PART II: CHEMISTRY

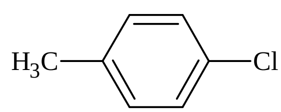
SECTION 1 [Maximum Marks: 28]

- This section contains **SEVEN** questions
- Each question has **FOUR** options [A], [B], [C] and [D]. **ONE OR MORE THAN ONE** of these four options is (are) correct.
- For each question, darken the bubble(s) corresponding to all the correct option(s) in the ORS
- For each question, marks will be awarded in one of the following categories:

Full Marks	: +4	If only the bubble(s) corresponding to all the correct option(s) is (are) darkened
Partial Marks	: +1	For darkening a bubble corresponding **to each correct option**, provided NO incorrect option is darkened.
Zero Marks	: 0	If none of the bubbles is darkened
Negative Marks	: –2	In all other cases

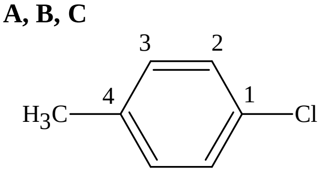
- For example, if [A], [C] and [D] are all the correct options for a question, darkening all these three will result in +4 marks; darkening only [A] and [D] will result in +2 marks; and darkening [A] and [B] will result in –2 marks, as a wrong option is also darkened.

*Q.19 The IUPAC name(s) of the following compound is(are)



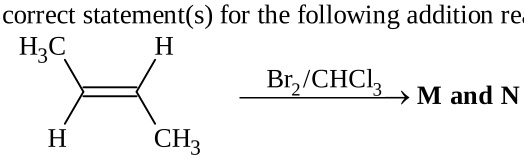
[A] 4-methylchlorobenzene
[B] 4-chlorotoluene
[C] 1-chloro-4-methylbenzene
[D] 1-methyl-4-chlorobenzene

Sol. **A, B, C**

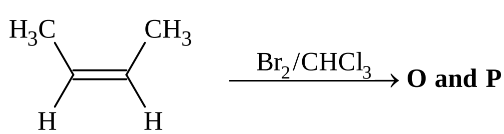


*Q.20 The correct statement(s) for the following addition reactions is(are)

(i)

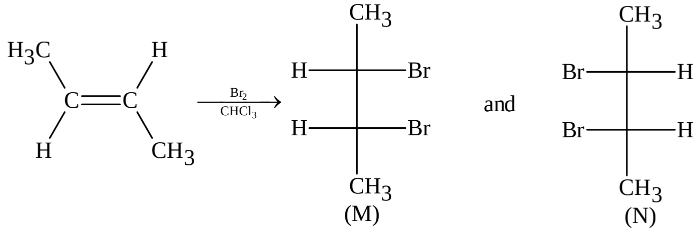


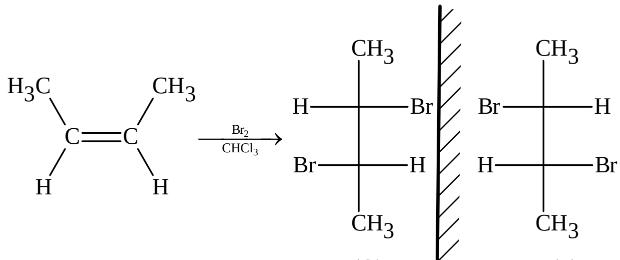
(ii)



[A] (**M** and **O**) and (**N** and **P**) are two pairs of diastereomers
[B] Bromination proceeds through *trans*-addition in both the reactions
[C] **O** and **P** are identical molecules
[D] (**M** and **O**) and (**N** and **P**) are two pairs of enantiomers

Sol. **A, B**





(O) (P)

(M and O) and (N and P) have no mirror image relationship. Hence these two pairs are diastereomers. Bromination proceeds through trans-addition in both the reactions.

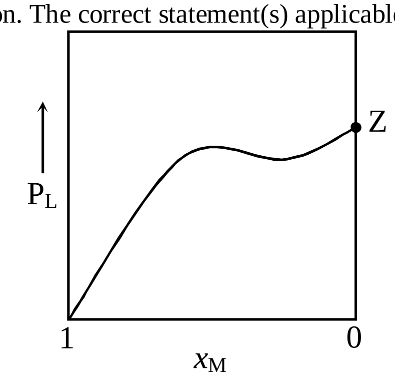
Q.21 Addition of excess aqueous ammonia to a pink coloured aqueous solution of $MCl_2.6H_2O$(**X**) and NH_4Cl gives an octahedral complex **Y** in the presence of air. In aqueous solution, complex **Y** behaves as 1 :3 electrolyte. The reaction of **X** with excess HCl at room temperature results in the formation of a blue coloured complex **Z**. The calculated spin only magnetic moment of **X** and **Z** is 3.87 B.M., whereas it is zero for complex **Y**.
Among the following options, which statement(s) is(are) correct?
[A] The hybridization of the central metal ion in **Y** is d^2sp^3
[B] **Z** is a tetrahedral complex
[C] Addition of silver nitrate to **Y** gives only two equivalents of silver chloride
[D] When **X** and **Z** are in equilibrium at 0^0C, the colour of the solution is pink

Sol. **A, B, D**

$$\underset{\substack{(X)\\ \text{Octahedral(pink)}\\ (\mu=3.87\text{ B.M.})}}{\left[Co(H_2O)_6\right]Cl_2} \xrightarrow[\text{air}]{\text{Aq.}NH_3+NH_4Cl} \underset{\substack{(Y)\\ (\mu=0)}}{\left[Co(NH_3)_6\right]Cl_3}$$

$$\underset{(X)}{\left[Co(H_2O)_6\right]^{2+}} + HCl(\text{excess}) \xrightleftharpoons{0^o C} \underset{\substack{\text{tetrahedral(blue)}\\ (\mu=3.87\text{ B.M.})}}{\left[CoCl_4\right]^{2-}} \;,\; \Delta H = +ve$$

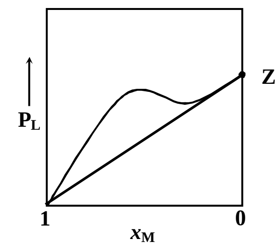
Q.22 For a solution formed by mixing liquids **L** and **M,** the vapour pressure of **L** plotted against the mole fraction of **M** in solution is shown in the following figure. Here x_L and x_M represent mole fractions of **L** and **M**, respectively, in the solution. The correct statement(s) applicable to this system is(are)



[A] Attractive intermolecular interactions between **L-L** in pure liquid **L** and **M-M** in pure liquid **M** are stronger than those between **L-M** when mixed in solution
[B] The point **Z** represents vapour pressure of pure liquid **M** and Raoult's law is obeyed when $x_L \rightarrow 0$
[C] The point **Z** represents vapour pressure of pure liquid **L** and Raoult's law is obeyed when $x_L \rightarrow 1$
[D] The point **Z** represents vapour pressure of pure liquid **M** and Raoult's law is obeyed from $x_L = 0$ to $x_L = 1$

Sol. **A, C**

From graph it is clear that there is +ve deviation w.r.t L. Therefore option A is correct. When $x_L \to 1$, then Z will have value equal to P_L^0 (vapour pressure of pure L). Therefore option C is also correct.



*Q.23 An ideal gas is expanded from (p_1, V_1, T_1) to (p_2, V_2, T_2) under different conditions. The correct statement(s) among the following is(are)

[A] The work done on the gas is maximum when it is compressed irreversibly from (p_2, V_2) to (p_1, V_1) against constant pressure p_1

[B] The work done by the gas is less when it is expanded reversibly from V_1 to V_2 under adiabatic conditions as compared to that when expanded reversibly from V_1 to V_2 under isothermal conditions

[C] The change in internal energy of the gas is (i) zero, if it is expanded reversibly with $T_1 = T_2$, and (ii) positive, if it is expanded reversibly under adiabatic conditions with $T_1 \neq T_2$

[D] If the expansion is carried out freely, it is simultaneously both isothermal as well as adiabatic

Sol. **A, B, D**

Q.24 The correct statement(s) about the oxoacids, $HClO_4$ and HClO, is(are)

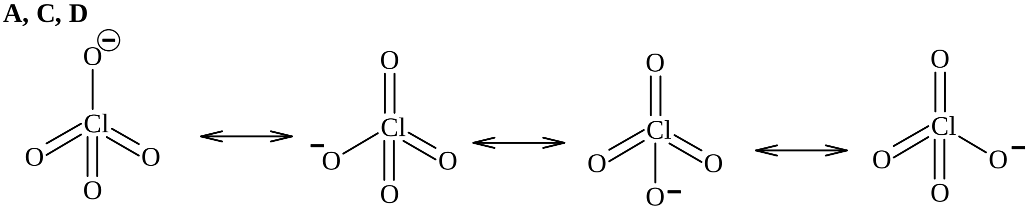
[A] $HClO_4$ is more acidic than HClO because of the resonance stabilization of its anion

[B] $HClO_4$ is formed in the reaction between Cl_2 and H_2O

[C] The central atom in both $HClO_4$ and HClO is sp^3 hybridized

[D] The conjugate base of $HClO_4$ is weaker base than H_2O

Sol. **A, C, D**



Conjugate base of $HClO_4$ has four canonical structures.

$Cl—O^{\ominus}$ (Conjugate base of HOCl) is not resonance stabilized

$\Rightarrow$ The central atoms Cl in $HClO_4$ and O in HOCl respectively are sp^3 hybridized.

$\Rightarrow$ $HClO_4$ is stronger acid than H_3O^+, so ClO_4^- is weaker base than H_2O.

Q.25 The colour of the X_2 molecules of group 17 elements changes gradually from yellow to violet down the group. This is due to

[A] the physical state of X_2 at atom temperature changes from gas to solid down the group

[B] decrease in HOMO-LUMO gap down the group

[C] decrease in π^*-σ^* gap down the group

[D] decrease in ionization energy down the group

Sol. **B, C**

Highest occupied molecular orbital (HOMO) $\Rightarrow \pi^*$

Lowest unoccupied molecular orbital (LUMO) $\Rightarrow \sigma^*$

On descending the group gap between π^* and σ^* decreases.

SECTION – 2 [Maximum Marks: 15]

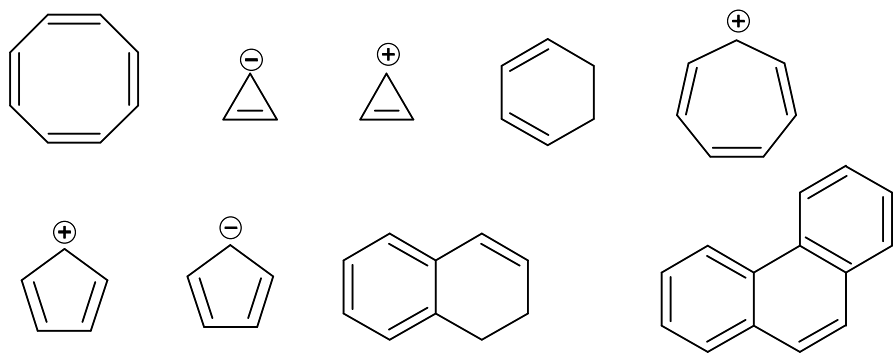
- This section contains **FIVE** questions.
- The answer to each question is a **SINGLE DIGIT INTEGER** ranging from 0 to 9, both inclusive.
- For each question, darken the bubble corresponding to the correct integer in the ORS.
- For each question, marks will be awarded in one of the following categories:
  Full Marks : +3 If only the bubble corresponding to the correct answer is darkened.
  Zero Marks : 0 In all other cases.

*Q.26 Among $H_2, He_2^+, Li_2, Be_2, B_2, C_2, N_2, O_2^-$, and F_2, the number of diamagnetic species is
(Atomic numbers: H = 1, He = 2, Li = 3, Be = 4, B = 5, C = 6, N = 7, O = 8, F = 9)

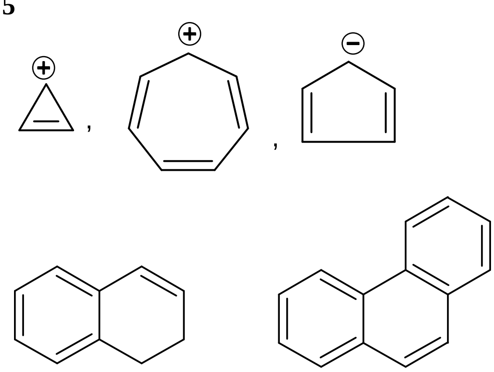
Sol. **6**
H_2, Li_2, Be_2, C_2, N_2 and F_2 are diamagnetic species.

* However because Be_2 does not exits the answer may well be 5

*Q.27 Among the following, the number of aromatic compound(s) is



Sol. **5**



Q.28 The conductance of a 0.0015 M aqueous solution of a weak monobasic acid was determined by using a conductivity cell consisting of platinized Pt electrodes. The distance between the electrodes is 120 cm with an area of cross section of 1 cm^2. The conductance of this solution was found to be 5×10^{-7} S. The pH of the solution is 4. The value of limiting molar conductivity $\left(\Lambda_m^o\right)$ of this weak monobasic acid in aqueous solution is $Z \times 10^2$ S cm^{-1} mol^{-1}. The value of Z is

Sol. **6**

$$\kappa = G \times \frac{\ell}{a}$$

$$\kappa = 5 \times 10^{-7} \times \frac{120\ \text{cm}}{1\ \text{cm}^2} = 6 \times 10^{-5}\ \text{S cm}^{-1}$$

$$\Lambda_m^C = \frac{\kappa \times 1000}{C} = \frac{6\times10^{-5}\times1000}{0.0015}$$

pH = 4, $[H^+] = 10^{-4} = C\alpha$

$$\alpha = \frac{10^{-4}}{0.0015}$$

$$\alpha = \frac{\Lambda_m^C}{\Lambda_m^o}$$

$$\frac{10^{-4}}{0.0015} = \frac{6\times10^{-5}\times1000}{0.0015\times\Lambda_m^o}$$

$\Lambda_m^0 = 6 \times 10^2$

Z = 6

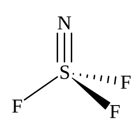
Q.29 The sum of the number of lone pairs of electrons on each central atom in the following species is

$$[TeBr_6]^{2-}, [BrF_2]^+, SNF_3, \text{ and } [XeF_3]^-$$

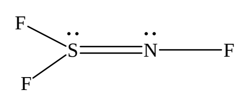
(Atomic numbers : N = 7, F = 9, S = 16, Br = 35, Te = 52, Xe = 54)

Sol. **6**

Species		Number of lone pairs
$[TeBr_6]^{-2}$	$\rightarrow$	1
$[BrF_2]^{+1}$	$\rightarrow$	2
SNF_3	$\rightarrow$	0



most stable



however an alternate structure also exits

$[XeF_3]^{-1}$	$\rightarrow$	3

$\therefore$ Sum is = 1 + 2 + 0 + 3 = 6 lone pair

Q.30 A crystalline solid of a pure substance has a face-centred cubic structure with a cell edge of 400 pm. If the density of the substance in the crystal is 8 g cm^{-3}, then the number of atoms present in 256 g of the crystal is $N \times 10^{24}$. The value of *N* is

Sol. **2**

$$d = \frac{Z\times M}{N_A \times a^3}$$

$$8 = \frac{4\times M}{6.022\times10^{23}\times\left(400\times10^{-10}\right)^3}$$

M = 76.8 g mol^{-1}

76.8 g contain = 6×10^{23} atoms

$\therefore$ 256 g will contain = 20×10^{23} atoms

= 2×10^{24} atoms

$\therefore$ N = 2

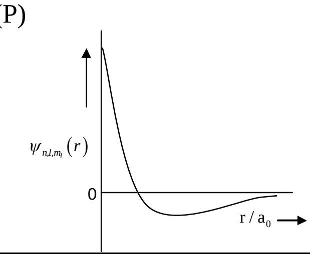
SECTION 3 (Maximum Marks: 18)

- This section contains **SIX** questions
- The section contains **TWO** tables (each having 3 columns and 4 rows)
- Based on each table, there are **THREE** questions
- Each question has **FOUR** options [A], [B], [C], and [D]. **ONLY ONE** of these four options is correct
- For each question, darken the bubble corresponding to the correct option in the ORS
- For each question, marks will be awarded in one of the following categories:

Full Marks : +3 If only the bubble corresponding to the correct option is darkened
Zero Marks : 0 If none of the bubbles is darkened
Negative Marks : - 1 In all other cases

Answer Q. 31, Q. 32 and Q. 33 by appropriately matching the information given in the three columns of the following table.

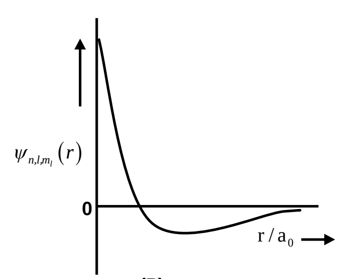
The wave function ψ_{n,l,m_l} is a mathematical function whose value depends upon spherical polar coordinates (r, θ, ϕ) of the electron and characterized by the quantum numbers n, l and m_l. Here r is distance from nucleus, θ is colatitude and ϕ is azimuth. In the mathematical functions given in the Table, Z is atomic number and a_0 is Bohr radius.

Column 1	Column 2	Column 3
(I) 1s orbital	(i) $\psi_{n,l,m_l} \propto \left(\frac{Z}{a_0}\right)^{\frac{3}{2}} e^{-\left(\frac{Zr}{a_0}\right)}$	(P) 
(II) 2s orbital	(ii) One radial node	(Q) Probability density at nucleus $\propto \frac{1}{a_0^3}$
(III) $2p_z$ orbital	(iii) $\psi_{n,l,m_l} \propto \left(\frac{Z}{a_0}\right)^{\frac{5}{2}} re^{-\left(\frac{Zr}{2a_0}\right)} \cos\theta$	(R) Probability density is maximum at nucleus
(IV) $3d_z^2$ orbital	(iv) *xy*-plane is a nodal plane	(S) Energy needed to excite electron from n = 2 state to n = 4 state is $\frac{27}{32}$ times the energy needed to excite electron from n = 2 state to n = 6 state

*Q.31 For the given orbital in Column 1, the only CORRECT combination for any hydrogen-like species is
[A] (IV) (iv) (R) [B] (II) (ii) (P) [C] (III) (iii) (P) [D] (I) (ii) (S)

Sol. **B**

$\underset{\text{(II)}}{\text{2s orbital}} - \text{One radial } \underset{\text{(ii)}}{\text{node}} (n - \ell - 1)$



(P)

*Q.32 For He^+ ion, the only **INCORRECT** combination is

[A] (II) (ii) (Q) [B] (I) (i) (S) [C] (I) (i) (R) [D] (I) (iii) (R)

Sol. **D**

1s orbital can not have θ function (angular function).
Therefore D is incorrect.

*Q.33 For hydrogen atom, the only CORRECT combination is

[A] (I) (iv) (R) [B] (I) (i) (P) [C] (II) (i) (Q) [D] (I) (i) (S)

Sol. **D**

For H-atom:

$$\underset{(I)}{\text{1s orbital}} - \Psi_{n\ell m} \propto \underset{(i)}{\left(\frac{Z}{a_0}\right)^{3/2}} e^{-\left(\frac{Zr}{a_0}\right)}, S$$

$$E_4 - E_2 = -\frac{13.6}{16} - \left(-\frac{13.6}{4}\right) = \frac{3 \times 13.6}{16}$$

$$E_6 - E_2 = -\frac{13.6}{36} - \left(-\frac{13.6}{4}\right) = \frac{8 \times 13.6}{36}$$

$E_4 - E_2$ is $\frac{27}{32}$ times of $E_6 - E_2$

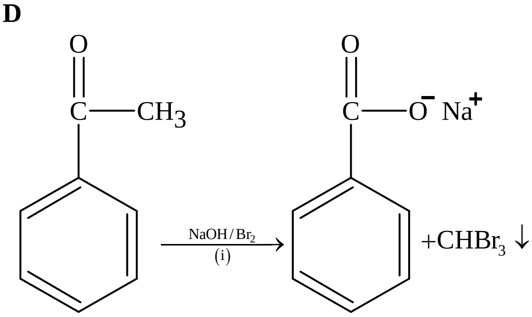
Answer Q. 34, Q. 35 and Q. 36 by appropriately matching the information given in the three columns of the following table.

Columns 1, 2 and 3 contain starting materials, reaction conditions, and type of reactions, respectively.		
Column 1	**Column 2**	**Column 3**
(I) Toluene	(i) $NaOH/Br_2$	(P) Condensation
(II) Acetophenone	(ii) $Br_2/h\nu$	(Q) Carboxylation
(III) Benzaldehyde	(iii) $(CH_3CO)_2O/CH_3COOK$	(R) Substitution
(IV) Phenol	(iv) $NaOH/CO_2$	(S) Haloform

Q.34 For the synthesis of benzoic acid, the only CORRECT combination is

[A] (III) (iv) (R) [B] (IV)(ii) (P) [C] (I) (iv) (Q) [D] (II) (i) (S)

Sol. **D**

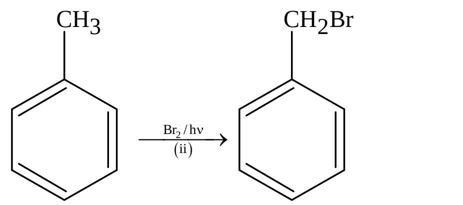


(II) Haloform reaction (S)

Q.35 The only CORRECT combination in which the reaction proceeds through radical mechanism is

[A] (I) (ii) (R) [B] (II) (iii) (R) [C] (III) (ii) (P) [D] (IV) (i) (Q)

Sol. **A**



(I) Free radical substitution(R)

Q.36 The only CORRECT combination that gives two different carboxylic acids is

[A] (IV) (iii) (Q) [B] (III) (iii) (P) [C] (II) (iv) (R) [D] (I) (i) (S)

Sol. **B**