JEE Main Chemistry Sample Paper-6

Duration: 1 Hour **Maximum Marks: 100**

Instructions

- This paper contains TWO sections: **Section A** (MCQs) and **Section B** (Numerical).
- Section A contains 20 Multiple Choice Questions.
- Section B contains 5 Numerical Value Questions.
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries **-1 mark**.
- No negative marking for unattempted questions.

Section A — Multiple Choice Questions

Q1. The incorrect statement regarding geometrical isomerism among the following is: [JEE Main 2021]

(A) Propene shows geometrical isomerism.
(B) Trans isomer has identical groups on opposite sides.
(C) Cis-but-2-ene has a higher dipole moment than trans-but-2-ene.
(D) 2-methylbut-2-ene shows two geometrical isomers.

Q2. Identify the metameric pair among the given organic compounds: [JEE Main 2022]

(A) Pentan-2-one and Pentan-3-one
(B) Ethoxyethane and Propoxymethane
(C) Both (A) and (B)
(D) None of these

Q3. The major product obtained when methylcyclohexane undergoes monochlorination at 300°C followed by treatment with ethanolic KOH is: [JEE Main 2023]

(A) 1-methylcyclohexene

(B) 3-methylcyclohexene

(C) Methylenecyclohexane

(D) 4-methylcyclohexene

Q4. Which of the following species is non-aromatic in nature? [JEE Main 2020]

(A) Cycloheptatrienyl cation

(B) Cyclooctatetraene

(C) Benzene

(D) Cyclopentadienyl anion

Q5. The reaction of tert-butyl methyl ether with cold HI results in the formation of: [JEE Main 2022]

(A) *tert*-butyl iodide + Methanol

(B) *tert*-butanol + Methyl iodide

(C) *tert*-butyl iodide + Methyl iodide

(D) No reaction occurs

Q6. Predict the product of the reaction between propyne and dilute H_2SO_4 in the presence of $HgSO_4$: [JEE Main 2021]

(A) Propanal

(B) Propanone

(C) Propan-1-ol

(D) Propanoic acid

Q7. Intramolecular Cannizzaro reaction of glyoxal ($CHO - CHO$) in the presence of concentrated $NaOH$ followed by acidification gives: [JEE Main 2019]

(A) Glycolic acid

(B) Oxalic acid

(C) Ethane-1,2-diol

(D) Methanoic acid

Q8. The basic strength of the following amines in aqueous solution follows the order: [JEE Main 2022]

(A) $(C_2H_5)_2NH > (C_2H_5)_3N > C_2H_5NH_2 > NH_3$

(B) $(C_2H_5)_3N > (C_2H_5)_2NH > C_2H_5NH_2 > NH_3$

(C) $(C_2H_5)_2NH > C_2H_5NH_2 > (C_2H_5)_3N > NH_3$

(D) $NH_3 > C_2H_5NH_2 > (C_2H_5)_2NH > (C_2H_5)_3N$

Q9. Disulfide linkage is a critical stabilizing force in the tertiary structure of proteins. It is formed by: [JEE Main 2023]

(A) Oxidation of two Cysteine residues

(B) Reduction of two Methionine residues

(C) Hydrolysis of Peptide bonds

(D) Condensation of Glycine residues

Q10. Which of the following molecules has a central atom with sp^3d^2 hybridization? [JEE Main 2022]

(A) SF_6

(B) PCl_5

(C) BrF_5

(D) Both (A) and (C)

Q11. The shape and number of lone pairs on the central atom of ICl_2^- are: [JEE Main 2021]

(A) Linear, 3

(B) Bent, 2

(C) Trigonal planar, 0

(D) Linear, 2

Q12. The magnetic moment (spin-only) of $[CoF_6]^{3-}$ is approximately: [JEE Main 2020]

(A) 4.90 BM

(B) 1.73 BM

(C) 0 BM

(D) 3.87 BM

Q13. Which of the following is a homoleptic complex? [JEE Main 2021]

(A) $[Co(NH_3)_6]Cl_3$

(B) $[Co(NH_3)_4Cl_2]Cl$

(C) $[Ni(CO)_4]$

(D) Both (A) and (C)

Q14. In the modern periodic table, the element with the highest electron gain enthalpy (magnitude) is: [JEE Main 2022]

(A) Fluorine

(B) Chlorine

(C) Bromine

(D) Iodine

Q15. The group and period for the element with $Z = 78$ (Platinum) are: [JEE Main 2021]

(A) Group 10, Period 6

(B) Group 8, Period 5

(C) Group 10, Period 5

(D) Group 12, Period 6

Q16. What is the cell potential (E_{cell}) for the reaction $Zn(s) + Cu^{2+}(0.1M) \rightarrow Zn^{2+}(1M) + Cu(s)$ at $298K$? ($E^\circ_{cell} = 1.10V$) [JEE Main 2022]

(A) 1.07 V

(B) 1.13 V

(C) 1.10 V

(D) 1.04 V

Q17. For a first-order reaction, if the rate constant k is 0.693 min^{-1}, the time required for 75% completion is: [JEE Main 2023]

(A) 1 min

(B) 2 min

(C) 3 min

(D) 0.5 min

Q18. Which of the following quantum number sets is NOT possible for an electron? [JEE Main 2021]

(A) $n = 3, l = 2, m_l = 0, m_s = +1/2$

(B) $n = 2, l = 2, m_l = 1, m_s = -1/2$

(C) $n = 4, l = 0, m_l = 0, m_s = +1/2$

(D) $n = 3, l = 1, m_l = -1, m_s = -1/2$

Q19. The correct order of energy for the orbitals in a multielectron atom is: [JEE Main 2020]

(A) $4s < 3d < 4p$

(B) $3d < 4s < 4p$

(C) $4s < 4p < 3d$

(D) $3d < 4p < 4s$

Q20. For the process $H_2O(l) \rightarrow H_2O(g)$ at 1 atm and 100°C, the correct set of thermodynamic parameters is: [JEE Main 2021]

(A) $\Delta G = 0, \Delta S > 0$

(B) $\Delta G < 0, \Delta S > 0$

(C) $\Delta G = 0, \Delta S < 0$

(D) $\Delta G > 0, \Delta S > 0$

Section B — Numerical Questions

Q21. The cell potential for the following cell is 0.92 V at 298 K: $Pt_{(s)}|H_2(g, 1\text{ bar})|H^+(aq, 1\text{ M})||Cu^{2+}(aq, 0.01\text{ M})|Cu_{(s)}$. Given $E^\circ_{Cu^{2+}/Cu} = 0.34$ V. Calculate the pH of the solution in the anode compartment. [JEE Main 2023]

Q22. For the reaction $2A(g) + B(g) \rightarrow 2C(g)$, $\Delta U^\circ = -10$ kJ and $\Delta S^\circ = -45$ J/K at 300 K. Calculate ΔG° in Joules. (Use $R = 8.314$ J/K · mol and round to the nearest hundred) [JEE Main 2022]

Q23. Calculate the spin-only magnetic moment (in B.M.) of the complex $[Fe(H_2O)_6]^{2+}$. (Round off to the nearest integer). [JEE Main 2024]

Q24. A 5% (w/w) solution of cane sugar (molar mass 342) has a freezing point of 271 K. The freezing point of pure water is 273.15 K. Calculate the freezing point of a 5% (w/w) glucose solution (molar mass 180). (Round off to nearest integer). [JEE Main 2021]

Q25. Among the following, how many molecules have a non-zero dipole moment? $NF_3, BeF_2, H_2O, CO_2, NH_3, CH_4, PCl_3$ [JEE Main 2023]

Detailed Solutions

Q1.

Solution

Concept: For a molecule to exhibit Geometrical Isomerism (GI), it must satisfy two conditions:

(a) Restricted rotation around a bond (like a $C = C$ double bond or a ring).

(b) Each atom involved in the restricted rotation must be bonded to two different groups. If either carbon has two identical groups, GI is impossible.

Solution: Let us evaluate the options:

- **Propene ($CH_3 - CH = CH_2$):** The terminal carbon ($= CH_2$) is bonded to two identical hydrogen atoms. Switching them does not create a new spatial arrangement. Therefore, propene cannot show geometrical isomerism.
- **Trans isomers:** By definition, these have identical or similar groups on opposite sides of the double bond.
- **Dipole moment:** Cis-but-2-ene has two electron-donating methyl groups on the same side, creating a net dipole moment. In trans-but-2-ene, they are on opposite sides, canceling each other out ($\mu = 0$).
- Since propene cannot show GI, statement A is the incorrect one.

Answer: (A)

Q2.

Solution

Concept: Metamerism is a type of structural isomerism that occurs in compounds containing a polyvalent functional group (such as $-O-$, $-CO-$, $-S-$, or $-NH-$). Metamers have the same molecular formula but differ in the nature of the alkyl groups attached to either side of the functional group.

Solution: Let's analyze the given pairs:

- **Pair (A):** Pentan-2-one ($CH_3 - CO - CH_2CH_2CH_3$) has a methyl and a propyl group. Pentan-3-one ($CH_3CH_2 - CO - CH_2CH_3$) has two ethyl groups. The molecular formula is $C_5H_{10}O$ for both, but the alkyl chains around the carbonyl group are different. They are metamers.
- **Pair (B):** Ethoxyethane ($CH_3CH_2 - O - CH_2CH_3$) has two ethyl groups. Propoxymethane ($CH_3CH_2CH_2 - O - CH_3$) has a propyl and a methyl group. Both share the formula $C_4H_{10}O$ but have different alkyl distributions around the ether oxygen. They are also metamers.
- Since both pairs exhibit metamerism, option C is correct.

Answer: (C)

Q3.

Solution

Concept: This is a two-step sequence involving free radical substitution followed by an elimination reaction:

(a) **Free Radical Halogenation:** Replaces the most reactive hydrogen (forming the most stable radical, usually 3°).

(b) **Dehydrohalogenation (E2):** Strong bases like ethanolic KOH eliminate a proton and a halide to form a double bond. Zaitsev's Rule dictates that the most substituted, most stable alkene is the major product.

Solution:

- **Step 1:** Methylcyclohexane undergoes monochlorination. The tertiary (3°) carbon holding the methyl group forms the most stable free radical due to extensive hyperconjugation. This results in the formation of 1-chloro-1-methylcyclohexane.
- **Step 2:** Treatment with ethanolic KOH causes an E2 elimination. The base can remove a β-hydrogen from the external methyl group or from the adjacent ring carbons.
- Removing a ring hydrogen yields a trisubstituted alkene inside the ring. Removing the methyl hydrogen yields a disubstituted exocyclic alkene.
- According to Zaitsev's rule, the more stable trisubstituted alkene, 1-methylcyclohexene, is the major product.

Answer: (A)

Q4.

Solution

Concept: To be classified as aromatic, a compound must fulfill Hückel's criteria:

(a) Cyclic and Planar.

(b) Fully conjugated (every atom in the ring must have an unhybridized p-orbital).

(c) Contain exactly $4n + 2$ π-electrons ($n = 0, 1, 2, \ldots$).

Solution:

- **(A) Cycloheptatrienyl cation:** 7 carbons, cyclic, planar. It has 3 double bonds $= 6\pi$ electrons ($4n + 2$, where $n = 1$). The positive charge provides an empty p-orbital for full conjugation. It is aromatic.
- **(C) Benzene:** Standard aromatic ring with 6π electrons.
- **(D) Cyclopentadienyl anion:** 5 carbons, cyclic, planar. 2 double bonds $(4e^-)$ + 1 lone pair $(2e^-) = 6\pi$ electrons. It is aromatic.
- **(B) Cyclooctatetraene (COT):** It has 4 double bonds, meaning 8π electrons ($4n$ rule). To avoid extreme instability, COT bends into a "tub shape". Because it is no longer planar, conjugation is broken, making it non-aromatic.

Answer: (B)

Q5.

Solution

Concept: Cleavage of asymmetrical ethers by hydrogen halides (HI) proceeds via S_N1 or S_N2:

- If primary or secondary alkyl groups are present, S_N2 dominates (halide attacks less hindered carbon).
- If a tertiary (3°), benzylic, or allylic group is present, the reaction strictly follows an S_N1 mechanism due to carbocation stability.

Solution:

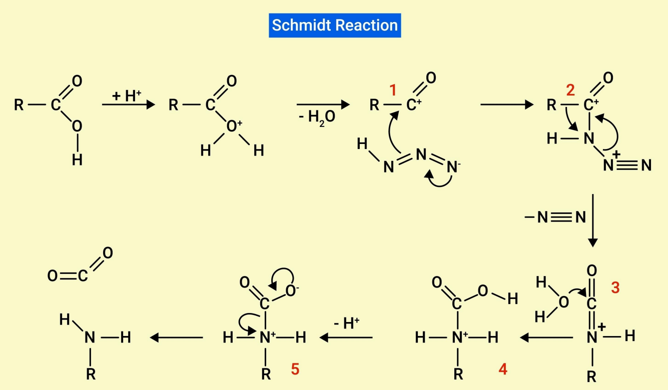
- The ether is tert-butyl methyl ether: $(CH_3)_3C - O - CH_3$.
- **Step 1:** Oxygen gets protonated by HI to form an oxonium ion.
- **Step 2:** Since the tert-butyl group forms a very stable 3° carbocation, the $C - O$ bond on the tertiary side breaks (S_N1). This releases methanol (CH_3OH).
- **Step 3:** The iodide ion (I^-) attacks the tert-butyl carbocation to form tert-butyl iodide.
- **Result:** tert-butyl iodide + Methanol.

Answer: (A)

Q6.

Solution

Concept: Alkyne reaction with dilute $H_2SO_4/HgSO_4$ is the **Kucherov reaction**. It follows Markovnikov's rule to form an enol intermediate, which tautomerizes to a carbonyl compound.



Solution:

- **Substrate:** Propyne $(CH_3 - C \equiv CH)$.
- **Electrophilic addition:** Water attacks the more substituted carbon (Hg^{2+} catalyst).
- **Intermediate:** Forms prop-1-en-2-ol (enol): $CH_3 - C(OH) = CH_2$.
- **Tautomerization:** Shifts to the keto form.
- **Final Product:** Propanone (Acetone), $CH_3 - CO - CH_3$.

Answer: (B)

Q7.

Solution

Concept: The **Cannizzaro reaction** is a redox disproportionation for aldehydes lacking α-hydrogens. When both groups are in the same molecule, it is intramolecular.
Solution:

- **Glyoxal** $(O = CH - CH = O)$ has zero α-hydrogens.
- Base (OH^-) attacks one carbonyl; a hydride ion (H^-) is ejected to the adjacent carbonyl.
- One side is oxidized to carboxylate $(-COO^-)$, the other reduced to alcohol $(-CH_2OH)$.
- Yields **Glycolic acid** $(HO - CH_2 - COOH)$.

$\boxed{\textbf{Answer: (A)}}$

Q8.

Solution

Concept: Aqueous basicity of amines depends on: 1. **Inductive effect $(+I)$:** Increases density. 2. **Solvation effect:** Stability by H-bonding with water. 3. **Steric hindrance:** Bulky groups block hydration.
Solution:

- For ethyl-substituted amines, the experimental basicity order is: **Secondary** > **Tertiary** > **Primary** > **Ammonia**.
- Mathematically: $(C_2H_5)_2NH > (C_2H_5)_3N > C_2H_5NH_2 > NH_3$.

$\boxed{\textbf{Answer: (A)}}$

Q9.

Solution

Concept: Tertiary protein structure is stabilized by various bonds, including covalent **disulfide bridges** $(-S - S-)$ formed by oxidation of specific sulfur-containing residues.
Solution:

- Glycine and Serine lack sulfur. Methionine's sulfur is in a thioether $(R - S - R)$ and cannot bridge.
- **Cysteine** contains a terminal sulfhydryl group $(-CH_2 - SH)$.
- Two cysteine side chains oxidize to form the disulfide bond.

$\boxed{\textbf{Answer: (A)}}$

Q10.

Solution

Concept: Hybridization calculated via Steric Number (SN): $H = \frac{1}{2}(V + M - C + A)$. SN of 6 = sp^3d^2.

Solution:

- SF_6**:** $H = \frac{1}{2}(6 + 6) = 6 \implies sp^3d^2$.
- PCl_5**:** $H = \frac{1}{2}(5 + 5) = 5 \implies sp^3d$.
- BrF_5**:** $H = \frac{1}{2}(7 + 5) = 6 \implies sp^3d^2$.
- Both SF_6 and BrF_5 have SN of 6.

Answer: (D)

Q11.

Solution

Concept: $SN = \frac{1}{2}(V + M - C + A)$. Lone pairs $= SN -$ bonded atoms.

Solution:

- ICl_2^-: Iodine ($V = 7$). $SN = \frac{1}{2}(7 + 2 + 1) = 5$.
- 3 lone pairs + 2 bond pairs.
- Lone pairs occupy equatorial positions; Cl atoms occupy axial positions.
- **Shape:** Linear.

Answer: (A)

Q12.

Solution

Concept: $\mu = \sqrt{n(n+2)}$ BM. n is unpaired electrons.

Solution:

- $[CoF_6]^{3-}$: Co is +3 ($3d^6$).
- F^- is a weak field ligand (High Spin).
- Filling: $t_{2g}^4 e_g^2 \implies n = 4$.
- $\mu = \sqrt{4(4+2)} = \sqrt{24} \approx 4.9$ BM.

Answer: (A)

Q13.

Solution

Concept: Homoleptic: Only one type of ligand. **Heteroleptic:** More than one type.
Solution:

- (A) $[Co(NH_3)_6]Cl_3$: Only NH_3 (Homoleptic).
- (B) $[Co(NH_3)_4Cl_2]Cl$: NH_3 and Cl^- (Heteroleptic).
- (C) $[Ni(CO)_4]$: Only CO (Homoleptic).

Answer: (D)

Q14.

Solution

Concept: Electron gain enthalpy ($\Delta_{eg}H$). Fluorine's small size causes inter-electronic repulsion.
Solution:

- Chlorine ($3p$) accommodates electrons better than Fluorine ($2p$).
- **Chlorine** (-349 kJ/mol) is more negative than Fluorine (-328 kJ/mol).

Answer: (B)

Q15.

Solution

Concept: The 5d series corresponds to Period 6.
Solution:

- **Platinum (Pt):** $Z = 78$. It belongs to the 5d series and is in **Group 10, Period 6**.

Answer: (A)

Q16.

Solution

Concept: Nernst Equation: $E_{cell} = E^{\circ}_{cell} - \frac{0.0591}{n}\log_{10} Q$.
Solution:

- $n = 2$, $Q = 1/0.1 = 10$.
- $E_{cell} = 1.10 - \frac{0.0591}{2}\log_{10}(10) = 1.07$ V.

$\boxed{\textbf{Answer: (A)}}$

Q17.

Solution

Concept: $t_{1/2} = 0.693/k$. 75% completion = 2 half-lives.
Solution:

- $t_{1/2} = 0.693/0.693 = 1$ min.
- Time $= 2 \times 1 = 2$ minutes.

$\boxed{\textbf{Answer: (B)}}$

Q18.

Solution

Concept: Quantum rules: $l < n$.
Solution:

- Option B $(n = 2, l = 2)$ is impossible. l must be ≤ 1.

$\boxed{\textbf{Answer: (B)}}$

Q19.

Solution

Concept: $(n + l)$ Rule for energy.
Solution:

- 4s (4), 3d (5), 4p (5). For tie, lower n fills first.
- $4s < 3d < 4p$.

$\boxed{\textbf{Answer: (A)}}$

Q20.

Solution

Concept: Phase equilibrium: $\Delta G = 0$. Vaporization: $\Delta S > 0$.

Solution:

- Water boiling at 100°C/1 atm is at equilibrium.
- $\Delta G = 0$ and $\Delta S > 0$.

Answer: (A)

Q21.

Solution

Solution:

(a) $E^\circ_{cell} = 0.34$ V, $n = 2$.

(b) $0.92 = 0.34 - \frac{0.059}{2} \log \frac{[H^+]^2}{0.01}$.

(c) $0.58 = -0.0295(2 \log[H^+] + 2)$.

(d) $\log[H^+] = -10.83 \implies \textbf{pH} = \textbf{10.83}$.

Answer: (10.83)

Q22.

Solution

Solution:

(a) $\Delta n_g = 2 - (2 + 1) = -1$.

(b) $\Delta H^\circ = \Delta U^\circ + \Delta n_g RT = -10,000 + (-1 \times 8.314 \times 300)$.

(c) $\Delta H^\circ = -10,000 - 2,494.2 = -12,494.2$ J.

(d) $\Delta G^\circ = \Delta H^\circ - T\Delta S^\circ = -12,494.2 - (300 \times -45)$.

(e) $\Delta G^\circ = -12,494.2 + 13,500 = 1,005.8$ J $\approx$ **1,000** J.

Answer: (1000)

Q23.

Solution

Solution:

(a) Fe in $[Fe(H_2O)_6]^{2+}$ is Fe^{2+}. Electronic configuration: $[Ar]3d^6$.

(b) H_2O is a weak field ligand; d-orbital distribution is $t_{2g}^4 e_g^2$.

(c) Number of unpaired electrons $(n) = 4$.

(d) $\mu = \sqrt{n(n+2)} = \sqrt{4(4+2)} = \sqrt{24} \approx 4.89$ B.M.

(e) Rounding to nearest integer: **5** B.M.

Answer: (5)

Q24.

Solution

Solution:

(a) For cane sugar: $\Delta T_f = 273.15 - 271 = 2.15$ K.

(b) $2.15 = K_f \times \frac{5\times1000}{342\times95}$.

(c) For glucose: $\Delta T_{f'} = K_f \times \frac{5\times1000}{180\times95}$.

(d) $\frac{\Delta T_{f'}}{2.15} = \frac{342}{180} \implies \Delta T_{f'} = 2.15 \times 1.9 = 4.085$ K.

(e) $T_f = 273.15 - 4.085 = 269.065$ K $\approx$ **269** K.

Answer: (269)

Q25.

Solution

Solution:

(a) Non-zero dipole moment $(\mu \neq 0)$ occurs in asymmetrical molecules.

(b) $\mu \neq 0$: NF_3 (Pyramidal), H_2O (Bent), NH_3 (Pyramidal), PCl_3 (Pyramidal).

(c) $\mu = 0$: BeF_2 (Linear), CO_2 (Linear), CH_4 (Tetrahedral).

(d) Total count of molecules with non-zero dipole moment = **4**.

Answer: (4)

Answer Key — Section A

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	C	3	A	4	B	5	A
6	B	7	A	8	A	9	A	10	D
11	A	12	A	13	D	14	B	15	A
16	A	17	B	18	B	19	A	20	A

Answer Key — Section B

Q	Ans	Q	Ans
21	10.83	22	1000
23	5	24	269
25	4		