt of NaOH}}{\text{Acidity of NaOH}} = \frac{40}{1} = 40$$

$$\therefore \quad \text{Number of gm equivalent of NaOH} = \frac{\text{Weight in gm}}{\text{Eq. wt.}} = \frac{12}{40} = 0{\cdot}3$$

(iv) *Calculation of normality*

250 ml of solution contain NaOH = 0·3 gm equivalents

$$\therefore \text{ 1000 ml of solution contain NaOH} = \frac{0{\cdot}3}{250} \times 1000 = 1{\cdot}2 \text{ geq}$$

Hence normality of solution = **1·2 N**

Second case : Wt. of H_2SO_4 dissolved = 9·8 gm

Volume of solution = 250 ml

(i) *Calculation of number of moles of the solute*

Mol. wt. of H_2SO_4 = 98

$$\therefore \text{ No. of moles of } H_2SO_4 = \frac{\text{Wt. in gm}}{\text{Mol. wt.}} = \frac{9{\cdot}8}{98} = 0{\cdot}1$$

(ii) *Calculation of molarity*

250 ml of the solution contain H_2SO_4 = 0·1 mole

$$\therefore \text{ 1000 ml of the solution contain } H_2SO_4 = \frac{0{\cdot}1}{250} \times 1000 = 0{\cdot}4 \text{ mole}$$

Hence molarity of the solution = **0·4 M**

(iii) *Calculation of number of gm equivalents*

$$\text{Eq. wt. of } H_2SO_4 = \frac{\text{Mol. wt. of } H_2SO_4}{\text{Basicity of } H_2SO_4} = \frac{98}{2} = 49$$

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No. of gm equivalents of H_2SO_4 = $\frac{\text{Wt. in gm}}{\text{Eq. wt.}} = \frac{9.8}{49} = 0.2$

(ii) *Calculation of normality*

250 ml of the solution contain H_2SO_4 = 0·2 gm equivalent

1000 ml of the solution contain H_2SO_4 = $\frac{0.2}{250} \times 1000$ = 0·8 gm equivalent

Hence normality of solution = **0·8 N**

Example 31. *The density of a 3 M sodium thiosulphate solution is 1·25 g ml^{-1}. Calculate (i) the % weight of sodium thiosulphate, (ii) the mole fraction of sodium thiosulphate and (iii) the molalities of Na^+ and $S_2O_3^{2-}$ ions.*

Solution. *(i) Calculation of % by weight of $Na_2S_2O_3$* **(I.I.T. 1985)**

Density of 3 M $Na_2S_2O_3$ = 1·25 g/ml solution = 1·25 g/ml

Wt. of 1000 ml of $Na_2S_2O_3$ solution = $\frac{1.25 \times 1000}{1}$ = 1250 g

Since 1 mole of $Na_2S_2O_3$ = 23 × 2 + 32 × 2 + 16 × 3 = 158 g

Wt. of $Na_2S_2O_3$ in 1000 ml of 3M solution = 3 × 158 = 474 g

1250 g of solution contain = 474 g $Na_2S_2O_3$

100 g of solution contain = $\frac{474 \times 100}{1250}$ = 37·92 g

∴ % by weight of sod. thiosulphate = **37·92%**

(ii) *Calculation of mole fraction of $Na_2S_2O_3$*

100 g of the solution contain = 37·92 g $Na_2S_2O_3$

100 g of the solution contain = 100 − 37·92 g water = 62·08 g water

No. of moles of $Na_2S_2O_3$ in 37·92 g of $Na_2S_2O_3$ = $\frac{37.92}{158}$ = 0·24 moles

Similarly,

No. of moles of H_2O in 62·08 g of water = $\frac{62.08}{18}$ = 3·45 moles

∴ Total No. of moles = 0·24 + 3·45 = 3·69 moles

∴ Mole fraction of $Na_2S_2O_3$ = $\frac{0.24}{3.69}$ = **0·065**

(iii) *Calculation of molalities of Na^+ and $S_2O_3^{2-}$ ions*

62·08 g of water contain = 0·24 moles of $Na_2S_2O_3$

1000 g of water contain = $\frac{0.24 \times 1000}{62.08}$ moles

= 3·865 moles of $Na_2S_2O_3$

Since 1 mole of $Na_2S_2O_3$ contain 2 moles of Na^+ and 1 mole of $S_2O_3^{2-}$

∴ Molality of Na^+ = 2 × 3·865 = **7·730**

Similarly, molality of $S_2O_3^{2-}$ = 1 × 3·865 = **3·865**

7·3. Colligative Properties.

Certain properties of dilute solutions containing non-volatile solute do not depend upon the nature of the solute dissolved but depend only upon concentration i.e. number of particles of the solute present in*

* It is important to note that the statement of colligative properties is strictly true only for dilute solutions which behave as nearly ideal solutions. Thus, these properties are termed as colligative properties of dilute solutions.

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Assignment

SECTION - A

Objective Type Questions

(Mole Concept)

1. The total number of electrons in 4.2 g of N^{3-} ion is (N_A is the Avogadro's number)

(1) 2.1 N_A (2) 4.2 N_A
(3) 3 N_A (4) 3.2 N_A

2. Suppose that A and B form the compounds B_2A_3 and B_2A. If 0.05 mole of B_2A_3 weighs 9 g and 0.1 mole of B_2A weighs 10 g, the atomic weight of A and B respectively are

(1) 30 and 40 (2) 40 and 30
(3) 20 and 5 (4) 15 and 20

3. Number of Fe atoms in 100 g Haemoglobin if it contains 0.33% Fe. (Atomic mass of Fe = 56)

(1) 0.035×10^{23} (2) 35
(3) 3.5×10^{23} (4) 7×10^{8}

4. The number of electrons in 1.6 g of CH_4 is approximately

(1) 25×10^{24} (2) 1.5×10^{24}
(3) 6×10^{23} (4) 3.0×10^{24}

5. Specific volume of cylindrical virus particle is 6.02×10^{-2} cc/gm whose radius and length are 7 Å and 10 Å respectively. If $N_A = 6.02 \times 10^{23}$, find molecular weight of virus.

(1) 15.4 kg/mol (2) 1.54×10^{4} kg/mol
(3) 3.08×10^{4} kg/mol (4) 3.08×10^{3} kg/mol

6. The number of mole of nitrogen in one litre of air containing 10% nitrogen by volume, under standard conditions, is

(1) 0.03 mole (2) 2.10 moles
(3) 0.186 mole (4) 4.46×10^{-3} mole

7. Number of significant figures in 6.62×10^{-34}.

(1) Two (2) Three
(3) Four (4) One

(Stoichiometry & Stoichiometric Calculations)

8. Liquid benzene (C_6H_6) burns in oxygen according to $2C_6H_6(l) + 15O_2(g) \longrightarrow 12CO_2(g) + 6H_2O(g)$

How many litres of O_2 at STP are needed to complete the combustion of 39 g of liquid benzene?

(1) 74 L (2) 11.2 L
(3) 22.4 L (4) 84 L

9. 1 mol of $KClO_3$ is thermally decomposed and excess of aluminium is burnt in the gaseous product. How many moles of Al_2O_3 are formed?

(1) 1 (2) 2
(3) 1.5 (4) 3

10. The amount of zinc required to produce 1.12 ml of H_2 at STP on treatment with dilute HCl will be

(1) 65 g (2) 0.065 g
(3) 32.5×10^{-4} g (4) 6.5 g

11. Volume of CO_2 obtained at STP by the complete decomposition of 9.85 g Na_2CO_3 is

(1) 2.24 litre (2) Zero
(3) 0.85 litre (4) 0.56 litre

12. One litre of CO_2 is passed through red hot coke. The volume becomes 1.4 litres at same temperature and pressure. The composition of products is

(1) 0.8 litre of CO_2 and 0.6 litre of CO
(2) 0.7 litre of CO_2 and 0.7 litre of CO
(3) 0.6 litre of CO_2 and 0.8 litre of CO
(4) 0.4 litre of CO_2 and 1.0 litre of CO

13. An organic compound containing C and H gave the following analysis C = 40%, H = 6.7%. Its empirical formula would be

(1) CH_4 (2) CH_2O
(3) $C_2H_4O_2$ (4) C_2H_4

14. How many litre of oxygen at STP is required to burn 60 g C_2H_6?

(1) 22.4 L (2) 11.2 L
(3) 22.4 × 7 L (4) 8.5 L

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15. For the formation of 3.65 g of HCl gas, what volume of hydrogen gas and chlorine gas are required at NTP conditions?

(1) 1 L, 1 L (2) 1.12 L, 2.24 L
(3) 3.65 L, 1.83 L (4) 1.12 L, 1.12 L

16. The crystalline salt $Na_2SO_4.xH_2O$ on heating loses 55.9% of its mass and becomes anhydrous. The formula of crystalline salt is

(1) $Na_2SO_4.5H_2O$ (2) $Na_2SO_4.7H_2O$
(3) $Na_2SO_4.2H_2O$ (4) $Na_2SO_4.10H_2O$

17. A certain amount of a metal whose equivalent mass is 28 displaces 0.7 L of H_2 at S.T.P. from an acid hence mass of the element is

(1) 1.75 g (2) 0.875 g
(3) 3.50 g (4) 7.00 g

(Reactions in Solutions)

18. When 100 ml of $\frac{M}{10}$ H_2SO_4 is mixed with 500 ml of $\frac{M}{10}$ NaOH then nature of resulting solution and normality of excess of reactant left is

(1) Acidic, $\frac{N}{5}$ (2) Basic, $\frac{N}{5}$
(3) Basic, $\frac{N}{20}$ (4) Acidic, $\frac{N}{10}$

19. Mole fraction of solvent in aqueous solution of NaOH having molality of 3 is

(1) 0.3 (2) 0.05
(3) 0.7 (4) 0.95

20. Concentrated aqueous sulphuric acid is 98% H_2SO_4 by mass and has a density of 1.80 gmL^{-1}. Volume of acid required to make one litre of 0.1 M H_2SO_4 solution is

(1) 16.65 mL (2) 22.20 mL
(3) 5.55 mL (4) 11.10 mL

21. Ammonia gas is passed into water, yielding a solution of density 0.93 g/cm^3 and containing 18.6% NH_3 by weight. The mass of NH_3 per cc of the solution is

(1) 0.17 g/cm^3 (2) 0.34 g/cm^3
(3) 0.51 g/cm^3 (4) 0.68 g/cm^3

22. 6.025×10^{20} molecules of acetic acid are present in 500 ml of its solution. The concentration of solution is

(1) 0.002 M (2) 10.2 M
(3) 0.012 M (4) 0.001 M

(Equivalent Mass)

23. 74.5 g of metal chloride contains 35.5 g Cl. The equivalent weight of metal is

(1) 74.5 (2) 39
(3) 35.5 (4) 7.45

24. Equivalent weight of crystalline oxalic acid is

(1) 90 (2) 63
(3) 53 (4) 45

25. Equivalent mass of H_3PO_4 (Molar mass = M) in the given reaction, $H_3PO_4 + Ca(OH)_2 \rightarrow CaHPO_4 + 2H_2O$ is

(1) $\frac{M}{1}$ (2) $\frac{M}{2}$
(3) 2 M (4) $\frac{M}{4}$

26. Equivalent mass of a metal is 12. Hence, equivalent mass of its oxide is

(1) 24 (2) 28
(3) 20 (4) 34

27. 4 g of a metal oxide contains 1.6 g oxygen, the equivalent mass of the metal is

(1) 3.2 (2) 24
(3) 12 (4) 20

SECTION - B

Previous Years Questions

1. The density of 2 M aqueous solution of NaOH is 1.2 g/cm^3. The molality of the solution is [Given that molecular mass of NaOH = 40 g mol^{-1}] **[NEET-2019 (Odisha)]**

(1) 1.32 m (2) 1.20 m
(3) 1.56 m (4) 1.67 m

2. The number of moles of hydrogen molecules required to produce 20 moles of ammonia through Haber's process is : **[NEET-2019]**

(1) 10
(2) 20
(3) 30
(4) 40

3. A mixture of 2.3 g formic acid and 4.5 g oxalic acid is treated with conc. H_2SO_4. The evolved gaseous mixture is passed through KOH pellets. Weight (in g) of the remaining product at STP will be **[NEET-2018]**
(1) 1.4
(2) 3.0
(3) 4.4
(4) 2.8

4. In which case is number of molecules of water maximum? **[NEET-2018]**
(1) 18 mL of water
(2) 0.18 g of water
(3) 10^{-3} mol of water
(4) 0.00224 L of water vapours at 1 atm and 273 K

5. Suppose the elements X and Y combine to form two compounds XY_2 and X_3Y_2. When 0.1 mole of XY_2 weighs 10 g and 0.05 mole of X_3Y_2 weighs 9 g, the atomic weights of X and Y are **[NEET-Phase-2-2016]**
(1) 40, 30
(2) 60, 40
(3) 20, 30
(4) 30, 20

6. What is the mass of the precipitate formed when 50 mL of 16.9% (w/v) solution of $AgNO_3$ is mixed with 50 mL of 5.8% (w/v) NaCl solution? (Ag = 107.8, N = 14, O = 16, Na = 23, Cl = 35.5) **[Re-AIPMT-2015]**
(1) 7 g
(2) 14 g
(3) 28 g
(4) 3.5 g

7. If Avogadro number N_A, is changed from 6.022×10^{23} mol^{-1} to 6.022×10^{20} mol^{-1}, this would change **[Re-AIPMT-2015]**
(1) The ratio of chemical species to each other in a balanced equation
(2) The ratio of elements to each other in a compound
(3) The definition of mass in units of grams
(4) The mass of one mole of carbon

8. 20.0 g of a magnesium carbonate sample decomposes on heating to give carbon dioxide and 8.0 g magnesium oxide. What will be the percentage purity of magnesium carbonate in the sample? (At. wt. : Mg = 24) **[Re-AIPMT-2015]**
(1) 60
(2) 84
(3) 75
(4) 96

9. A mixture of gases contains H_2 and O_2 gases in the ratio of 1 : 4 (w/w). What is the molar ratio of the two gases in the mixture? **[AIPMT-2015]**
(1) 2 : 1
(2) 1 : 4
(3) 4 : 1
(4) 16 : 1

10. 1.0 g of magnesium is burnt with 0.56 g O_2 in a closed vessel. Which reactant is left in excess and how much? (At. wt. Mg = 24; O = 16) **[AIPMT-2014]**
(1) Mg, 0.16 g
(2) O_2, 0.16 g
(3) Mg, 0.44 g
(4) O_2, 0.28 g

11. When 22.4 litres of H_2 (g) is mixed with 11.2 litres of Cl_2(g), each at S.T.P, the moles of HCl(g) formed is equal to **[AIPMT-2014]**
(1) 1 mol of HCl (g)
(2) 2 mol of HCl (g)
(3) 0.5 mol of HCl (g)
(4) 1.5 mol of HCl (g)

12. 6.02×10^{20} molecules of urea are present in 100 mL of its solution. The concentration of solution is **[NEET-2013]**
(1) 0.01 M
(2) 0.001 M
(3) 0.1 M
(4) 0.02 M

13. How many grams of concentrated nitric acid solution should be used to prepare 250 mL of 2 M HNO_3? The concentrated acid is 70% (w/w) HNO_3. **[NEET-2013]**
(1) 90.0 g conc. HNO_3
(2) 70.0 g conc. HNO_3
(3) 54.0 g conc. HNO_3
(4) 45.0 g conc. HNO_3

14. Mole fraction of the solute in a 1.00 molal aqueous solution is **[AIPMT (Prelims)-2011]**
(1) 1.7700
(2) 0.1770
(3) 0.0177
(4) 0.0344

15. Which has the maximum number of molecules among the following? **[AIPMT (Mains)-2011]**
(1) 8 g H_2
(2) 64 g SO_2
(3) 44 g CO_2
(4) 48 g O_3

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16. The number of atoms in 0.1 mol of a triatomic gas is (N_A=6.02 × 10^{23} mol^{-1}) **[AIPMT (Prelims)-2010]**
(1) 6.026 × 10^{22} (2) 1.806 × 10^{23}
(3) 3.600 × 10^{23} (4) 1.800 × 10^{22}

17. 25.3 g of sodium carbonate, Na_2CO_3 is dissolved in enough water to make 250 mL of solution. If sodium carbonate dissociates completely, molar concentration of sodium ion, Na^+ and carbonate ions, CO_3^{2-} are respectively (Molar mass of Na_2CO_3 = 106 g mol^{-1}) **[AIPMT (Prelims)-2010]**
(1) 0.955 M and 1.910 M
(2) 1.910 M and 0.955 M
(3) 1.90 M and 1.910 M
(4) 0.477 M and 0.477 M

18. 10 g of hydrogen and 64 g of oxygen were filled in a steel vessel and exploded. Amount of water produced in this reaction will be **[AIPMT (Prelims)-2009]**
(1) 3 mol (2) 4 mol
(3) 1 mol (4) 2 mol

19. How many moles of lead (II) chloride will be formed from a reaction between 6.5g of PbO and 3.2 g of HCl? **[AIPMT (Prelims)-2008]**
(1) 0.029 (2) 0.044
(3) 0.333 (4) 0.011

20. Volume occupied by one molecule of water (density = 1 g cm^{-3}) is **[AIPMT (Prelims)-2008]**
(1) 5.5 × 10^{-23} cm^3
(2) 9.0 × 10^{-23} cm^3
(3) 6.023 × 10^{-23} cm^3
(4) 3.0 × 10^{-23} cm^3

21. What volume of oxygen gas (O_2) measured at 0°C and 1 atm, is needed to burn completely 1 L of propane gas (C_3H_8) measured under the same conditions? **[AIPMT ((Prelims)-2008]**
(1) 10 L (2) 7 L
(3) 6 L (4) 5 L

22. An organic compound contains carbon, hydrogen and oxygen. Its elemental analysis gave C, 38.71% and H, 9.67%. The empirical formula of the compound would be **[AIPMT (Prelims)-2008]**
(1) CH_4O (2) CH_3O
(3) CH_2O (4) CHO

23. An element, X has the following composition; ^{200}X:90%; ^{199}X:8.0%; ^{202}X:2.0%
The weighted average atomic mass of the naturally occurring element X is closest to **[AIPMT (Prelims)-2007]**
(1) 199 amu
(2) 200 amu
(3) 201 amu
(4) 202 amu

24. Concentrated aqueous sulphuric acid is 98% H_2SO_4 by mass and has a density of 1.80 g mL^{-1}. Volume of acid required to make one litre of 0.1 M H_2SO_4 is **[AIPMT (Prelims)-2007]**
(1) 5.55 mL
(2) 11.10 mL
(3) 16.65 mL
(4) 22.20 mL

Questions asked prior to Medical Ent. Exams. 2005

25. How many grams of CH_3OH should be added to water to prepare 150 ml solution of 2 M CH_3OH?
(1) 9.6 × 10^3 (2) 2.4 × 10^3
(3) 9.6 (4) 2.4

26. The total number of valence electrons in 4.2 g of N_3^- ion is (N_A is the Avogadro's number)
(1) 2.1 N_A (2) 4.2 N_A
(3) 1.6 N_A (4) 3.2 N_A

27. The number of mole of oxygen in one litre of air containing 21% oxygen by volume, under standard conditions, is
(1) 0.0093 mole (2) 2.10 moles
(3) 0.186 mole (4) 0.21 mole

28. The amount of zinc required to produce 224 ml of H_2 at STP on treatment with dilute H_2SO_4 will be (Zn = 65)
(1) 65 g (2) 0.065 g
(3) 0.65 g (4) 6.5 g

29. Given the numbers : 161 cm, 0.161 cm, 0.0161 cm. The number of significant figures for the three numbers is
(1) 3, 3 and 4 respectively
(2) 3, 4 and 4 respectively
(3) 3, 4 and 5 respectively
(4) 3, 3 and 3 respectively

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30. Change in volume when 100 mL PH_3 decomposed to solid phosphorus and H_2 gas.

(1) Increase in 50 mL (2) Decrease in 50 mL
(3) Increase in 150 mL (4) Decrease in 200 mL

31. In the reaction,

$$4NH_3(g) + 5O_2(g) \rightarrow 4NO(g) + 6H_2O(l)$$

when 1 mole of ammonia and 1 mole of O_2 are made to react to completion

(1) All the oxygen will be consumed
(2) 1.0 mole of NO will be produced
(3) 1.0 mole of H_2O is produced
(4) All the ammonia will be consumed

32. An organic compound containing C, H and N gave the following analysis C = 40%, H = 13.33%, N = 46.67%. Its empirical formula would be

(1) CH_4N (2) CH_5N
(3) $C_2H_7N_2$ (4) C_2H_7N

33. How many g of dibasic acid (mol. weight 200) should be present in 100 ml. of the aqueous solution to give strength of 0.1 N?

(1) 10 g (2) 2 g
(3) 1 g (4) 20 g

34. The number of atoms in 4.25 g of NH_3 is approximately

(1) 4×10^{23} (2) 2×20^{23}
(3) 1×10^{23} (4) 6×10^{23}

35. Volume of CO_2 obtained at STP by the complete decomposition of 9.85 gm $BaCO_3$ is (Mol. wt. of $BaCO_3$ = 197)

(1) 2.24 litre (2) 1.12 litre
(3) 0.85 litre (4) 0.56 litre

36. Percentage of Se in peroxidase anhydrous enzyme is 0.5% by weight (at. wt. = 78.4) then minimum molecular weight of peroxidase anhydrous enzyme is

(1) 1.568×10^4 (2) 1.568×10^3
(3) 15.68 (4) 2.136×10^4

37. 2.5 litre of 1 M NaOH solution mixed with another 3 litre of 0.5 M NaOH solution. Then find out molarity of resultant solution.

(1) 0.80 M (2) 1.0 M
(3) 0.73 M (4) 0.50 M

38. Which has maximum molecules?

(1) 7 gm N_2 (2) 2 gm H_2
(3) 16 gm NO_2 (4) 16 gm O_2

39. In Haber process 30 litres of dihydrogen and 30 litres of dinitrogen were taken for reaction which yielded only 50% of the expected product. What will be the composition of gaseous mixture under the aforesaid condition in the end?

(1) 20 litres ammonia, 20 litres nitrogen, 20 litres hydrogen
(2) 10 litres ammonia, 25 litres nitrogen, 15 litres hydrogen
(3) 20 litres ammonia, 10 litres nitrogen, 30 litres hydrogen
(4) 20 litres ammonia, 25 litres nitrogen, 15 litres hydrogen

40. The maximum number of molecules is present in

(1) 15 L of water at STP
(2) 15 L of H_2O gas at STP
(3) 15 g of ice
(4) Same in all

41. Concentrated aqueous sulphuric acid is 98% H_2SO_4 (w/v) and has a density of 1.80 gmL^{-1}. Molarity of solution

(1) 1 M (2) 1.8 M
(3) 10 M (4) 1.5 M

42. An element, X has the following isotopic composition ^{56}X : 90% ^{57}X : 8% ^{59}X : 2.0%. The weighted average atomic mass of the naturally occurring element X is closest to

(1) 56.14 amu (2) 56.8 amu
(3) 60 amu (4) 55 amu

43. 10 g of hydrogen and 64 g of oxygen were filled in a steel vessel and exploded. Volume of gaseous product after reaction

(1) 1 × 22.4 L (2) 2 × 22.4 L
(3) 3 × 22.4 L (4) 4 × 22.4 L

44. What is the $[OH^-]$ in the final solution prepared by mixing 20.0 mL of 0.050 M HCl with 30.0 mL of 0.10 M $Ba(OH)_2$?

(1) 0.12 M (2) 0.10 M
(3) 0.40 M (4) 0.0050 M

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45. The number of atoms in 0.1 mol of a triatomic gas is ($N_A = 6.02 \times 10^{23}\ mol^{-1}$)

(1) 1.800×10^{22} (2) 6.026×10^{22}

(3) 1.806×10^{23} (4) 3.600×10^{23}

46. The total number of electrons in 2.0 g of D_2O to that in 1.8 g of H_2O

(1) Double (2) Same

(3) Triple (4) One fourth

47. From 200 mg of CO_2 when *x* molecules are removed, 2.89×10^{-3} moles of CO_2 are left. *x* will be

(1) 10^{20} molecules

(2) 10^{10} molecules

(3) 21 molecules

(4) 10^{21} molecules

48. If the weight of metal oxide is *x* g containing *y* g of oxygen, the equivalent weight of metal will be

(1) $E = \frac{8x}{y}$ (2) $E = \frac{8(y-x)}{x}$

(3) $E = \frac{y}{8}$ (4) $E = \frac{8(x-y)}{y}$

49. The number of significant figures in 2.653×10^4 is

(1) 8 (2) 4

(3) 7 (4) 1

50. Mole fraction of solute in aqueous solution of 30% NaOH is

(1) 0.16 (2) 0.05

(3) 0.25 (4) 0.95

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