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CHEMISTRY

11th Standard

VOLUME - I & II

Based on the Updated New Textbook

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  - (iv) Assertion & Reason
  - (v) Choosing the correct Statement
  - (vi) Choosing the Incorrect Statement
- Govt. Model Question Paper-2018 ***[Govt. MQP. 2018]***, First Mid-Term Test (2018) ***[First Mid. 2018]***, Quarterly Exam - 2018 & 2019 ***[QY-2018 & 2019]***, Half Yearly Exam - 2018 & 2019 ***[HY-2018 & 2019]***, March - 2019 ***[Mar-2019]***, June - 2019 ***[June-2019]*** and Govt. Suppl. Exam. September - 2020 & 2021 ***[Sep-2020 & Sep-2021]*** questions are incorporated in the appropriate sections.
- Govt. Supply. Exam. **September 2021** question paper is given with answers.

SURA PUBLICATIONS
Chennai

2022-23 Edition

ISBN : 978-93-92559-24-2
Code No : SG 266

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Published by :
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1620, 'J' Block, 16th Main Road, Anna Nagar,
Chennai - 600 040.
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NOTE FROM PUBLISHER

It gives me great pride and pleasure in bringing to you **Sura's Chemistry** guide Vol. I & II for **11th Standard**. A deep understanding of the text and exercises is rudimentary to have an insight into the subject. The students have to carefully understand the topics and exercises.

Sura's Chemistry 11th Standard Guide encompasses all the requirements of the students to comprehend the text and the evaluation of the textbook.

It will be a teaching companion to teachers and a learning companion to students.

- Chapter Snapshot, Concept Map, Formulae to Remember, Must know Definitions are given in almost each chapter.
- Exhaustive Additional MCQs, SA, LA questions with Answers are given in each chapter. Solved numerical problems are given wherever necessary.
- These features will help students practice and learn effectively all the sections of the textbook.

In order to learn effectively, I advise students to learn the subject sectionwise and practice the exercises given.

Though these salient features are available in our Sura's Chemistry Guide 11th Standard, I cannot negate the indispensable role of the teachers in assisting the student to understand the subject thoroughly.

I sincerely believe this guide satisfies the needs of the students and bolsters the teaching methodologies of the teachers.

I pray the almighty to bless the students for consummate success in their examinations.

Subash Raj, B.E., M.S.
- Publisher
Sura Publications

All the Best

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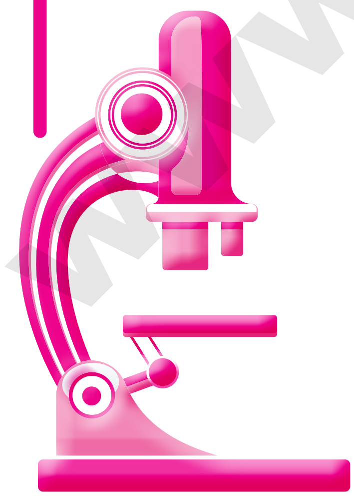
VOLUME - II

CHEMISTRY

Volume I



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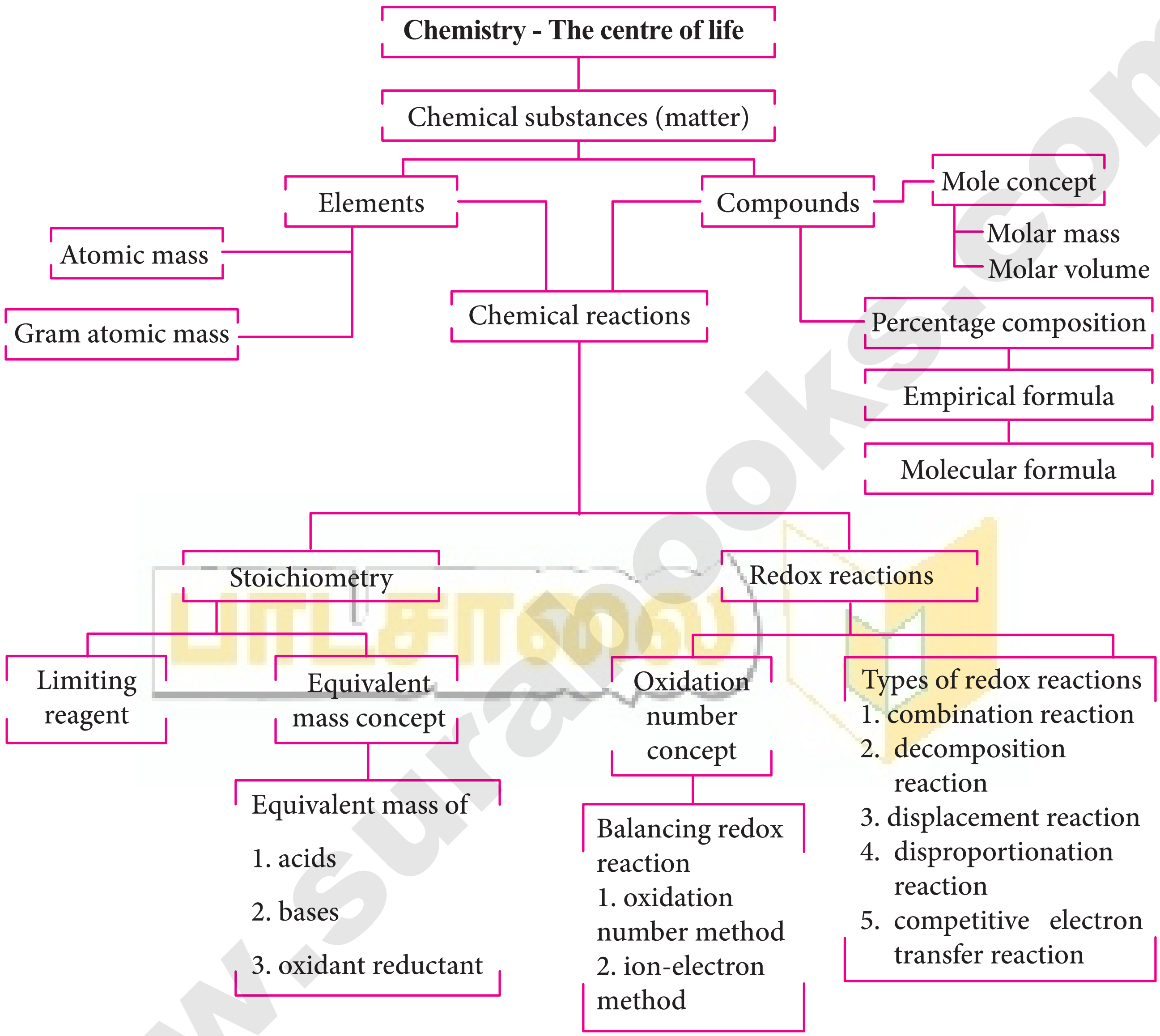
CHAPTER SNAPSHOT

CONCEPT MAP


Chemistry - The centre of life
Chemical substances (matter)
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Molar volume
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FORMULAE TO REMEMBER

- $\text{Atomic mass} = \dfrac{\text{Mass of an atom}}{\left(\frac{1}{12}\right) \times \text{mass of carbon atom } ^{12}C}$
- Molecular Mass = n × Vapour Density
- $\text{Molar mass} = \dfrac{\text{Mass}}{\text{Mole}}$
- Molecular Formula = n × Empirical Formula
- $\text{Mass \% of an element} = \dfrac{\text{Mass of that element in the compound}}{\text{Molar mass of the compound}} \times 100$
- $\text{Equivalent Mass of Acid} = \dfrac{\text{Molar mass of the Acid}}{\text{Basicity of Acid}}$
- $\text{Equivalent Mass of Base} = \dfrac{\text{Molar mass of the Base}}{\text{Acidity of Base}}$
- $\text{Molarity} = \dfrac{\text{No. of moles of solute}}{\text{Volume of solution in litres}}$
- $\text{Molality} = \dfrac{\text{No. of moles of solute}}{\text{Mass of solvent in Kg}}$
- $\text{Normality} = \dfrac{\text{No. of gram equivalents of solute}}{\text{Volume of solution in litres}}$
- Mole fraction = In a solution of two components A & B

  $\text{Mole fraction of A} = \dfrac{\text{No. of moles of A}}{\text{Total no. of moles in solution}} = \dfrac{nA}{nA + nB}$

  $\text{Mole fraction of B} = \dfrac{nB}{nA + nB}$

MUST KNOW DEFINITIONS

Matter	:	Matter is defined as anything that has mass and occupies space. All matter is composed of atoms.
Mixtures	:	Mixtures consist of more than one chemical entity present without any chemical interactions.
Pure substances	:	Pure substances are composed of simple atoms or molecules. They are further classified as elements and compounds.
Element	:	An element consists of only one type of atom. Element can exist as monatomic or polyatomic units. The polyatomic elements are called molecules.

Compound	:	Compounds are made up of molecules which contain two or more atoms of different elements.
Relative atomic mass	:	The relative atomic mass is defined as the ratio of the average atomic mass factor to the unified atomic mass unit.
Relative molecular mass	:	Relative molecular mass is defined as the ratio of the mass of a molecule to the unified atomic mass unit. The relative molecular mass of any compound can be calculated by adding the relative atomic masses of its constituent atoms.
Mole	:	One mole is the amount of substance that contains as many elementary particles as the number of atoms in 12 g of carbon-12 isotope.
Avogadro Number	:	The total number of entities present in one mole of any substance is equal to 6.022×10^{23}. This number is called Avogadro number
Molar Mass	:	Molar mass is defined as the mass of one mole of a substance. The molar mass of a compound is equal to the sum of the relative atomic masses of its constituents expressed in g mol^{-1}.
Molar Volume	:	The volume occupied by one mole of any substance in the gaseous state at a given temperature and pressure is called molar volume.
Gram equivalent mass	:	Gram equivalent mass of an element, compound or ion is the mass that combines or displaces 1.008 g hydrogen or 8 g oxygen or 35.5 g chlorine.
Empirical formula	:	Empirical formula of a compound is the formula written with the simplest ratio of the number of different atoms present in one molecule of the compound as subscript to the atomic symbol.
Molecular formula	:	Molecular formula of a compound is the formula written with the actual number of different atoms present in one molecule as a subscript to the atomic symbol.
Stoichiometry	:	Stoichiometry is the quantitative relationship between reactants and products in a balanced chemical equation in moles. The quantity of reactants and products can be expressed in moles or in terms of mass unit or as volume.
Limiting reagent	:	when a reaction is carried out using non-stoichiometric quantities of the reactants, the product yield will be determined by the reactant that is completely consumed. It limits the further reaction from taking place and is called as the limiting reagent.
Oxidation Number	:	It is defined as the imaginary charge left on the atom when all other atoms of the compound have been removed in their usual oxidation states that are assigned according to set of rules.
Combination reactions	:	Redox reactions in which two substances combine to form a single compound are called combination reaction.
Decomposition reaction	:	Redox reactions in which a compound breaks down into two or more components are called decomposition reactions. These reactions are opposite to combination reactions.
Displacement reactions	:	Redox reactions in which an ion (or an atom) in a compound is replaced by an ion (or atom) of another element are called displacement reactions.
Disproportionation reaction	:	In some redox reactions, the same compound can undergo both oxidation and reduction. In such reactions, the oxidation state of one and the same element is both increased and decreased. These reactions are called disproportionation reactions.

Oxidation	:	Classical concept - Addition of oxygen (or) Removal of hydrogen. Electronic concept - Loss of electrons (or) Increase in oxidation number.
Reduction	:	Classical concept - Addition of Hydrogen (or) Removal of oxygen. Electronic concept - Gain of electrons (or) Decrease in oxidation number
Redox Reaction	:	The reaction that involve the oxidation and reduction as its two half reactions are called redox reactions.
Oxidising Agent	:	**Classical Concept :** In a redox reaction, the substance which oxidises the other (or) reduces itself is called oxidising agent. **Electron Transfer concept :** The substance that gains electrons.
Reducing Agent	:	**Classical Concept :** In a redox reaction, the substance which reduces the other (or) oxidises itself is called reducing agent. **Electron Transfer concept :** The substance that loss or donate electrons.

EVALUATION

I. Choose The Best Answer :

1. 40 ml of methane is completely burnt using 80 ml of oxygen at room temperature The volume of gas left after cooling to room temperature is

(a) 40 ml CO_2 gas
(b) 40 ml CO_2 gas and 80 ml H_2O gas
(c) 60 ml CO_2 gas and 60 ml H_2O gas
(d) 120 ml CO_2 gas **[Ans. (a) 40 ml CO_2 gas]**

Hint: $CH_{4(g)} + 2O_{2(g)} \longrightarrow CO_{2(g)} + 2H_2O_{(l)}$

2. An element X has the following isotopic composition ^{200}X = 90%, ^{199}X = 8% and ^{202}X = 2%. The weighted average atomic mass of the element X is closest to

(a) 201 u (b) 202 u (c) 199 u (d) 200 u
[Ans. (d) 200 u]

Hint: $= \dfrac{(200\times 90)+(199\times 8)+(202\times 2)}{100}$

$= 199.96 = 200u$

3. Assertion : Two mole of glucose contains 12.044×10^{23} molecules of glucose

Reason : Total number of entities present in one mole of any substance is equal to 6.02×10^{22} ***[FIRST MID-2018]***

(a) both assertion and reason are true and the reason is the correct explanation of assertion
(b) both assertion and reason are true but reason is not the correct explanation of assertion
(c) assertion is true but reason is false
(d) both assertion and reason are false
[Ans. (c) assertion is true but reason is false]

Hint: Based on Avogadro's law. One mole of any substance is equal to 6.022×10^{23}.

4. Carbon forms two oxides, namely carbon monoxide and carbon dioxide. The equivalent mass of which element remains constant?

(a) Carbon (b) oxygen
(c) both carbon and oxygen
(d) neither carbon nor oxygen **[Ans. (b) oxygen]**

Hint: **React 1 :** $2C + O_2 \longrightarrow 2CO$

2 × 12g carbon combines with 32g of oxygen

$\therefore$ Equivalent mass of carbon $= \dfrac{2\times 12}{32}\times 8 = 6$

React 2 : $C + O_2 \longrightarrow CO_2$

12g carbon combines with 32g of oxygen

$\therefore$ Equivalent mass of carbon $\dfrac{12}{32}\times 8 = 3$

5. The equivalent mass of a trivalent metal element is 9 g eq^{-1} the molar mass of its anhydrous oxide is

(a) 102 g (b) 27 g (c) 270 g (d) 78 g

[Ans. (a) 102 g]

Hint: Atomic mass of the metal oxide is equal to 2 multiple atomic mass of metal + 3 multiple atomic mass of oxygen

6. The number of water molecules in a drop of water weighing 0.018 g is *[FIRST MID-2018]*

(a) 6.022×10^{26} (b) 6.022×10^{23}

(c) 6.022×10^{20} (d) 9.9×10^{22}

[Ans. (c) 6.022×10^{20}]

Hint: $0.001 \times 6.023 \times 10^{23}$

7. 1 g of an impure sample of magnesium carbonate (containing no thermally decomposable impurities) on complete thermal decomposition gave 0.44 g of carbon dioxide gas. The percentage of impurity in the sample is

(a) 0% (b) 4.4% (c) 16% (d) 8.4 %

[Ans. (c) 16%]

Hint: impurity is equal to 1 × 100/1.84.

8. When 6.3 g of sodium bicarbonate is added to 30 g of acetic acid solution, the residual solution is found to weigh 33 g. The number of moles of carbon dioxide released in the reaction is

(a) 3 (b) 0.75 (c) 0.075 (d) 0.3

[Ans. (c) 0.075]

Hint: Number of moles of CO_2 is equal to given weight/ molecular weight.

9. When 22.4 litres of H_2 (g) is mixed with 11.2 litres of Cl_2(g), each at 273 K at 1 atm the moles of HCl (g), formed is equal to

(a) 2 moles of HCl (g) (b) 0.5 moles of HCl (g)

(c) 1.5 moles of HCl (g) (d) 1 moles of HCl (g)

[Ans. (d) 1 moles of HCl (g)]

Hint: $H_2(g) + Cl_2(g) \longrightarrow 2HCl$

1 mole of an ideal gas occupies at 22.4 *l*.

10. Hot concentrated sulphuric acid is a moderately strong oxidising agent. Which of the following reactions does not show oxidising behaviour?

(a) $Cu + 2H_2SO_4 \longrightarrow CuSO_4 + SO_2 + 2H_2O$

(b) $C + 2H_2SO_4 \longrightarrow CO_2 + 2SO_2 + 2H_2O$

(c) $BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HCl$

(d) none of the above

[Ans. (c) $BaCl_2 + H_2SO_4 \longrightarrow BaSO_4 + 2HCl$]

11. Choose the disproportionation reaction among the following redox reactions.

(a) $3Mg_{(s)} + N_{2(g)} \longrightarrow Mg_3N_{2(s)}$

(b) $P_{4(s)} + 3\,NaOH + 3H_2O \longrightarrow PH_{3(g)} + 3NaH_2PO_{2(aq)}$

(c) $Cl_{2(g)} + 2KI_{(aq)} \longrightarrow 2KCl_{(aq)} + I_2$

(d) $Cr_2O_{3(s)} + 2Al_{(s)} \longrightarrow Al_2O_{3(s)} + 2Cr_{(s)}$

[Ans. (b) $P_{4(s)} + 3\ NaOH + 3H_2O \longrightarrow PH_{3(g)} + 3NaH_2PO_{2(aq)}$]

12. The equivalent mass of potassium permanganate in alkaline medium is

$$MnO_4^- + 2H_2O + 3e^- \longrightarrow MnO_2 + 4OH^-$$

(a) 31.6 (b) 52.7

(c) 79 (d) None of these

[Ans. (b) 52.7]

Hint: The reduction reaction of the oxidising agent (MnO_4^-) involves gain of 3 electrons.

Hence the equivalent mass = $\frac{\text{Molar mass of } KMnO_4}{3} = \frac{158.1}{3} = 52.7.$

13. Which one of the following represents 180g of water? *[QY-2019; Sep-2021]*

(a) 5 Moles of water (b) 90 moles of water

(c) $\frac{6.022 \times 10^{23}}{180}$ molecules of water

(d) 6.022×10^{24} molecules of water

[Ans. (d) 6.022×10^{24} molecules of water]

Hint: $10 \times 6.023 \times 10^{23}$

14. 7.5 g of a gas occupies a volume of 5.6 litres at 0° C and 1 atm pressure. The gas is *[HY-2018]*

(a) NO (b) N_2O (c) CO (d) CO_2

[Ans. (a) NO]

Hint: $\frac{7.5g}{5.6l} \times 22.4l = 30g$

Molar mass of NO (14 + 16) = 30g.

Government Exam Questions and Answers

Choose the Correct Answer — 1 Mark

1. The equivalent mass of a divalent metal element is 10 g eq^{-1}. The molar mass of its anhydrous oxide is *[Govt. MQP-2018]*

(a) 46 g (b) 36 g
(c) 52 g (d) none of these

[Ans. (c) 52 g]

Hint: Atomic mass of divalent metal is equal to 2 multiple of atomic mass of metal + 2 multiple of atomic mass of oxygen

2. Match the list I with List II correctly by using the code given below the list. *[QY-2018]*

List I (no. of moles)		List II (Amount)	
A	0.1 mole	1	4480 *ml* of CO_2
B	0.2 mole	2	200 mg of hydrogen gas
C	0.25 mole	3	9 *ml* of water
D	0.5 mole	4	1.51×10^{23} molecules of oxygen

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

[Ans. (d) 2 1 4 3]

Hint: Number of moles is equal to Mass/ Molar mass
Number of moles is equal to Volume/ molar volume

3. The oxidation number of chromium in dichromate (ion) is *[QY-2018]*

(a) +4 (b) +6 (c)+5 (d) 0

[Ans. (b) +6]

4. The empirical formula of glucose is : *[HY-2019]*

(a) CH_2O (b) CHO
(c) CH_2O_2 (d) CH_3O_2

[Ans. (a) CH_2O]

5. The oxidation number of carbon in CH_2F_2 is ____. *[June-2019]*

(a) +4 (b) –4 (c) 0 (d) +2

[Ans. (c) 0]

6. The relative molecular mass of ethanol is *[Sep-2020]*

(a) 0.46 g (b) 4.6 g
(c) 460 g (d) 46 g **[Ans. (d) 46 g]**

Answer the Questions — 2 Marks

1. Write the electronic concept of oxidation and reduction reactions. *[QY & HY-2018]*

Ans. The process can be explained on the basis of electrons. The reaction involving loss of electron is termed oxidation

$Fe^{2+} \rightarrow Fe^{3+} + e^-$ (loss of electron-oxidation).

The reaction involving gain of electron is termed reduction.

$Cu^{2+} + 2e^- \rightarrow Cu$ (gain of electron-reduction)

2. How many moles of hydrogen is required to produce 10 moles of ammonia ? *[HY-2018]*

Ans. $N_2(g) + 3H_2(g) \longrightarrow 2NH_3(g)$

To produce 2 moles of ammonia, 3 moles of hydrogen are required

To produce 10 moles of ammonia

$= \dfrac{3 \text{ moles of } H_2}{2 \text{ moles of } NH_3} \times \overset{5}{10 \text{ moles of } NH_3}$

= 15 moles of hydrogen are required.

3. Calculate oxidation number of oxygen in H_2O_2. *[Mar-2019]*

Ans. hydrogen peroxide (H_2O_2)

$2(+1) + 2x = 0; \Rightarrow 2x = -2; \Rightarrow x = -1$

4. What is combination reaction? Give example. *[HY-2019]*

Ans. When two or more substance combine to form a single substance, the reactions are combination reactions.

$$A + B \longrightarrow C$$

$$\text{Ex} - 2Mg + O_2 \longrightarrow 2MgO$$

5. Calculate the oxidation states of oxygen in H_2O_2 and KO_2. *[QY-2019]*

Ans. Hydrogen peroxide (H_2O_2) is –1.

$2(+1) + 2x = 0; \Rightarrow 2x = -2; \Rightarrow x = -1$

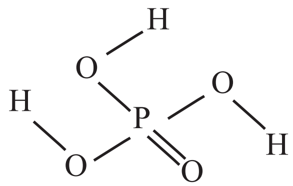
Super oxides such as KO_2 is = –1/2

$+1 + 2x = 0; \Rightarrow 2x = -1; \Rightarrow x = -1/2.$

6. Define basicity. Find the basicity of ortho-phosphoric acid. *[Sep-2020]*

Ans. **(i) Basicity :** The number of replaceable hydrogen atoms present in a molecule of the acid is referred to as its basicity.

(ii) Basicity of ortho-phosphoric acid - H_3PO_4



The number of Hydrogen atoms bonded to the oxtgen atoms in this compound is 3. Therefore, the basicity of ortho-phosphoric acid is 3.

Answer the Questions — 3 MARKS

1. Statement 1 : Two mole of glucose contains 12.044 × 10^{23} molecules of glucose

Statement 2 : Total number of entities present in one mole of any substance is equal to 6.02 × 10^{22}. *[Govt. MQP-2018]*

Whether the above statements are true? Is there any relation between these two statements?

Ans. The statements 1 & 2 are true. But there is no relation between statement 1 and statement 2.

2. Calculate the total number of electrons present in 17g of ammonia. *[Govt. MQP-2018]*

Ans. No. of electrons present in one ammonia (NH_3) molecule (7 + 3) = 10

$$\text{No. of moles of } NH_3 = \frac{\text{Mass}}{\text{Molar mass}} = \frac{17g}{17g\ \text{mol}^{-1}} = 1 \text{ mol}$$

No. of molecules present in 1 mol of NH_3

$= 6.023 \times 10^{23}$

No. of electrons present in 1 mol of NH_3

$= 10 \times 6.023 \times 10^{23}$

$= 6.023 \times 10^{24}$

3. Calculate the amount of water produced by the combustion of 32 g of methane. *[QY-2018]*

Ans. $CH_4(g) + 2O_2(g) \rightarrow CO_2(g) + 2H_2O(g)$

As per the stoichiometric equation,

Combustion of 1 mole (16 g) CH_4 produces 2 moles (2 × 18 = 36 g) of water.

CH_4: $(12) + (4 \times 1) = 16 \text{ g mol}^{-1}$

H_2O: $(2\times1) + (1 \times 16) = 18 \text{ g mol}^{-1}$

Combustion of 32 g CH_4 produces

$$\frac{36 \text{ g } H_2O}{16 \text{ g } CH_4} \times \overset{2}{32 \text{ g } CH_4} = 72 \text{ g of water}$$

4. Calculate the equivalent mass of H_2SO_4. *[Mar-2019]*

Ans. H_2SO_4 basicity $= 2\text{eq mol}^{-1}$

Molar mass of H_2SO_4 $= (2 \times 1) + (1 \times 32) + (4 \times 16)$

$= 98 \text{ g mol}^{-1}$

$$\text{Gram equivalent of } H_2SO_4 = \frac{98}{2} = 49 \text{ g eq}^{-1}$$

5. $X_2 + 3Y_2 \rightarrow 2XY_3$ In this reaction 2 moles of X_2 and 4.5 moles of Y_2 react to give products. Which is the limiting agent (reagent) and calculate the no. of moles of X_2, Y_2 and XY_3 in the reaction mixture? *[QY-2019]*

Ans.

	X_2 +	$3Y_2$ →	$2XY_3$
No. of moles	2	4.5	?
SC	1	3	2
ratio	2/1	4.5/3	-
	2(ER)	1.5(LR)	-

mole-mole $= \frac{nX_2}{1} = \frac{nY_2}{3} = \frac{nXY_3}{2}$

$= \frac{2}{1} = \frac{4.5}{3} = \frac{nXY_3}{2}$

$\frac{4.5}{3} = \frac{nXY_3}{2} = 3 \text{ moles}$

No. of moles of $2XY_3$ = 3 moles

Answer All the Questions — 5 MARKS

1. Define oxidation number. Balance the following equation using oxidation number method.

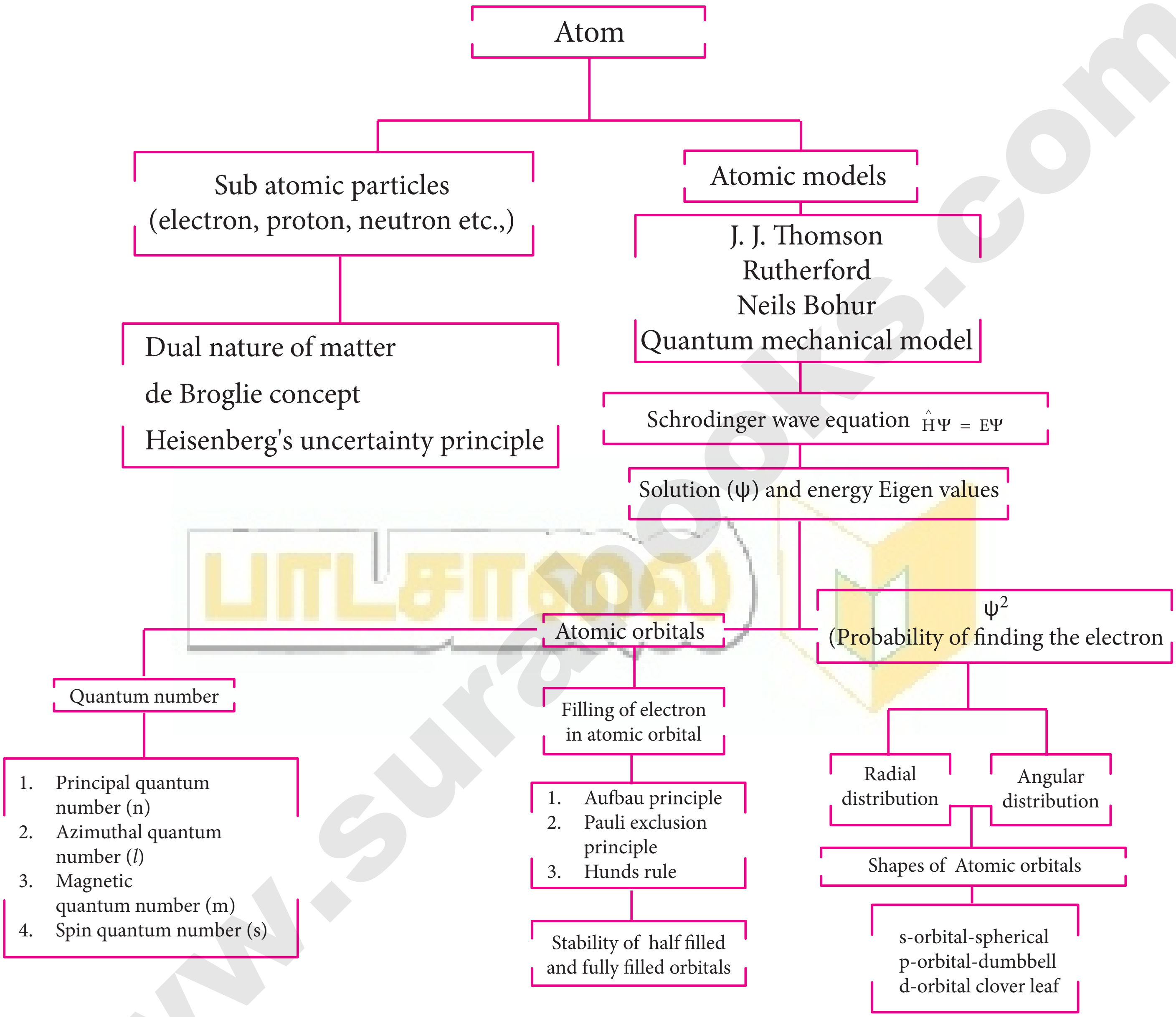
$As_2S_3 + HNO_3 + H_2O \longrightarrow H_3AsO_4 + H_2SO_4 + NO$ *[Govt. MQP-2018]*

Ans. **Oxidation number :** It is defined as the imaginary charge left on the atom when all other atoms of the compound have been removed in their usual oxidation states that are assigned according to set of rules.

02 QUANTUM MECHANICAL MODEL OF ATOM

CHAPTER SNAPSHOT

CONCEPT MAP


Atom
Sub atomic particles (electron, proton, neutron etc.,)
Atomic models
J. J. Thomson
Rutherford
Neils Bohur
Quantum mechanical model
Dual nature of matter
de Broglie concept
Heisenberg's uncertainty principle
Schrodinger wave equation $\hat{H}\Psi = E\Psi$
Solution (ψ) and energy Eigen values
Atomic orbitals
ψ^2
(Probability of finding the electron
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2. Azimuthal quantum number (l)
3. Magnetic quantum number (m)
4. Spin quantum number (s)
Filling of electron in atomic orbital
1. Aufbau principle
2. Pauli exclusion principle
3. Hunds rule
Stability of half filled and fully filled orbitals
Radial distribution
Angular distribution
Shapes of Atomic orbitals
s-orbital-spherical
p-orbital-dumbbell
d-orbital clover leaf

FORMULAE TO REMEMBER

- Mass Number = No. of protons + No. of neutrons
- Atomic Number = No. of protons + No. of neutrons
- **Planck's Quantum theory :** $E = hv$

  E = energy ; h = plank's constant ; v = frequency
- **Einstein's equation :** $E = mc^2$

  E = energy ; m = mass ; c = velocity of light
- **de-Broglie equation :** $\lambda = \frac{h}{mc} \text{(or)} \frac{h}{mv} \text{(or)} \frac{h}{p}$

  $p = mv$

  p = momentum of the particle ; m = mass ; v = Velocity
- **Kinetic energy :** $K.E = \frac{1}{2}mv^2$

  K.E = kinetic energy; m = mass ; v = Velocity
- **Heisenberg's Uncertainty Principle :** $\Delta x.\Delta p \geq \frac{h}{4\pi}$ (or) $\Delta x.m\Delta v \geq \frac{h}{4\pi}$

  Δx = uncertainty in position

  Δp = uncertainty in momentum

  h = plank's constant
- **Schrodinger wave equation :** $\frac{\partial^2\psi}{\partial x^2} + \frac{\partial^2\psi}{\partial y^2} + \frac{\partial^2\psi}{\partial z^2} + \frac{8\pi^2 m}{h^2}(E - V)\psi = 0$

  ψ = amplitude of wave; E = total energy of electron

  V = potential energy; m = mass of electron
- **Bohr's atomic model :**

  (i) Energy of electron in n^{th} orbit (E_n) = $\frac{-2\pi^2 mz^2 e^4}{n^2 h^2}$

  (ii) Angular momentum of n^{th} orbit : $mvr = \frac{nh}{2\pi}$
- **de-Broglie wavelength :** $\lambda = \frac{h}{mv} = \frac{h}{p}$ (p-momentum)
- Maximum no. of electrons that a shell can accommodate is **$2n^2$**
- Total number of nodes = **$n - 1$**
- Radial nodes = **$n - l$**
- Angular nodes = **l**

EVALUATION

I. Choose The Best Answer :

1. Electronic configuration of species M^{2+} is $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$ and its atomic weight is 56. The number of neutrons in the nucleus of species M is

(a) 26 (b) 22 (c) 30 (d) 24

[Ans. (c) 30]

Hint: M^{2+} : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^6$

M : $1s^2\ 2s^2\ 2p^6\ 3s^2\ 3p^6\ 3d^8$

Atomic number = 26

Mass number = 56

No. of neutrons = 56 – 26 = 30

2. The energy of light of wavelength 45 nm is **[HY-2018]**

(a) 6.67×10^{15}J (b) 6.67×10^{11}J

(c) 4.42×10^{-18}J (d) 4.42×10^{-15}J

[Ans. (c) 4.42×10^{-18}J]

Hint: $E = h\nu = hc/\lambda$

$$= \frac{6.626\times10^{-34}\ \text{Js}\times3\times10^{8}\ \text{ms}^{-1}}{45\times10^{-9}\ \text{m}} = 4.42\times10^{-18}\ \text{J.}$$

3. The energies E_1 and E_2 of two radiations are 25 eV and 50 eV respectively. The relation between their wavelengths ie λ_1 and λ_2 will be

(a) $\frac{\lambda_1}{\lambda_2} = 1$ (b) $\lambda_1 = 2\lambda_2$

(c) $\lambda_1 = \sqrt{25\times50}\ \lambda_2$ (d) $2\lambda_1 = \lambda_2$

[Ans. (b) $\lambda_1 = 2\lambda_2$]

Hint: $$\frac{E_1}{E_2} = \frac{25\text{eV}}{50\text{eV}} = \frac{1}{2}$$

$$\frac{hc}{\lambda_1}\times\frac{\lambda_2}{hc} = \frac{1}{2}$$

$$2\lambda_2 = \lambda_1$$

4. Splitting of spectral lines in an electric field is called ***[FIRST MID-2018; Mar-2019]***

(a) Zeeman effect (b) Shielding effect

(c) Compton effect (d) Stark effect

[Ans. (d) Stark effect]

Hint: Splitting of spectral lines in magnetic field is called zeeman effect and splitting of spectral lines in electric field is called stark effect.

5. Based on equation $E = -2.178 \times 10^{-18}\text{J}\left(\frac{z^2}{n^2}\right)$, certain conclusions are written. Which of them is not correct ? ***(NEET)***

(a) Equation can be used to calculate the change in energy when the electron changes orbit

(b) For n = 1, the electron has a more negative energy than it does for n = 6 which means that the electron is more loosely bound in the smallest allowed orbit

(c) The negative sign in equation simply means that the energy of electron bound to the nucleus is lower than it would be if the electrons were at the infinite distance from the nucleus.

(d) Larger the value of n, the larger is the orbit radius.

[Ans. (b) For n = 1, the electron has a more negative energy than it does for n = 6 which means that the electron is more loosely bound in the smallest allowed orbit]

6. According to the Bohr Theory, which of the following transitions in the hydrogen atom will give rise to the least energetic photon ?

(a) n = 6 to n = 1 (b) n = 5 to n = 4

(c) n = 5 to n = 3 (d) n = 6 to n = 5

[Ans. (d) n = 6 to n = 5]

7. Assertion : The spectrum of He^+ is expected to be similar to that of hydrogen

Reason : He^+ is also one electron system.

(a) If both assertion and reason are true and reason is the correct explanation of assertion.

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

(c) If assertion is true but reason is false

(d) If both assertion and reason are false

[Ans. (a) If both assertion and reason are true and reason is the correct explanation of assertion.]

8. Which of the following pairs of d-orbitals will have electron density along the axes ? *(NEET Phase - II)*

(a) d_{z^2}, d_{xz} (b) d_{xz}, d_{yz}
(c) $d_{z^2}, d_{x^2-y^2}$ (d) $d_{xy}, d_{x^2-y^2}$

[Ans. (c) $d_{z^2}, d_{x^2-y^2}$]

9. Two electrons occupying the same orbital are distinguished by

(a) azimuthal quantum number
(b) spin quantum number
(c) magnetic quantum number
(d) orbital quantum number

[Ans. (b) spin quantum number]

10. The electronic configuration of Eu (Atomic no. 63) Gd (Atomic no. 64) and Tb (Atomic no. 65) are *(NEET Phase - II)*

(a) $[Xe]\,4f^6\,5d^1\,6s^2$, $[Xe]\,4f^7\,5d^1\,6s^2$ and $[Xe]\,4f^8\,5d^1\,6s^2$
(b) $[Xe]\,4f^7, 6s^2$, $[Xe]\,4f^7\,5d^1\,6s^2$ and $[Xe]\,4f^9\,6s^2$
(c) $[Xe]\,4f^7, 6s^2$, $[Xe]\,4f^8\,6s^2$ and $[Xe]\,4f^8\,5d^1\,6s^2$
(d) $[Xe]\,4f^6\,5d^1\,6s^2$, $[Xe]\,4f^7\,5d^1\,6s^2$ and $[Xe]\,4f^9\,6s^2$

[Ans. (b) $[Xe]\,4f^7, 6s^2$, $[Xe]\,4f^7\,5d^1\,6s^2$ and $[Xe]\,4f^9\,6s^2$]

11. The maximum number of electrons in a sub shell is given by the expression

(a) $2n^2$ (b) $2l + 1$
(c) $4l + 2$ (d) none of these

[Ans. (c) 4l + 2]

Hint: $2(2l + 1) = 4l + 2$

12. For d-electron, the orbital angular momentum is

(a) $\frac{\sqrt{2}h}{2\pi}$ (b) $\frac{\sqrt{2}h}{2\pi}$
(c) $\frac{\sqrt{2\times4}h}{2\pi}$ (d) $\frac{\sqrt{6}h}{2\pi}$ **[Ans. (d) $\frac{\sqrt{6}h}{2\pi}$]**

Hint: Orbital angular momentum

$$= \frac{\sqrt{l(l+1)}h}{2\pi}$$

$$\text{For d orbital} = \frac{\sqrt{(2\times3)}h}{2\pi} = \frac{\sqrt{6}h}{2\pi}$$

13. What is the maximum numbers of electrons that can be associated with the following set of quantum numbers ? n = 3, *l* = 1 and m = –1

(a) 4 (b) 6 (c) 2 (d) 10

[Ans. (c) 2]

14. Assertion : Number of radial and angular nodes for 3p orbital are 1, 1 respectively.

Reason : Number of radial and angular nodes depends only on principal quantum number.

(a) both assertion and reason are true and reason is the correct explanation of assertion.
(b) both assertion and reason are true but reason is not the correct explanation of assertion.
(c) assertion is true but reason is false
(d) both assertion and reason are false

[Ans. (c) assertion is true but reason is false]

Hint: Radial nodes is equal to n–l–1 and angular nodes is equal to n – 1

15. The total number of orbitals associated with the principal quantum number n = 3 is

(a) 9 (b) 8 (c) 5 (d) 7

[Ans. (a) 9]

16. If n = 6, the correct sequence for filling of electrons will be,

(a) ns ⟶ (n – 2) f ⟶ (n – 1)d ⟶ np
(b) ns ⟶ (n – 1) d ⟶ (n – 2) f ⟶ np
(c) ns ⟶ (n – 2) f ⟶ np ⟶ (n – 1) d
(d) none of these are correct

[Ans. (a) ns ⟶ (n – 2) f ⟶ (n – 1)d ⟶ np]

17. Consider the following sets of quantum numbers :

	n	*l*	m	s
(i)	3	0	0	$+\frac{1}{2}$
(ii)	2	2	1	$-\frac{1}{2}$
(iii)	4	3	–2	$+\frac{1}{2}$
(iv)	1	0	–1	$+\frac{1}{2}$
(v)	3	4	3	$-\frac{1}{2}$

NUMERICAL PROBLEMS

1. Calculate the uncertainty in the velocity of a wagon of mass 3000kg whose position is known to an accuracy of ±10 pm. (Planck's constant = 6.626×10^{-34} kg m^2 s^{-1})

Sol:

Given : $m = 3000$ kg; $\Delta x = 10\ pm$

$= 10 \times 10^{-12}\ m = 10^{-11}\ m$

By uncertainty principle,

$$\Delta v = \frac{h}{4\pi \times m \times \Delta x}$$

$$= \frac{6.626 \times 10^{-34}}{4 \times \frac{22}{7} \times 3000 \times 10^{-11}} ms^{-1}$$

$$= 1.76 \times 10^{-27}\ ms^{-1}$$

$$\boxed{\Delta v = 1.76 \times 10^{-27}\ ms^{-1}}$$

2. The uncertainty in the position and velocity of a particle are 10^{-2} m and 5.27×10^{-24} ms^{-1} respectively. Calculate the mass of the particle.

Sol:

Given : $h = 6.626 \times 10^{-34}$ kg m^2 s^{-1}

$\Delta v = 5.27 \times 10^{-24}\ ms^{-1}$; $\Delta x = 10^{-2}\ m$

Mass of the particle,

$$m = \frac{h}{4\pi \Delta x \Delta v} \text{kg}$$

$$= \frac{6.626 \times 10^{-34} \text{kg}\ m^2 s^{-1}}{4 \times 3.143 \times 10^{-2} m \times 5.27 \times 10^{-24} ms^{-1}}$$

$$= 1 \times 10^{-9} \text{ kg}$$

$$\boxed{m = 1 \times 10^{-9} \text{ kg}}$$

3. Calculate the product of the uncertainties of displacement and velocity of a moving electron having a mass of 9.1×10^{-28} g.

Sol:

Given : $h = 6.626 \times 10^{-34}$ kg m^2 s^{-1}

$m = 9.1 \times 10^{-28}$ g $= 9.1 \times 10^{-31}$ kg

Product of uncertainties,

$$\Delta x \Delta v \geq \frac{h}{4\pi m} m^2 s^{-1}$$

$$\geq \frac{6.626 \times 10^{-34} \text{kg}\ m^2\ s^{-1}}{4 \times 3.143 \times 9.1 \times 10^{-31} \text{kg}}$$

$$\geq 5.77 \times 10^{-5}\ m^2\ s^{-1}$$

$$\boxed{\Delta x . \Delta v \geq 5.77 \times 10^{-5}\ m^2\ s^{-1}}$$

4. A beam of helium atoms moves with a velocity of 2.0×10^3 ms^{-1}. Find the wavelength of the particles constituting the beam. ($h = 6.626 \times 10^{-34}$ Js).

Sol: Given, velocity of beam of helium atoms

$= 20 \times 10^3$ m sec^{-1}

Mass of helium atom $= \dfrac{4}{6.022 \times 10^{23}}$

$= 6.64 \times 10^{-24}$ g $= 6.64 \times 10^{-27}$ kg

According to de-Broglie equation, $\lambda = \dfrac{h}{mv}$

$$= \frac{6.626 \times 10^{-34} \text{kg}\ m^2 s^{-1}}{(6.64 \times 10^{-27} \text{kg}) \times (2.0 \times 10^3 ms^{-1})}$$

$$= 4.99 \times 10^{-11} \text{ m} = 49.9 \text{ pm}$$

✶ ✶ ✶

05

ALKALI AND ALKALINE EARTH METALS

CHAPTER SNAPSHOT

MUST KNOW DEFINITIONS

Alkali metals : Group 1s elements are called alkali metals because sodium and potassium carbonate salts are in larger proportions in ash of shrubs or plants. The other reason is that they react with water and form the hydroxides which are alkaline in nature.

Alkaline earth metals : Except beryllium, all other group elements of 2s are known as alkaline earth metals because their oxides and hydroxides are alkaline in nature and their oxides are available in the crust.

Quick lime (CaO) : It is obtained by heating lime stone ($CaCO_3$) at 1070 – 1270 K temperature in rotary kiln.

$$CaCO_3 \xrightleftharpoons[1070-1270K]{Heat} CaO_{(s)} + CO_{2(g)}$$

Plaster of paris : Plaster of pairs is calcium sulphate hemihydrate. When gypsum is heated at 393K plaster of paris is formed.

$$2CaSO_4.2H_2O_{(s)} \xrightarrow{393K} 2(CaSO_4).H_2O_{(l)} + 3H_2O_{(g)}$$

s-block elements : The elements belonging to the group 1 and 2 in the modern periodic table are called s-block elements.

Milk of lime : CaO is a white powder. It is sparingly soluble in water. The aqueous solution is known as lime water and a suspension of slaked lime in water is known as milk of lime.

Desert rose : Gypsum crystals are sometimes found to occur in a form that resembles the petals of a flower. This type of formation is referred to as 'desert rose', as they mostly occur in arid areas or desert terrains.

Dead burnt plaster : When gypsum, $CaSO_4{\cdot}2H_2O$, is heated above 393 K, no water of crystallisation is left and anhydrous calcium sulphate, $CaSO_4$ is formed. This is known as 'dead burnt plaster'.

ALKALI METALS			
ELEMENT	**SYMBOL**	**ATOMIC NUMBER**	**ELECTRONIC CONFIGURATION**
Lithium	Li	3	$1s^2, 2s^1$
Sodium	Na	11	$1s^2, 2s^2, 2p^6, 3s^1$
Potassium	K	19	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^1$
Rubedium	Rb	31	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^6, 5s^1$
Caesium	Cs	55	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^6, 4d^{10}, 5s^2, 5p^6, 6s^1$
Francium	Fr	87	$[Rn]\ 7s^1$
ALKALINE EARTH METALS			
Beryllium	Be	4	$1s^2, 2s^2$
Magnesium	Mg	12	$1s^2, 2s^2, 2p^6, 3s^2$
Calcium	Ca	20	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2$
Strontium	Sr	38	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 4s^2, 3d^{10}, 4p^6, 5s^2$
Barium	Ba	56	$1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^{10}, 4s^2, 4p^6, 4d^{10}, 5s^2, 5p^6, 6s^2$
Radium	Ra	88	$[Rn]\ 7s^2$

	Flourspar Flourapatite Chloropatite	CaF_2 $[Ca_5(PO_4)_3F]$ $[Ca_5(PO_4)_3Cl]$
Strontium	Strontianide Silastine	$SrCO_3$ $SrSO_4$
Barium	Witherite Baryte	$BaCO_3$ $BaSO_4$

EVALUATION

I. Choose The Best Answer :

1. For alkali metals, which one of the following trends is incorrect ?
(a) Hydration energy : Li > Na > K > Rb
(b) Ionisation energy : Li > Na > K > Rb
(c) Density : Li < Na < K < Rb
(d) Atomic size : Li < Na < K < Rb
[Ans. (c) Density : Li < Na < K < Rb]

2. Which of the following statements is incorrect ?
(a) Li^+ has minimum degree of hydration among alkali metal cations.
(b) The oxidation state of K in KO_2 is +1
(c) Sodium is used to make Na / Pb alloy
(d) $MgSO_4$ is readily soluble in water
[Ans. (a) Li^+ has minimum degree of hydration among alkali metal cations.]

3. Which of the following compounds will not evolve H_2 gas on reaction with alkali metals ?
(a) ethanoic acid (b) ethanol
(c) phenol (d) none of these
[Ans. (d) none of these]

4. Which of the following has the highest tendency to give the reaction

$$M^+_{(g)} \xrightarrow[\text{Medium}]{\text{Aqueous}} M^+_{(aq)}$$

(a) Na (b) Li (c) Rb (d) K
[Ans. (b) Li]

5. sodium is stored in *[QY-2018]*
(a) alcohol (b) water
(c) kerosene (d) none of these
[Ans. (c) kerosene]

6. RbO_2 is
(a) superoxide and paramagnetic
(b) peroxide and diamagnetic
(c) superoxide and diamagnetic
(d) peroxide and paramagnetic
[Ans. (a) superoxide and paramagnetic]

7. Find the wrong statement
(a) sodium metal is used in organic qualitative analysis
(b) sodium carbonate is soluble in water and it is used in inorganic qualitative analysis
(c) potassium carbonate can be prepared by solvay process
(d) potassium bicarbonate is acidic salt
[Ans. (c) potassium carbonate can be prepared by solvay process]

8. Lithium shows diagonal relationship with
(a) sodium (b) magnesium
(c) calcium (d) aluminium
[Ans. (b) magnesium]

Hint: adjacent second and third period of the elements. Example: Li and Mg, Be and Al, B and si.

9. In case of alkali metal halides, the ionic character increases in the order
(a) MF < MCl < MBr < MI
(b) MI < MBr < MCl < MF
(c) MI < MBr < MF < MCl
(d) none of these
[Ans. (b) MI < MBr < MCl < MF]

10. In which process, fused sodium hydroxide is electrolysed for extraction of sodium ?
(a) Castner's process (b) Cyanide process
(c) Down process (d) All of these
[Ans. (a) Castner's process]

11. The product obtained as a result of a reaction of nitrogen with CaC_2 is ***(NEET- Phase I)*** *[HY-2018]*
(a) $Ca(CN)_3$ (b) CaN_2
(c) $Ca(CN)_2$ (d) Ca_3N_2
[Ans. (c) $Ca(CN)_2$]

12. Which of the following has highest hydration energy
(a) $MgCl_2$ (b) $CaCl_2$ (c) $BaCl_2$ (d) $SrCl_2$
[Ans. (a) $MgCl_2$]

13. Match the flame colours of the alkali and alkaline earth metal salts in the bunsen burner *[HY-2019; Sep-2021]*

(p) Sodium	(1)	Brick red
(q) Calcium	(2)	Yellow
(r) Barium	(3)	Lilac (violet)
(s) Strontium	(4)	Apple green
(t) Cesium	(5)	Crimson red
(u) Potassium	(6)	Blue

(a) p - 2, q - 1, r - 4, s - 5, t - 6, u - 3
(b) p - 1, q - 2, r - 4, s - 5, t - 6, u - 3
(c) p - 4, q - 1, r - 2, s - 3, t - 5, u - 6
(d) p - 6, q - 5, r - 4, s - 3, t - 1, u - 2

[Ans. (a) p - 2, q - 1, r - 4, s - 5, t - 6, u - 3]

14. Assertion : Generally alkali and alkaline earth metals form superoxides
Reason : There is a single bond between O and O in superoxides.

(a) both assertion and reason are true and reason is the correct explanation of assertion
(b) both assertion and reason are true but reason is not the correct explanation of assertion
(c) assertion is true but reason is false
(d) both assertion and reason are false

[Ans. (d) both assertion and reason are false]

15. Assertion : $BeSO_4$ is soluble in water while $BaSO_4$ is not
Reason : Hydration energy decreases down the group from Be to Ba and lattice energy remains almost constant.

(a) both assertion and reason are true and reason is the correct explanation of assertion
(b) both assertion and reason are true but reason is not the correct explanation of assertion
(c) assertion is true but reason is false
(d) both assertion and reason are false

[Ans. (a) both assertion and reason are true and reason is the correct explanation of assertion]

16. Which is the correct sequence of solubility of carbonates of alkaline earth metals ?

(a) $BaCO_3 > SrCO_3 > CaCO_3 > MgCO_3$
(b) $MgCO_3 > CaCO_3 > SrCO_3 > BaCO_3$
(c) $CaCO_3 > BaCO_3 > SrCO_3 > MgCO_3$
(d) $BaCO_3 > CaCO_3 > SrCO_3 > MgCO_3$

[Ans. (b) $MgCO_3 > CaCO_3 > SrCO_3 > BaCO_3$]

17. In context with beryllium, which one of the following statements is incorrect ? *(NEET Phase -2)*

(a) It is rendered passive by nitric acid
(b) It forms Be_2C
(c) Its salts are rarely hydrolysed
(d) Its hydride is electron deficient and polymeric

[Ans. (c) Its salts are rarely hydrolysed]

18. The suspension of slaked lime in water is known as *(NEET Phase -II)* *[QY-2019]*

(a) lime water
(b) quick lime
(c) milk of lime
(d) aqueous solution of slaked lime

[Ans. (c) milk of lime]

19. A colourless solid substance (A) on heating evolved CO_2 and also gave a white residue, soluble in water. Residue also gave CO_2 when treated with dilute HCl.

(a) Na_2CO_3 (b) $NaHCO_3$
(c) $CaCO_3$ (d) $Ca(HCO_3)_2$

[Ans. (b) $NaHCO_3$]

20. The compound (X) on heating gives a colourless gas and a residue that is dissolved in water to obtain (B). Excess of CO_2 is bubbled through aqueous solution of B, C is formed. Solid (C) on heating gives back X. (B) is

(a) $CaCO_3$ (b) $Ca(OH)_2$
(c) Na_2CO_3 (d) $NaHCO_3$

[Ans. (b) $Ca(OH)_2$]

21. Which of the following statement is false ? *(NEET-Phase -I)*

(a) Ca^{2+} ions are not important in maintaining the regular beating of the heart
(b) Mg^{2+} ions are important in the green parts of the plants
(c) Mg^{2+} ions form a complex with ATP
(d) Ca^{2+} ions are important in blood clotting

[Ans. (a) Ca^{2+} ions are not important in maintaining the regular beating of the heart]

22. The name 'Blue John' is given to which of the following compounds ? *[Mar-2019]*

(a) CaH_2 (b) CaF_2
(c) $Ca_3(PO_4)_2$ (d) CaO **[Ans. (b) CaF_2]**

23. Formula of Gypsum is *[Sep-2020]*

(a) $CaSO_4.2H_2O$ (b) $CaSO_4.½ H_2O$
(c) $3CaSO_4.H_2O$ (d) $2CaSO_4.2H_2O$

[Ans. (a) $CaSO_4.2H_2O$]

24. When CaC_2 is heated in atmospheric nitrogen in an electric furnace the compound formed is *[June-2019]*

(a) $Ca(CN)_2$ (b) CaNCN
(c) CaC_2N_2 (d) $CaNC_2$

[Ans. (b) CaNCN]

25. Among the following the least thermally stable is
(a) K_2CO_3 (b) Na_2CO_3
(c) $BaCO_3$ (d) Li_2CO_3
[Ans. (d) Li_2CO_3]

Hint: Li_2CO_3 is least stable.

II. Write Brief Answer To The Following Questions.

26. Why sodium hydroxide is much more water soluble than sodium chloride? *[QY-2019]*

Ans. NaOH is much more soluble than NaCl.
Enthalpy of a solution can be expressed as the sum of lattice enthalpy and enthalpy of hydration of a compound.

ΔH solu NaCl	=	+3.9KJ/mol
ΔH solu NaOH	=	–44.5 KJ/mol
ΔH_0 Lattice enthalpy of NaCl	=	+787.6 KJ
Hydration enthalpy	=	–784.1KJ
Therefore ΔH solu	=	+787.6 –784.1
	=	+ 3.5KJ

Dissolution of NaCl is accompanied by very small heat change so solubility of NaCl is less than NaOH.

27. Write the chemical equations for the reactions involved in solvay process of preparation of sodium carbonate.

Ans. The equations involved in solvay process are,

$2NH_3 + H_2O + CO_2 \longrightarrow (NH_4)_2CO_3$

$(NH_4)_2CO_3 + H_2O + CO_2 \longrightarrow 2NH_4HCO_3$

$2NH_4HCO_3 + NaCl \longrightarrow NH_4Cl + NaHCO_3$

$2NaHCO_3 \longrightarrow Na_2CO_3 + CO_2 + H_2O$

The ammonia used in this process can be recovered by treating the resultant ammonium chloride solution with calcium hydroxide. Calcium chloride is formed as a by-product.

28. An alkali metal (x) forms a hydrated sulphate, $X_2SO_4.10H_2O$. Is the metal more likely to be sodium (or) potassium.

Ans. X forms $X_2SO_4.10H_2O$. The metal is more likely be sodium. So X is $Na_2SO_4.10H_2O$. It is a otherwise called as Glauder's salt.

29. Write balanced chemical equation for each of the following chemical reactions.
(i) Lithium metal with nitrogen gas
(ii) heating solid sodium bicarbonate
(iii) Rubidum with oxygen gas
(iv) solid potassium hydroxide with CO_2
(v) heating calcium carbonate
(vi) heating calcium with oxygen

Ans. (i) $6Li_{(s)} + 3N_{2(g)} \longrightarrow 2Li_3N_{(s)}$
Lithium, Nitrogen, Lithium Nitride

(ii) $2NaHCO_3 \xrightarrow{\Delta} Na_2CO_3 + CO_2\uparrow + H_2O$
Sodium bicarbonate, Sodium carbonate

(iii) $Rb + O_2 \longrightarrow RbO_2$
Rubidium, Rubidium super oxidi

(iv) $2KOH_{(s)} + CO_2 \longrightarrow K_2CO_3 + H_2O$
Potassium hydroxide, Potassium carbonate

(v) $CaCO_3 \xrightarrow{\Delta} CaO_{(s)} + CO_2\uparrow$
Calcium carbonate, Quick lime

(vi) $2Ca_{(s)} + O_{2(g)} \longrightarrow 2CaO_{(s)}$
Calcium, Calcium oxide

30. Discuss briefly the similarities between beryllium and aluminium. *[QY-2018; June-2019; Sep-2021]*

Ans. Beryllium shows a diagonal relationship with aluminium. In this case, the size of these ions is not as close. However, their charge per unit area and electro-negativity values are almost similar. Similarities between Beryllium and Aluminium

S.No.	Properties
1	Beryllium chloride forms a dimeric structure like aluminium chloride with chloride bridges.
2	Beryllium hydroxide dissolves in excess of alkali and gives beryllate ion $[Be(OH)_4]^{2-}$ as aluminium hydroxide which gives aluminate ion, $[Al(OH)_4]^-$.
3	Beryllium and aluminum ions have strong tendency to form complexes, BeF_4^{2-}, AlF_6^{3-}.
4	Both beryllium and aluminium hydroxides are amphoteric in nature.
5	Carbides of beryllium (Be_2C) like aluminum carbide (Al_4C_3) give methane on hydrolysis.
6	Both beryllium and aluminium are rendered passive by nitric acid.

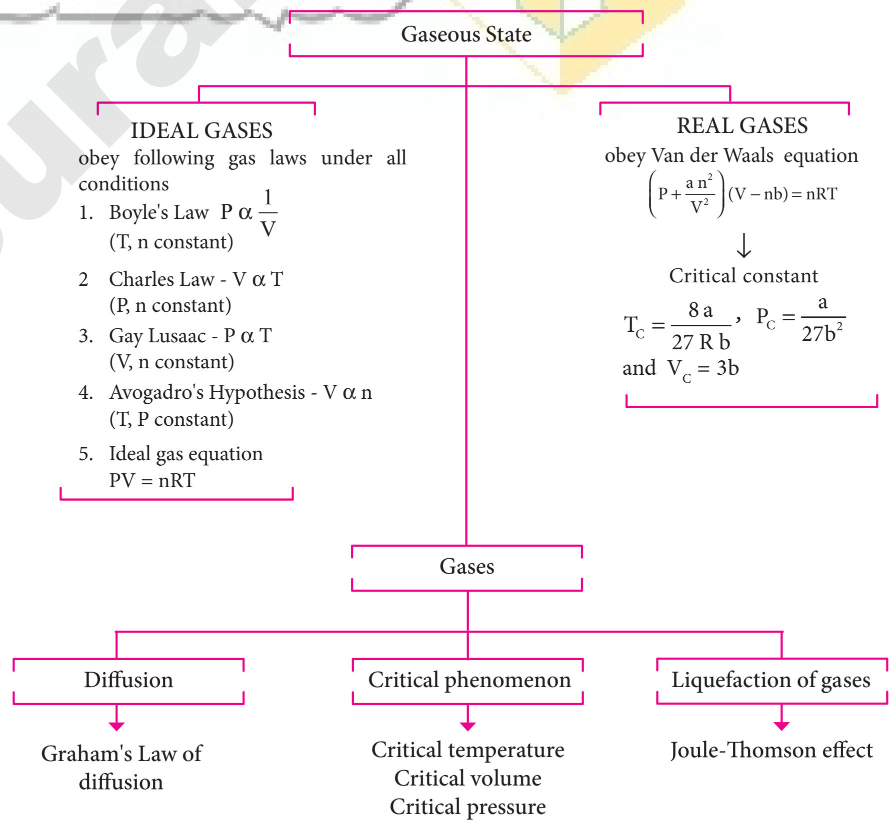
31. Give the systematic names for the following
(i) milk of magnesia (ii) lye
(iii) lime (iv) Caustic potash
(v) washing soda (vi) soda ash (vii) trona

Ans. (i) Milk of magnesia - $Mg(OH)_2$ - Magnesium hydroxide
(ii) lye - NaOH - Sodium hydroxide
(iii) lime - $Ca(OH)_2$ - Calcium oxide
(iv) Caustic potash - KOH - Potassium hydroxide
(v) washing soda - $Na_2CO_3.10H_2O$ - Sodium carbonate
(vi) soda ash - Na_2CO_3 - Sodium carbonate
(vii) trona - $Na_2CO_3.NaHCO_3.2H_2O$ - Sodium sesquicarbonate

06 Gaseous State

CHAPTER SNAPSHOT

CONCEPT MAP



MUST KNOW DEFINITIONS

Pressure	:	Pressure is defined as force divided by the area to which the force is applied.
Pascal	:	The SI unit of pressure is pascal which is defined as 1 Newton per square meter (Nm^{-2}).
Boyle's law	:	At a given temperature the volume occupied by a fixed mass of a gas is inversely proportional to its pressure.
Charles Law	:	For a fixed mass of a gas at constant pressure, the volume is directly proportional to its temperature (K).
Gay-Lussac's Law	:	At constant volume the pressure of a fixed mass of a gas is directly proportional to temperature.
Avogadro's Hypothesis	:	Avogadro hypothesis says that equal volumes of all gases under the same conditions of temperature and pressure contain equal number of molecules.
Dalton's law	:	"The total pressure of a mixture of non-reacting gases is the sum of partial pressures of the gases present in the mixture"
Diffusion	:	When two non -reactive gases are allowed to mix, the gas molecules migrate from region of higher concentration to a region of lower concentration. This property of gas which involves the movement of the gas molecules through another gases is called diffusion.
Effusion	:	Effusion is another process in which a gas escapes from a container through a very small hole.
Graham's law of diffusion/effusion	:	The rate of diffusion or effusion is inversely proportional to the square root of molar mass. This statement is called Graham's law of diffusion/effusion.
Compressibility factor	:	The deviation of real gases from ideal behaviour is measured in terms of a ratio of PV to nRT. This is termed as compressibility factor.
Boyle temperature	:	The temperature at which a real gas obeys ideal gas law over an appreciable range of pressure is called Boyle temperature or Boyle point.
Critical temperature (T_c)	:	Critical temperature (T_c) of a gas is defined as the temperature above which it cannot be liquefied even at high pressure.
Critical pressure (P_c)	:	Critical pressure (P_c) of a gas is defined as the minimum pressure required to liquefy 1 mole of a gas at its critical temperature.
Critical volume (V_c)	:	Critical volume (V_c) is defined as the volume occupied by 1 mole of a gas at its critical temperature and critical pressure.
Joule- Thomson effect	:	The phenomenon of lowering of temperature when a gas is made to expand adiabatically from a region of high pressure into a region of low pressure is known as Joule- Thomson effect.
Inversion	:	The temperature below which a gas obeys Joule-Thomson effect is called inversion temperature (T_i).
Aqueous tension	:	Pressure exerted by saturated water vapour is called aqueous tension.

NUMERICAL PROBLEMS

1. Find the pressure of 5 mole Cl_2 gas filled in a 2 litre vessel at 27 °C temperature.

Sol : **Given :** n = 5; V = 2 litre; T = 27 + 273 = 300 K

$$P = \frac{nRT}{V} \quad [\because PV = nRT]$$

$$P = \frac{5 \times 8.314 \times 300}{2} = 62.355 \text{ bar}$$

∴ The pressure of Cl_2 gas will be 62.355 bar.

2. Find the moles of O_2 gas having pressure 250 bar in 500 ml vessel at 350 K temperature.

Sol :

Given : P = 250 bar; T = 350 K; V = 500 ml = 0.5 litre.

$$n = \frac{PV}{RT} \quad [\because PV = nRT]$$

$$= \frac{250 \times 0.5}{8.314 \times 10^{-2} \times 350} = 4.296 \text{ mol}$$

∴ n = 4.296 mol.

3. Find the pressure of neon gas having density 0.9 gm lit^{-1} at 350 K temperature.

Sol : **Given :** Density (d) = 0.9 gm lit^{-1}

T = 350 K

Mass of neon (M) = 20 gm mol^{-1}

$$P = \frac{dRT}{M} \quad \left(\because n = \frac{d}{M}\right)$$

$$= \frac{0.9 \times 8.314 \times 10^{-2} \times 350}{20} = 1.309 \text{ bar}$$

Pressure of neon = 1.309 bar

4. At 27 °C temperature and 4 bar pressure CO is filled in 2 litre vessel. Find the pressure if it is filled in 4 litre vessel at 77 °C temperature.

Sol : **Given :** P_1 = 4 bar; P_2 = ?

V_1 = 2 litre; V_2 = 4 litre

T_1 = 27 + 273 = 300 K

T_2 = 77 + 273 = 350 K

$$\frac{P_1V_1}{T_1} = \frac{P_2V_2}{T_2}$$

$$P_2 = \frac{P_1V_1}{T_1} \times \frac{T_2}{V_2} = \frac{4 \times 2 \times 350}{300 \times 4} = 2.33 \text{ bar}$$

The pressure of CO gas will be 2.33 bar.

5. A neon-dioxygen mixture contains 60.8 g dioxygen and 167.5 g neon. If pressure of the mixture of gases in the cylinder is 20 bar, what is the partial pressure of dioxygen and neon in the mixture?

Sol : **Given :** Mass of neon = 167.5

Mass of dioxygen = 60.8 g

Pressure = 20 bar

$$\text{No. of moles of dioxygen} = \frac{60.8\ g}{32\ g\ mol} = 1.9\ mol$$

$$\text{No. of moles of neon} = \frac{167.5\ g}{20\ g\ mol} = 8.375\ mol$$

Mole fraction of dioxygen

$$= \frac{1.9}{1.9 + 8.375} = \frac{1.9}{10.275} = 0.185$$

$$\text{Mole fraction of neon} = \frac{8.375}{1.9 + 8.375} = \frac{8.375}{10.275} = 0.815$$

Partial pressure of gas = Mole fraction × Total pressure

Partial pressure of dioxygen = 0.185 × 20 = 3.7 bar

Partial pressure of neon = 0.815 × 20 = 16.3 bar.

6. If a gas diffuses at the rate of one-half as fast as O_2, find the molecular mass of the gas.

Sol : Applying Graham's law of Diffusion,

$$\frac{r_1}{r_2} = \sqrt{\frac{M_2}{M_1}}; \quad \frac{1/2}{1} = \sqrt{\frac{32}{M_1}}$$

Squaring both sides of the equation,

$$\left(\frac{1}{2}\right)^2 = \frac{32}{M_1}; \quad \frac{1}{4} = \frac{32}{M_1}$$

∴ M_1 = 128

Thus the molecular mass of the unknown gas is 128.

7. 75 ml of gas A effuses through a pin hole in 73 seconds the same volume of SO_2 under identical conditions effuses in seconds. Calculate the molecular mass of A.

Sol :

Given : Time taken for effusion of gas A = 73 seconds

Time taken for effusion of SO_2 gas = 75 seconds

Volume of gases (A & SO_2) taken = 75 ml each.

$$\text{Molecular mass of } SO_2 = \frac{\text{Effusion rate of } SO_2}{\text{Effusion rate of A}} = \sqrt{\frac{M_A}{M_{SO_2}}}$$

$$\frac{75/75}{75/73} = \sqrt{\frac{M_A}{M_{SO_2}}}; \quad \frac{1}{1.027} = \sqrt{\frac{M_A}{64}}$$

$$(0.9737)^2 = \frac{M_A}{64}; \quad M_A = 60.67$$

∴ Molecular mass of A is 60.67.

8. Vanderwaal's constant for a gas (g) are a = 6.34 atm lit^{-2}; and b = 52.6 ml mol^{-1}. Find the critical temperature and critical pressure of the gas.

Sol : Given :

a = 6.34 atm lit^{-2}; b = 52.6 ml mol^{-1}

b = 0.056 lit mol^{-1}

$$T_C = \frac{8a}{27Rb}$$

$$= \frac{8 \times 6.34}{27 \times 0.0821 \times 0.0526} = 434.997 \simeq 435 \text{ K}$$

T_C = 162 °C

$$P_C = \frac{a}{27b^2} = \frac{6.34}{27 \times (0.0526)^2} = 84.87$$

P_C = 84.87 atm.

9. Vanderwaal's constant for gas are a = 3.67 atm lit^2 mol^{-2} b = 0.0408 lit mol^{-1}. Find the critical temperature and critical pressure of the gas.

Sol :Given: a = 3.67 atm lit^2 mol^{-2}

b = 0.0408 lit mol^{-1}

R = 0.0821 atm lit K^{-1} mol^{-1}

(i) $$T_C = \frac{8a}{27Rb} = \frac{8 \times 3.67}{27 \times 0.082 \times 0.0408} = 324.7 \text{ K}$$

T_C = 324.7 K

(ii) $$P_C = \frac{a}{27b^2} = \frac{3.67}{27 \times (0.0408)^2} = 81.6$$

P_C = 81.6 atm.

10. The vanderwaal's constants a = 2.095 lit^2 atm mol^{-1} and b = 0.0189 lit mol^{-1} respectively. Calculate the inversion temperature.

Sol : Given :

a = 2.095 lit^2 atm mol^{-1};

R = 0.0821 dm^3 atm lit K^{-1} mol^{-1}

b = 0.0189 lit mol^{-1}

$$T_i = \frac{2a}{Rb} = \frac{2 \times 2.095}{0.0821 \times 0.0189} = 2700.28 \text{ K}$$

T_i = 2700.28 K

11. If a scuba diver takes a breath at the surface filling his lungs with 5.82 dm^3 of air what volume will the air in his lungs occupy when he drives to a depth where the pressure is 1.92 atm. (assume temperature is constant and the pressure at the surface is exactly)

Sol : Given, data P_1 = 1 atm V_1 = 5.82 dm^3

P_1 = 1.92 atm V_2 = ?

According to Boyles law,

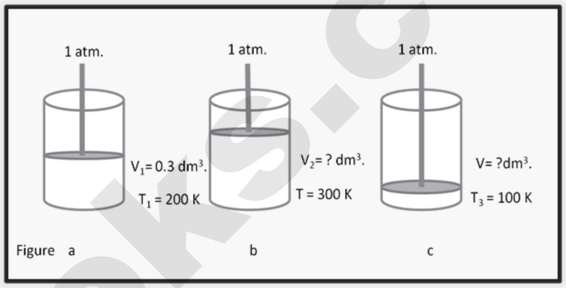
$$P_1 V_1 = P_2 V_2$$

$$V_2 = \frac{P_1 V_1}{P_2}$$

$$V_2 = \frac{1 \text{ atm} \times 5.82 \text{ dm}^3}{1.92 \text{ atm}}$$

$$V_2 = 3.031 \text{ dm}^2$$

12. Solve



Effect of temperature on volume of the gas to verify Charles law

All the container a, b and c have same pressure of 1 atm. If T_1, T_2, and T_3 are, respectively, at 200, 300 and 100 K, and V_1 = 0.3 dm^3, calculate V_2 and V_3.

Sol : Pressure P = 1 atm

Container *a*

V_1 = 0.3 dm^3

T_1 = 200 K

According to charles law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{03}{200} = \frac{V_2}{300}$$

$$V_2 = \frac{0.3 \times 300}{200} = 0.45 \text{ dm}^2$$

Container *b* V_2 = ?

T_2 = 300 K

Container *c* V_3 = ?

T_3 = 100 K

According to charles law

$$\frac{V_1}{T_1} = \frac{V_3}{T_3}$$

$$\frac{0.3}{200} = \frac{V_3}{100}$$

$$V_3 = \frac{0.3 \times 100}{200} = 0.15 \text{ dm}^2$$

13. If the weather balloon at a pressure 0.0965 atm. At ground level has a volume of 10.0 m^3. What will be the pressure at an altitude of 5300 m where its volume is 20.0 m^3?

Sol : Pressure of a gas at ground level P_1 = 0.965 atm

Volume of the gas at ground level V_1 = 10.0 m^3

Volume of the gas at an attitude of 5300m V_2 =20.0m^3

Pressure of the gas at an altitude of 5300 P_2 = ?

According to Boyle's law = $T_1 V_1 = P_2 V_2$

$$0.0965 \times 10 = P_2 \times 20.0$$

$$P_2 = \frac{0.0965 \times 10.0}{20.0} = 0.04825$$

Pressure of the gas at an attitude of 5300m

$$P_2 = 0.04825 \text{ atm}$$

14. At sea level a balloon has volume of 785 ×10^{-3} dm^3. What will be its volume, if it taken to a place where the pressure is 0052 atm. Less than the atmospheric pressure of 1 atm.

Sol : At sea level pressure P_1 = 1 atm

Volume occupied at sea level V_1 = 785 × 10^{-3} dm^3

If the pressure P_2 = 0.052 atm

the volume of the balloon V_2 = ?

According to Boyle's law

$$P_1 V_1 = P_2 V_2$$

$$1 \times 785 \times 10^{-3} = 0.052 \times V_2$$

$$V_2 = \frac{1 \times 785 \times 10^{-3}}{0.052}$$

$$= 15096.15 \times 10^{-3} \text{ dm}^3$$

15. When the temperature of a gas increases from 0°C the volume of the gas increases by a factor of 1.25.what is the final temperature?

Sol : Initial temperature T_1 of the gas = 0°C = 0 + 273

= 273°C

Let the Initial volume of the gas V_1 = x ml

The final volume V_2 of the gas = 1.25× x ml

According to Charle's law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$\frac{x}{273} = \frac{1.25 \times x}{T_2}$$

$$T_2 = \frac{1.25 \times \cancel{x} \times 273}{\cancel{x}} = 341.25 \text{ K}$$

The final temperature = 341.25 K

16. In an experiment of verification of Charle's law, the following are the set of readings taken by a student

Experiment	Volume (L)	Temperature (°C)
1	1.54	20
2	1.65	40
3	1.95	100
4	2.07	120

What is the average value of the constant of proportionality?

Sol : According to charles law

$$\frac{V_1}{T_1} = \frac{1.54}{293}$$

$$= 0.0052$$

$$T_1 = 20 \text{ C} + 273 = 293 \text{ K}$$

$$T_2 = 40^oC$$

$$\frac{V_2}{T_2} = \frac{1.65}{40+273} = \frac{1.65}{313} = 0.0052$$

$$T_3 = 100^o \text{ C} + 273 = 373 \text{ K}$$

$$\frac{V_3}{T_3} = \frac{1.95}{373K} = 0.0052$$

$$T_4 = 120^oC + 273 = 393 \text{ K}$$

$$\frac{V_4}{T_4} = \frac{2.07}{393} = 0.0052$$

The average value of constant of proportionality is 0.0052.

17. A helium filled balloon had a volume of 400 ml, when it is cooled to –120 °C. what will be its volume if the balloon is warmed in an oven to 100°C assuming changes in pressure.

Sol : Volume of the gas in the balloon V_1 = 400 ml

temperature T_1 = –120°C + 273

= 153 K

If the balloon is warmed T_2 = 100° C + 273

to a temperature = 373 K

Then the volume of the gas V_2 = ?

According to charles law $\frac{V_1}{T_1} = \frac{V_2}{T_2}$

$$V_2 = \frac{V_2}{T_1} \times T_2$$

$$= \frac{400}{153} \times 373 = 975 \text{ ml}$$

∴ Volume of helium gas in the balloon at a temperature of 100°C = 975 ml

18. Suppose a 375 ml sample of neon gas at 78 °C is cooled to 22 °C at constant pressure. What will be the new volume of neon sample?

Sol : Volume of the neon gas $V_1 = 375$ ml

of a temperature $T_1 = 78°C + 273 = 351K$

At a temperature of $T_2 = 22°C + 273 = 295$ K

The volume of neon gas $V_2 = ?$

According to charles law

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_2 = \frac{V_1T_2}{T_1}$$

$$V_2 = \frac{375 \times 295}{351} = 315.17 \text{ ml}$$

∴Volume of neon gas at a temperature of 22° C = 315.17 ml

19. Which of following flasks has higher pressure

(a) 5.00 L containing 4.15 g of Helium at 298 K

(b) 10.0 L containing 56.2 g Argon at 303 K

Sol: (a) Volume of the flask V = 5.00 L

Temperature T = 298 K

Gas constant R = 0.0821 L atm K mol^{-1}

Mass of He = 4.15g

No. of moles He = $\frac{\text{Mass}}{\text{Molarmass}} = \frac{4.15}{4}$

= 1.0375 moles

According to Ideal gas equation

PV = nRT

$$P = \frac{n}{V}RT = \frac{1.0375 \times 0.0821 \times 298}{5}$$

Pressure of helium = 5.076 atm

(b) Volume of Ar = 10.0L

Temperature = 303 K

Mass of Ar = 56.2 g

No. of Moles of Ar = $\frac{\text{Mass}}{\text{Molar mass}} = \frac{56.2}{40}$

= 1.405 moles

According to ideal gas equation

PV = nRT

$$P = \frac{n}{V}RT = \frac{1.405 \times 0.0821 \times 303}{10}$$

= 3.495 atm

20. At what temperature would 4.25 g of oxygen gas O_2 exert a pressure of 1.21 atm. in a 2.15 dm^3 flask.

Sol: Mass of oxygen = 4.25g

No. of moles of oxygen = $\frac{4.25}{32}$ = 0.1328 moles

Pressure P = 1.21 atm, volume V = 2.15 dm^3

According to ideal gas equation

PV = nRT

$$T = \frac{PV}{nR} = \frac{1.21 \times 2.15}{0.1328 \times 0.0821}$$

∵ R is the gas constant

R = 0.0821 L atm K mol^{-1}

$$= \frac{2.6015}{0.0109} = 238 \text{ K}$$

21. For a gaseous mixture of 2.41g of helium and 2.79gof neon in an evacuated 1.04 dm^3 container at 298 K calculate the partial pressure of each gas and hence find the total pressure of the mixture.

Sol: Mass of He = 2.41g

No. of moles of He = $\frac{\text{Mass}}{\text{Molar Mass}} = \frac{2.41}{4}$

= 0.6025 moles

Mass of Ne = 2.79 g

No. of moles of Ne = $\frac{\text{Mass}}{\text{Molar Mass}} = \frac{2.79}{20}$

= 0.1395 moles

Volume of the Total no. of moles of the mixture

= 0.6025 + 0.1395 = 0.7420 moles

Container V = 1.04 dm^3

Temperature T = 298 K

Pressure P = $\frac{1}{V}RT$

According to ideal gas equation PV = nRT

$$P = \frac{0.7420 \times 0.0821 \times 298}{1.04} = 17.45 \text{ atm}$$

Partial pressure P = molefraction × Total pressure

$$= \frac{n_A}{n_A + n_B} \times P$$

Partial Pressure of Helium = $p_{He} = \frac{0.6025}{0.7420} \times 17.45$

According to Dalton's law of partial pressure

= 3.280 atm.

$P = P_1 + P_2 + P_3 ...$

$P_{Total} = P_{He} + P_{Ne} = 14.169 + 3.280 = 17.449$ atm

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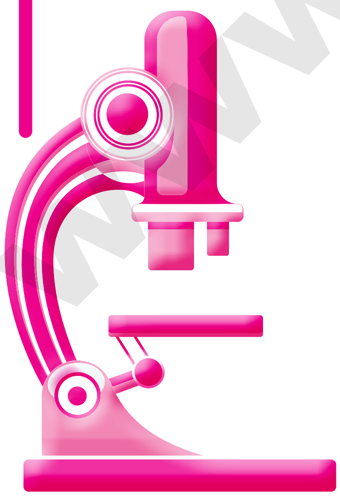
CHEMISTRY

Volume II

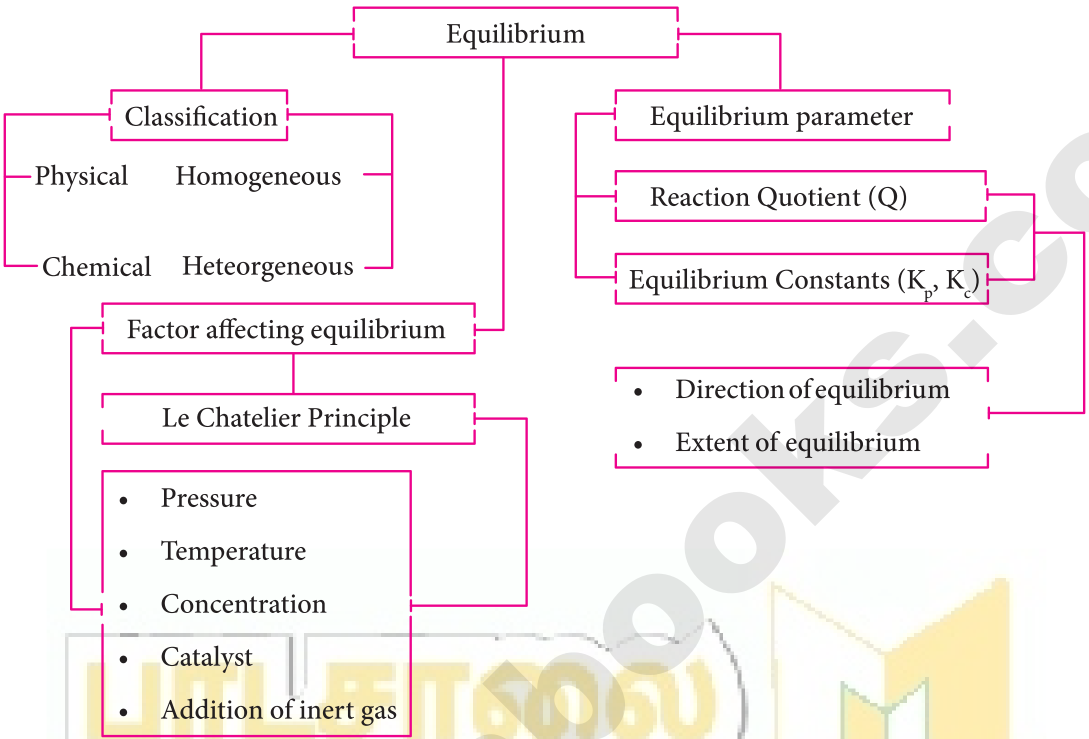


CONTENTS

08 PHYSICAL AND CHEMICAL EQUILIBRIUM

CHAPTER SNAPSHOT

CONCEPT MAP



FORMULAE TO REMEMBER

- $a\text{A} + b\text{B} \rightleftharpoons c\text{C} + d\text{D}$
- **Rate of forward reaction (R_f) :**
  $R_f = k_f\ [A]^a\ [B]^b$
  k_f - rate constant of forward reaction
  $[A]^a\ [B]^b$ - molar concentrations of A and B.
- **Rate of backward reaction (R_b) :**
  $R_b = k_b\ [C]^c\ [D]^d$
  k_b - rate constant of backward reaction
  $[C]^c\ [D]^d$ - molar concentrations of C and D.
- **Equilibrium constant in terms of moles (K_c) :**
  $$K_C = \frac{[C]^c\,[D]^d}{[A]^a\,[B]^b}$$
- **Equilibrium constant in terms of partial pressure (K_p) :**
  $$K_p = \frac{p_C^c\ p_D^d}{p_A^a\ p_B^b}$$
  p_A, p_B, p_C, and p_D - partial pressures of A, B, C and D in the reaction.

✷ **Relation between K_p and K_c :**

$K_p = K_c (RT)^{\Delta n_g}$

K_p & K_c

R - Gas constant

$\Delta n_g = n_p - n_r$

Δn_g = Total no. of moles of gaseous products (n_p) - Total no. of moles of reactants (n_r).

✷ **Reaction Quotient (Q) :**

Under non-equilibrium condition

$$Q_c = \frac{[C]^c [D]^d}{[A]^a [B]^b} \qquad Q_p = \frac{p_A^a \; p_B^b}{p_C^c \; p_D^d}$$

Q_c and Q_p - reaction quotient in terms of molar concentration and partial pressure.

✷ **Vant - Hoff Equation :**

$$\log \frac{K_2}{K_1} = \frac{\Delta H}{2.303\ R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right]$$

$$\log \frac{K_2}{K_1} = \frac{\Delta H}{2.303\ R}\left[\frac{T_2 - T_1}{T_1 T_2}\right]$$

MUST KNOW DEFINITIONS

Irreversible reaction	:	Reaction when go to completion and never proceed in the reverse direction are called irreversible reactions.
Reversible reaction	:	Reaction which can go in the forward and backward direction simultaneously are called reversible reactions.
State of chemical equilibrium	:	In case of reversible reactions, when the concentration of reactants and products do not change with time (or) the stage at which the rate of forward reaction becomes equal to rate of backward reaction is called chemical equilibrium state.
Physical equilibrium	:	If the opposing process involve only physical changes, the equilibrium is called physical equilibrium.
Solid - liquid equilibrium	:	Melting of Ice $\underset{\text{Ice}}{H_2O_{(s)}} \rightleftharpoons \underset{\text{Water}}{H_2O_{(l)}}$
Liquid - vapour equilibrium	:	Evaporation of water in a closed vessel $H_2O_{(l)} \rightleftharpoons H_2O_{(g)}$
Solid - vapour equilibrium	:	Sublimation equilibrium $Camphor_{(s)} \rightleftharpoons Camphor_{(Vapour)}$
Solid in liquid	:	Dissolution of sugar in water $Sugar_{(s)} \rightleftharpoons Sugar_{(in\ solution)}$

EVALUATION

I. Choose The Best Answer :

1. If K_b and K_f for a reversible reactions are 0.8×10^{-5} and 1.6×10^{-4} respectively, the value of the equilibrium constant is, *[June-2019]*

(a) 20 (b) 0.2×10^{-1} (c) 0.05

(d) none of these **[Ans. (a) 20]**

Hint: Equilibrium constant, K_C is equal to K_b/k_f

2. At a given temperature and pressure, the equilibrium constant values for the equilibria

$$3A_2 + B_2 + 2C \underset{}{\overset{K_1}{\rightleftharpoons}} 2A_3BC \text{ and}$$

$$A_3BC \overset{K_2}{\rightleftharpoons} \frac{3}{2}[A_2] + \frac{1}{2}B_2 + C$$

The relation between K_1 and K_2 is

(a) $K_1 = \frac{1}{\sqrt{K_2}}$ (b) $K_2 = K_1^{-1/2}$

(c) $K_1^2 = 2K_2$ (d) $\frac{K_1}{2} = K_2$

[Ans. (b) $K_2 = K_1^{-1/2}$]

3. The equilibrium constant for a reaction at room temperature is K_1 and that at 700 K is K_2. If $K_1 > K_2$, then

(a) The forward reaction is exothermic

(b) The forward reaction is endothermic

(c) The reaction does not attain equilibrium

(d) The reverse reaction is exothermic

[Ans. (a) The forward reaction is exothermic]

4. The formation of ammonia from $N_{2(g)}$ and $H_{2(g)}$ is a reversible reaction

$$N_{2(g)} + 3H_{2(g)} \rightleftharpoons 2NH_{3(g)} + \text{Heat}$$

What is the effect of increase of temperature on this equilibrium reaction

(a) equilibrium is unaltered

(b) formation of ammonia is favoured

(c) equilibrium is shifted to the left

(d) reaction rate does not change

[Ans. (c) Equilibrium is shifted to the left]

5. Solubility of carbon dioxide gas in cold water can be increased by

(a) increase in pressure (b) decrease in pressure

(c) increase in volume (d) none of these

[Ans. (a) increase in pressure]

Hint: It is because due to increase in intra molecular force of attraction. Solubility of carbon dioxide gas in cold water is increased.

6. Which one of the following is incorrect statement ?

(a) for a system at equilibrium, Q is always less than the equilibrium constant.

(b) equilibrium can be attained from either side of the reaction.

(c) presence of catalyst affects both the forward reaction and reverse reaction to the same extent.

(d) equilibrium constant varied with temperature.

[Ans. (a) for a system at equilibrium, Q is always less than the equilibrium constant.]

7. K_1 and K_2 are the equilibrium constants for the reactions respectively.

$$N_{2(g)} + O_{2(g)} \overset{K_1}{\rightleftharpoons} 2NO_{(g)}$$

$$2NO_{(g)} + O_{2(g)} \overset{K_2}{\rightleftharpoons} 2NO_{2(g)}$$

What is the equilibrium constant for the reaction $NO_{2(g)} \rightleftharpoons ½N_{2(g)} + O_{2(g)}$

(a) $\frac{1}{\sqrt{K_1K_2}}$ (b) $(K_1 = K_2)^{1/2}$

(c) $\frac{1}{2K_1K_2}$ (d) $\left(\frac{1}{K_1K_2}\right)^{3/2}$

[Ans. (a) $\frac{1}{\sqrt{K_1K_2}}$]

8. In the equilibrium,

$$2A(g) \rightleftharpoons 2B(g) + C_2(g)$$

the equilibrium concentrations of A, B and C_2 at 400 K are 1×10^{-4} M, 2.0×10^{-3} M, 1.5×10^{-4} M respectively. The value of K_C for the equilibrium at 400 K is

(a) 0.06 (b) 0.09 (c) 0.62 (d) 3×10^{-2}

[Ans. (a) 0.06]

Hint: Law of mass action formula.

9. An equilibrium constant of 3.2×10^{-6} for a reaction means, the equilibrium is *[HY-2018]*

(a) largely towards forward direction
(b) largely towards reverse direction
(c) never established
(d) none of these

[Ans. (b) largely towards reverse direction]

10. $\frac{K_C}{K_p}$ for the reaction,

$N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$ is

(a) $\frac{1}{RT}$ (b) $\sqrt{RT}$ (c) RT (d) $(RT)^2$

[Ans. (d) $(RT)^2$]

Hint: K_p and K_C is the relationship between k_p is equal to K_c. (RT) Δn_g.

11. For the reaction $AB(g) \rightleftharpoons A(g) + B(g)$, at equilibrium, AB is 20% dissociated at a total pressure of P, The equilibrium constant K_P is related to the total pressure by the expression

(a) $P = 24\ K_P$ (b) $P = 8\ K_P$
(c) $24\ P = K_P$ (d) none of these

[Ans. (a) $P = 24\ K_P$]

12. In which of the following equilibrium, K_P and K_C are not equal?

(a) $2\ NO(g) \rightleftharpoons N_2(g) + O_2(g)$
(b) $SO_2(g) + NO_2 \rightleftharpoons SO_3(g) + NO(g)$
(c) $H_2(g) + I_2(g) \rightleftharpoons 2HI(g)$
(d) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

[Ans. (d) $PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$]

13. If x is the fraction of PCl_5 dissociated at equilibrium in the reaction

$$PCl_5 \rightleftharpoons PCl_3 + Cl_2$$

then starting with 0.5 mole of PCl_5, the total number of moles of reactants and products at equilibrium is

(a) 0.5 – x (b) x + 0.5
(c) 2x + 0.5 (d) x + 1

[Ans. (b) x + 0.5]

14. The values of K_{P_1} and K_{P_2} for the reactions

$$X \rightleftharpoons Y + Z$$

$A \rightleftharpoons 2B$ are in the ratio 9 : 1 if degree of dissociation and initial concentration of X and A be equal then total pressure at equilibrium P_1, and P_2 are in the ratio

(a) 36 : 1 (b) 1 : 1
(c) 3 : 1 (d) 1 : 9

[Ans. (a) 36 : 1]

15. In the reaction,

$Fe(OH)_3(s) \rightleftharpoons Fe^{3+}(aq) + 3OH^-(aq)$,

if the concentration of OH^- ions is decreased by ¼ times, then the equilibrium concentration of Fe^{3+} will

(a) not changed
(b) also decreased by ¼ times
(c) increase by 4 times (d) increase by 64 times

[Ans. (d) increase by 64 times]

16. Consider the reaction where $K_P = 0.5$ at a particular temperature

$$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$$

if the three gases are mixed in a container so that the partial pressure of each gas is initially 1 atm, then which one of the following is true

(a) more PCl_3 will be produced
(b) more Cl_2 will be produced
(c) more PCl_5 will be produced
(d) none of these

[Ans. (c) more PCl_5 will be produced]

17. Equimolar concentrations of H_2 and I_2 are heated to equilibrium in a 1 litre flask. What percentage of initial concentration of H_2 has reacted at equilibrium if rate constant for both forward and reverse reactions are equal

(a) 33% (b) 66%
(c) $(33)^2$ % (d) 16.5 %

[Ans. (a) 33%]

18. In a chemical equilibrium, the rate constant for the forward reaction is 2.5×10^2 and the equilibrium constant is 50. The rate constant for the reverse reaction is, *[HY-2019]*

(a) 11.5 (b) 5
(c) 2×10^2 (d) 2×10^{-3}

[Ans. (b) 5]

19. Which of the following is not a general characteristic of equilibrium involving physical process

(a) Equilibrium is possible only in a closed system at a given temperature.
(b) The opposing processes occur at the same rate and there is a dynamic but stable condition.
(c) All the physical processes stop at equilibrium.
(d) All measurable properties of the system remains constant.

[Ans. (c) All the physical processes stop at equilibrium.]

Short Answers Questions: 3 MARKS

1. A liquid is in equilibrium with its vapour in a sealed container at a fixed temperature. The volume of the container is suddenly increased.

(i) What is the initial effect of change on vapour pressure?

(ii) How do rates of evaporation and condensation change initially?

(iii) What happens when equilibrium is restored finally and what will be the final vapour pressure?

Ans. $A_{(l)} \longrightarrow A_{(g)}$

Low pressure High pressure

If volume is increased at constant temperature, pressure decreases, since, $p \propto 1/V$ at constant temperature.

(i) Decrease in pressure shifts the equilibrium in the direction of high pressure i.e. more vapour is formed hence vapour pressure increases.

(ii) Rate of evaporation increases and rate of condensation decreases.

(iii) When equilibrium is restored finally the rate of evaporation again becomes equal to the rate of condensation and the final vapour pressure becomes equal to the vapour pressure that was before the sudden increase in the volume of the container.

2. Find out the value of K_c for each of the following equilibria from the value of K_p

(i) $2NOCl_{(g)} \rightleftharpoons 2NO_{(g)} + Cl_{2(g)}$; $K_p = 2.1 \times 10^{-2}$ at 500 K

(ii) $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$; $K_p = 165$ at 1073 K.

Ans. (i) $2NOCl_{(g)} \rightleftharpoons 2NO_{(g)} + Cl_{2(g)}$

$$K_p = 2.1 \times 10^{-2} \text{ at } 500\text{ K}$$

$$\Delta n_g = n_p - n_R = 3 - 2 = 1$$

$$K_c = \frac{K_P}{(RT)^{\Delta n_g}} = \frac{2.1\times10^{-2}}{0.0821\times500} = 5.12 \times 10^{-4}$$

(ii) $CaCO_{3(s)} \rightleftharpoons CaO_{(s)} + CO_{2(g)}$

$$K_p = 165 \text{ at } 1073\text{ K}$$

$$\Delta n_g = n_p - n_R = 1$$

$$K_c = \frac{K_P}{(RT)^{\Delta n_g}} = \frac{165}{0.0821\times1073} = 1.87.$$

3. List out few examples of irreversible reactions (changes) taking place in our daily life activity.

Ans. (i) Ripening of fruits and vegetables in few days.

(ii) Tarnishing of silver in few months.

(iii) Rusting of iron slowly.

4. (i) Write a note on biochemical reversible change

(ii) State whether the existence of equilibrium is possible in our lungs or not. Give reason.

Ans. (i) The transport of oxygen by haemoglobin in our body as an illustration for a reversible change. The haemoglobin combines with oxygen in lungs to form oxyhaemoglobin. The oxy-haemoglobin has a tendency to form haemoglobin by releasing oxygen. In fact, in our lungs all the three species coexist.

(ii) The state of equilibrium exist in our lungs because, the three species namely haemoglobin, oxygen (reactants) and oxyhaemoglobin (product) are said to co-exist in our lungs.

5. Discuss the equilibrium involving dissolution of solids or gases in liquids.

Ans. **Solid in liquids :**

- When you add sugar to water at a particular temperature, it dissolves to form sugar solution. If you continue to which the added sugar remains as solid and the resulting solution is called a saturated solution. Here, as in the previous cases a dynamic equilibrium is established between the solute molecules in the solid phase and in the solution phase.

Sugar (Solid) $\rightleftharpoons$ Sugar (Solution)

In this process

Rate of dissolution of solute = Rate of crystallisation of solute

Gas in liquids :

- When a gas dissolves in a liquid under a given pressure, there will be an equilibrium between gas molecules in the gaseous state and those dissolved in the liquid.
- In carbonated beverages the following equilibrium exists. $CO_2\text{ (g)} \rightleftharpoons CO_2\text{ (s)}$
- Henry's law is used to explain such gas-solution equilibrium processes.

6. Give the relationship between K_p and K_c for the following cases with example.

(i) $\Delta n_g = +ve$ (ii) $\Delta n_g = -ve$ (iii) $\Delta n_g = 0$

Ans. (i) **When $\Delta n_g = +ve$**

$K_p = K_c (RT)^{+ve}$

$K_p > K_c$

Example :

$2NH_3(g) \rightleftharpoons N_2(g) + 3H_2(g)$

$PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)$

10 CHEMICAL BONDING

CHAPTER SNAPSHOT

FORMULAE TO REMEMBER

- Dipole moment (μ) = Charge (Q) × Distance of separation (*r*)
- According to Linear combination of Atomic Orbitals,
  - $\Psi_{MO} = \Psi_A \pm \Psi_B$
  - $\Psi_{bonding} = \Psi_A + \Psi_B$
  - $\Psi_{antibonding} = \Psi_A - \Psi_B$
- Bond order = $\frac{1}{2} = (N_b - N_a)$

MUST KNOW DEFINITIONS

Octet rule	:	The atoms transfer or share electrons so that all atoms involved in chemical bonding obtain 8 electrons in their outer shell (valence shell).
Chemical bond	:	The strong force of binding between two or many atoms is referred to as a chemical bond.
Ionic bond	:	The electrostatic attraction force existing between the cation and anion produced by the electron transfer from one atom to other is known as ionic bond.
Co-ordinate bond	:	The bond formed between the donor and acceptor atoms is called co-ordinate or co-ordinate covalent bond.
Covalent bond	:	A chemical bond formed when two atoms mutually share a pair of electron is called covalent bond.
Single covalent bond	:	When two atoms share one electron pair they are said to be joined by a single covalent bond.
Double covalent bond	:	If two atoms share two pairs of electrons, the covalent bond between them is called a double bond.
Triple bond	:	When combining atoms share three electron pairs a triple bond is formed.
Lattice Enthalpy	:	The lattice enthalpy of an ionic solid is defined as the energy required to completely separate one mole of a solid ionic compound into gaseous constituent ions.
Bond length	:	Bond length is defined as the distance between the nuclei of two covalenty bonded atoms in a molecule.
Bond angle	:	It is defined as the angle between the orbitals containing bonding electron pairs around the central atom in a molecule/complex ion
Bond enthalpy	:	It is defined as the amount of energy required to break one mole of a particular bond in molecules in their state. The unit of bond enthalpy is kJ mol^{-1}.

Resonance	:	According to the concept of resonance, whenever a single Lewis structure cannot describe a molecule accurately, a number of structures with similar energy, positions of nuclei, bonding and non-bonding pairs of electrons are taken as the canonical structures of the hybrid which describes the molecule accurately.
Dipole moment	:	The dipole moment is defined as the product of the magnitude of the charge and the distance between the centres of positive and negative charge.
Pi bond	:	A bond formed by the sidewise overlapping of p orbitals is called pi bond. It is weaker than sigma bond.
Sigma bond	:	A bond formed due to the overlapping of orbitals along the internuclear axis is called sigma bond. It is stronger than pi bond
Hybridisation	:	It is defined as "Inter mixing of orbitals of the same atom with comparable energy to form equal number of new equivalent orbitals with same energy".
Bonding molecular orbital	:	The molecular orbital formed as a result of the constructive interference of the atomic orbitals. $\Psi_{BMO} = \Psi_A + \Psi_B$
Anti-Bonding molecular orbital	:	Antibonding molecular orbital can be formed as a result of the destructive interference of the atomic orbitals.
Bond order	:	Bond order is defined as half the difference between the number of electrons in bonding and the number of electrons in antibonding molecular orbitals..
Diamagnetic	:	If all the electrons in the molecule are paired, then the molecule is diamagnetic in nature.
Paramagnetic	:	If the molecule has unpaired electrons, then it is said to be paramagnetic in nature.

EVALUATION

I. Choose The Best Answer :

1. In which of the following Compounds does the central atom obey the octet rule?

(a) XeF_4 (b) $AlCl_3$
(c) SF_6 (d) SCl_2 **[Ans. (d) SCl_2]**

Hint: All atoms accept or donate until there are 8 electrons in its outermost orbit.

2. In the molecule O_A ═ C ═ O_B, the formal charge on O_A, C and O_B are respectively.

(a) –1, 0, + 1 (b) +1, 0, –1
(c) –2, 0, +2 (d) 0, 0, 0

[Ans. (d) 0, 0, 0]

3. Which of the following is electron deficient? *[Sep-2020]*

(a) PH_3 (b) $(CH_3)_2$
(c) BH_3 (d) NH_3 **[Ans. (c) BH_3]**

Hint: Each Boron atom contains 6 electrons, in their outer shell so Octet rule is incomplete, because diborane is electron deficient

4. Which of the following molecule contain no π bond?

(a) SO_2 (b) NO_2
(c) CO_2 (d) H_2O **[Ans. (d) H_2O]**

5. The ratio of number of sigma (σ) and pi (π) bonds in 2- butynal is

(a) 8/3 (b) 5/3 (c) 8/2 (d) 9/2

[Ans. (a) 8/3]

Hint: single bond contains one sigma bond; double bond contains one sigma bond and one P_1 bond.

6. Which one of the following is the likely bond angles of sulphur tetrafluoride molecule?
(a) 120°,80° (b) 109°.28 (c) 90° (d) 89°,117°
[Ans. (d) 89°,117°]

7. Assertion : Oxygen molecule is paramagnetic.
Reason : It has two unpaired electron in its bonding molecular orbital.
(a) both assertion and reason are true and reason is the correct explanation of assertion
(b) both assertion and reason are true but reason is not the correct explanation of assertion
(c) assertion is true but reason is false
(d) Both assertion and reason are false
[Ans. (c) assertion is true but reason is false]

8. According to Valence bond theory, a bond between two atoms is formed when
(a) fully filled atomic orbitals overlap
(b) half filled atomic orbitals overlap
(c) non-bonding atomic orbitals overlap
(d) empty atomic orbitals overlap
[Ans. (b) half filled atomic orbitals overlap]

9. In ClF_3, NF_3 and BF_3 molecules the chlorine, nitrogen and boron atoms are
(a) sp^3 hybridised
(b) sp^3, sp^3 and sp^2 respectively
(c) sp^2 hybridised
(d) sp^3d, sp^3 and sp^2 hybridised respectively
[Ans. (d) sp^3d, sp^3 and sp^2 hybridised respectively]

10. When one s and three p orbitals hybridise,
(a) four equivalent orbitals at 90° to each other will be formed
(b) four equivalent orbitals at 109° 28' to each other will be formed.
(c) four equivalent orbitals, that are lying the same plane will be formed
(d) none of these
[Ans. (b) four equvivalent orbitals at 109° 28' to each other will be formed.]

11. Which of these represents the correct order of their increasing bond order.
(a) $C_2 < C_2^{2-} < O_2^{2-} < O_2$ (b) $C_2^{2-} < C_2^{+} < O_2 < O_2^{2-}$
(c) $O_2^{2-} < O_2 < C_2^{2-} < C_2^{+}$ (d) $O_2^{2-} < C_2^{+} < O_2 < C_2^{2-}$
[Ans. (d) $O_2^{2-} < C_2^{+} < O_2 < C_2^{2-}$]

12. Hybridisation of central atom in PCl_5 involves the mixing of orbitals.
(a) s, p_x, p_y, $d_x{}^2$, $d_{x^2-y^2}$ (b) s, p_x . p_y, p_{xy} . $d_{x^2-y^2}$
(c) s, p_x, p_y, p_z, $d_{x^2-y^2}$ (d) s, p_x, p_y, d_{xy}, $d_{x^2-y^2}$
[Ans. (c) s, p_x, p_y, p_z, $d_{x^2-y^2}$]

13. The correct order of O-O bond length in hydrogen peroxide, ozone and oxygen is
(a) $H_2O_2 > O_3 > O_2$ (b) $O_2 > O_3 > H_2O_2$
(c) $O_2 > H_2O_2 > O_3$ (d) $O_3 > O_2 > H_2O_2$
[Ans. (b) $O_2 > O_3 > H_2O_2$]

14. Which one of the following is diamagnetic?
(a) O_2 (b) O_2^{2-} (c) O_2^{+}
(d) None of these **[Ans. (b) O_2^{2-}]**

15. Bond order of a species is 2.5 and the number of electons in its bonding molecular orbital is formed to be 8. The no. of electons in its antibonding molecular orbital is
(a) three (b) four
(c) zero
(d) can not be calculated from the given information.
[Ans. (a) three]

16. Shape and hybridisation of IF_5 are *[June-2019]*
(a) Trigonal bipyramidal, Sp^3d^2
(b) Trigonal bipyramidal, Sp^3d
(c) Square pyramidal, Sp^3d^2
(d) Octahedral, Sp^3d^2
[Ans. (c) Square pyramidal, Sp^3d^2]

17. Pick out the incorrect statement from the following.
(a) Sp^3 hybrid orbitals are equivalent and are at an angle of 109° 28' with eachother
(b) dsp^2 hybrid orbitals are equivalent and bond angle between any two of them is 90°
(c) All five sp^3d hybrid orbitals are not equivalent out of these five sp^3d hybrid orbitals, three are at an angle of 120°, remaining two are perpendicular to the plane containing the other three
(d) None of these
[Ans. (c) All five sp^3d hybrid orbitals are not equivalent out of these five sp^3d hybrid orbitals, three are at an angle of 120°, remaining two are perpendicular to the plane containing the other three]

18. The molecules having same hybridisation, shape and number of lone pairs of electons are
(a) SeF_4, XeO_2F_2 (b) SF_4, XeF_2
(c) $XeOF_4$, TeF_4 (d) $SeCl_4$, XeF_4
[Ans. (a) SeF_4, XeO_2F_2]

19. In which of the following molecules / ions BF_3, NO_2^-, H_2O the central atom is sp^2 hybridised?
(a) NH_2^- and H_2O (b) NO_2^- and H_2O
(c) BF_3 and NO_2^- (d) BF_3 and NH_2^-
[Ans. (c) BF_3 and NO_2^-]

20. Some of the following properties of two species, NO_3^- and H_3O^+ are described below. which one of them is correct?
(a) dissimilar in hybridisation for the central atom with different structure.
(b) isostructural with same hybridisation for the Central atom.
(c) different hybridiration for the central atom with same structure
(d) none of these
[Ans. (a) dissimilar in hybridisation for the central atom with different structure.]

21. The types of hybridiration on the five carbon atom from right to left in the, 2,3 pentadiene.
(a) sp^3, sp^2, sp, sp^2, sp^3 (b) sp^3, sp, sp, sp, sp^3
(c) sp^2, sp, sp^2, sp^2, sp^3 (d) sp^3, sp^3, sp^2, sp^3, sp^3
[Ans. (a) sp^3, sp^2, sp, sp^2, sp^3]

22. XeF_2 is isostructural with
(a) $SbCl_2$ (b) $BaCl_2$
(c) TeF_2 (d) ICl_2^- **[Ans. (d) ICl_2^-]**

23. The percentage of s-character of the hybrid orbitals in methane, ethane, ethene and ethyne are respectively
(a) 25, 25, 33.3, 50 (b) 50, 50, 33.3, 25
(c) 50, 25, 33.3, 50 (d) 50, 25, 25, 50
[Ans. (a) 25, 25, 33.3, 50]

24. Of the following molecules, which have shape similar to carbon dioxide?
(a) $SnCl_2$ (b) NO_2
(c) C_2H_2 (d) All of these
[Ans. (c) C_2H_2]

25. According to VSEPR theory, the repulsion between different parts of electrons obey the order.
(a) l.p – l.p > b.p – b.p > l.p – b.p
(b) b.p – b.p > b.p – l.p > l.p – b.p
(c) l.p – l.p > b.p – l.p > b.p – b.p
(d) b.p – b.p > l.p – l.p > b.p – l.p
[Ans. (c) l.p – l.p > b.p – l.p > b.p – b.p]

26. Shape of ClF_3 is *[HY-2019]*
(a) Planar triangular (b) Pyramidal
(c) 'T' Shaped (d) none of these
[Ans. (c) 'T' Shaped]

27. Non-Zero dipole moment is shown by
(a) CO_2 (b) p-dichlorobenzene
(c) carbontetrachloride (d) water
[Ans. (d) water]

28. Which of the following conditions is not correct for resonating structures?
(a) the contributing structure must have the same number of unpaired electrons
(b) the contributing structures should have similar energies
(c) the resonance hybrid should have higher energy than any of the contributing structure.
(d) none of these
[Ans. (c) the resonance hybrid should have higher energy than any of the contributing structures.]

29. Among the following, the compound that contains, ionic, covalent and co-ordinate linkage is
(a) NH_4Cl (b) NH_3
(c) NaCl (d) none of these
[Ans. (a) NH_4Cl]

30. CaO and NaCl have the same crystal structure and approximately the same radii. If U is the lattice energy of NaCl, the approximate lattice energy of CaO is
(a) U (b) 2U
(c) U/2 (d) 4U
[Ans. (d) 4U]

II. Write Brief Answer To The Following Questions:

31. Define the following
i) Bond order *[HY-2019; Sep-2021]*
ii) Hybridisation *[Sep-2020]*
iii) σ- bond

Ans. i) **Bond order :** The number of bonds formed between the two bonded atoms in a molecule is called the bond order.

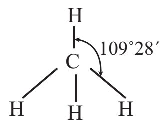
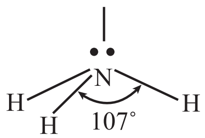
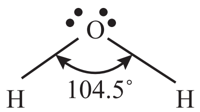
ii) **Hybridisation :** Hybridisation is the process of mixing of atomic orbitals of the same atom with comparable energy to form equal number of new equivalent orbitals with same energy.

iii) **σ- bond :** When two atomic orbitals overlap linearly along the intermolecular, the resultant bond is called a sigma (σ) bond.

32. What is a pi bond?
Ans. When two atomic orbitals overlaps sideways, the resultant covalent bond is called a pi (π) bond.

33. In CH_4, NH_3 and H_2O, the central atom undergoes sp^3 hybridisation - yet their bond angles are different. why?

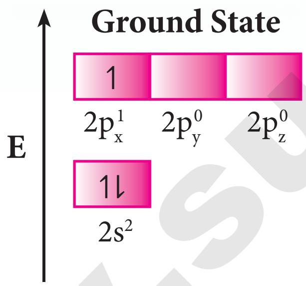
Ans.

Molecule	Structure	Atomic arrangement	Bond angle	Reason for reduction in bond angle
CH_4		❑ The central carbon atom has four valence electrons and each hydrogen atom gives one electron ❑ Minimum repulsions between the bond pairs	109°28'	The minimum repulsion between the bond pairs leads to a regular tetrahedron with an angle of 109° 28'
NH_3		❑ The central N-atom is surrounded by three bond pairs and one lone pair. ❑ lp – bp repulsions > bp – bp repulsion	107°	The repulsion between these electron pairs will be minimum if the shape of NH_3 is pyramidal. Hence the bond angle gets reduced from 109° 28' to 107°
H_2O		❑ The central O -atom has 2 lone pairs & 2 bond pairs. ❑ The lp – lp repulsions > lp – bp repulsion.	104°5'	Due to greater lp – lp repulsion the bond angle gets reduced to 104° 5'

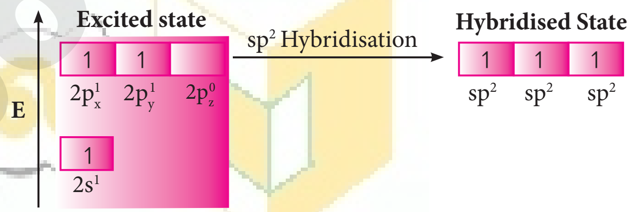
34. Explain sp^2 hybridisation in BF_3.

Ans. **sp^2 Hybridisation :**

- ❑ Consider boron trifluoride molecule. The valence shell electronic configuration of boron atom is $1s^2\ 2s^2\ 2p^1$.

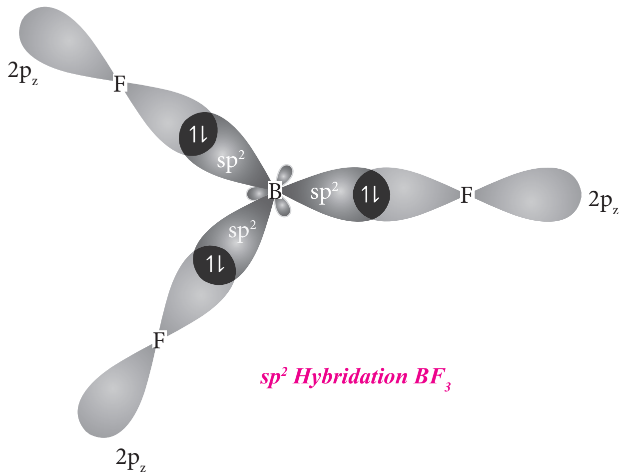


- ❑ In the ground state boron has only one unpaired electron in the valence shell. In order to form three covalent bonds with fluorine atoms, three unpaired electrons are required. To achieve this, one of the paired electrons in the 2s orbital is promoted to the $2p_y$ orbital in the excited state.
- ❑ In boron, one s orbital and two p orbitals (p_x and p_y) in the valence shell hybridses, to generate three equivalent sp^2 orbitals as shown in the Figure. These three orbitals lie in the same xy plane and the angle between any two orbitals is equal to 120°



Overlap with 2pz orbitals of fluorine :

- ❑ The three sp^2 hybridised orbitals of boron now overlap with the $2p_z$ orbitals of fluorine (3 atoms). This overlap takes place along the axis as shown below.



sp^2 Hybridation BF_3

35. Draw the M.O diagram for oxygen molecule calculate its bond order and show that O_2 is paramagnetic.

Ans. **Molecular orbital diagram of oxygen molecule (O_2) :**

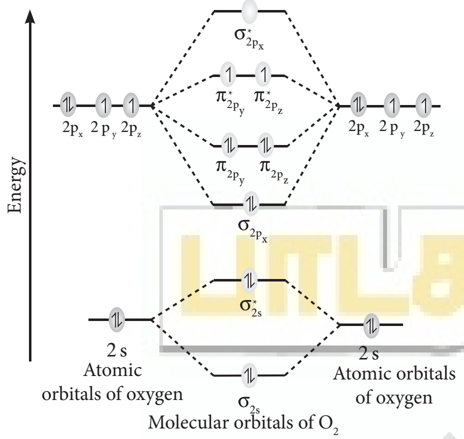
Electronic configuration of O atom $1s^2\ 2s^2\ 2p^4$

Electronic configuration of O_2 molecule

$$\sigma_{1s}^2,\ \sigma_{1s}^{*2},\ \sigma_{2s}^2,\ \sigma_{2s}^{*2},\ \sigma_{2p_x}^2,\ \pi_{2p_y}^2,\ \pi_{2p_z}^2,\ \pi_{2p_y}^{*1},\ \pi_{2p_z}^{*1}$$

$$\text{Bond order} = \frac{N_b - N_a}{2} = \frac{10-6}{2} = 2$$

Molecule has two unpaired electrons hence it is paramagnetic.



MO Diagram for O_2 molecule

36. Draw MO diagram of CO and calculate its bond order. *[June-2019]*

Ans. **Bonding in some heteronuclear di-atomic molecules :**

Molecular orbital diagram of Carbon monoxide molecule (CO)

Electronic configuration of C atom $1s^2\ 2s^2\ 2p^2$

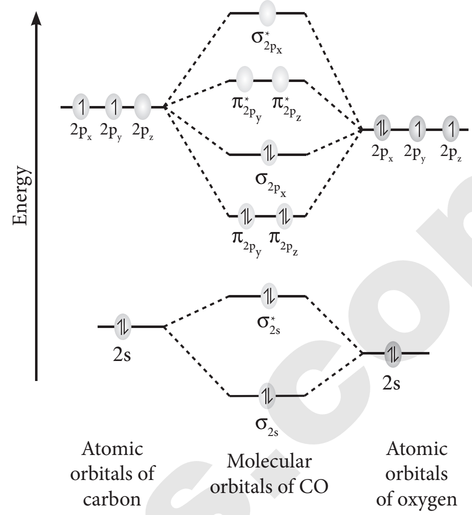
Electronic configuration of O atom $1s^2\ 2s^2\ 2p^4$

Electronic conguration of CO molecule

$$\sigma_{1s}^2,\ \sigma_{1s}^{*2},\ \sigma_{2s}^2,\ \sigma_{2s}^{*2},\ \pi_{2p_y}^2,\ \pi_{2p_z}^2,\ \sigma_{2p_x}^2$$

$$\text{Bond order} = \frac{N_b - N_a}{2} = \frac{10-4}{2} = 3$$

Molecule has no unpaired electrons hence it is diamagnetic.



MO Diagram for CO molecule

37. What do you understand by Linear combination of atomic orbitals in MO theory.

Ans. **Linear combination of atomic orbitals :**

- The wave functions for the molecular orbitals can be obtained by solving Schrödinger wave equation for the molecule. Since solving the Schrödinger equation is too complex, approximation methods are used to obtain the wave function for molecular orbitals. The most common method is the linear combination of atomic orbitals (LCAO).
- The atomic orbitals are represented by the wave function ψ. Let us consider two atomic orbitals represented by the wave function ψ_A and ψ_B with comparable energy, combines to form two molecular orbitals. One is bonding molecular orbital ($\psi_{bonding}$) and the other is antibonding molecular orbital ($\psi_{antibonding}$). The wave functions for these two molecular orbitals can be obtained by the linear combination of the atomic orbitals ψ_A and ψ_B as below.

$$\psi_{bonding} = \psi_A + \psi_B$$
$$\psi_{antibonding} = \psi_A - \psi_B$$

- The formation of bonding molecular orbital can be considered as the result of constructive interference of the atomic orbitals and the formation of anti-bonding molecular orbital can be the result of the destructive interference of the atomic orbitals. The formation of the two molecular orbitals from two 1s orbitals is shown below.