JEE Main Chemistry Sample Paper-8

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. Which of the following carbocations is the most stable? [JEE Main 2022]

(A) $(CH_3)_3C^+$

(B) $C_6H_5CH_2^+$

(C) $CH_2 = CH - CH_2^+$

(D) $CH_3 - O - CH_2^+$

Q2. The number of stereoisomers possible for 2,3-dichlorobutane is: [JEE Main 2021]

(A) 2

(B) 3

(C) 4

(D) 5

Q3. An alkene on ozonolysis gives Methanal and 2-Butanone. The IUPAC name of the alkene is: [JEE Main 2023]

(A) 2-Methylbut-1-ene

(B) 2-Methylbut-2-ene

(C) Pent-2-ene

(D) 3-Methylbut-1-ene

Q4. Which will undergo S_N1 reaction fastest? [JEE Main 2022]

(A) CH_3CH_2Br

(B) $(CH_3)_3CBr$

(C) C_6H_5Br

(D) $CH_2 = CHBr$

Q5. The major product of the reaction of Phenol with Br_2 in CS_2 at 273 K is: [JEE Main 2020]

(A) 2,4,6-Tribromophenol

(B) o-Bromophenol

(C) p-Bromophenol

(D) m-Bromophenol

Q6. Which of the following will NOT undergo Cannizzaro reaction? [JEE Main 2023]

(A) Formaldehyde

(B) Benzaldehyde

(C) Trimethylacetaldehyde

(D) Acetaldehyde

Q7. The correct order of acidity for the following compounds is: [JEE Main 2021]

(A) $CF_3COOH > CCl_3COOH > CHCl_2COOH > CH_3COOH$

(B) $CH_3COOH > CHCl_2COOH > CCl_3COOH > CF_3COOH$

(C) $CCl_3COOH > CF_3COOH > CHCl_2COOH > CH_3COOH$

(D) $CF_3COOH > CHCl_2COOH > CCl_3COOH > CH_3COOH$

Q8. Hinsberg's reagent reacts with a primary amine to form a product that is: [JEE Main 2022]

(A) Insoluble in KOH

(B) Soluble in KOH

(C) Soluble in HCl

(D) A clear liquid

Q9. The glycosidic linkage between C1 of α-D-glucose and C2 of β-D-fructose is found in: [JEE Main 2023]

(A) Maltose

(B) Lactose

(C) Sucrose

(D) Amylose

Q10. The shape of XeF_4 and the number of lone pairs on Xe are: [JEE Main 2022]

(A) Tetrahedral, 0

(B) Square Planar, 2

(C) Octahedral, 2

(D) Square Pyramidal, 1

Q11. According to Molecular Orbital Theory (MOT), which of the following is diamagnetic? [JEE Main 2021]

(A) O_2

(B) B_2

(C) C_2

(D) N_2^+

Q12. Which molecule has the highest dipole moment? [JEE Main 2023]

(A) NF_3

(B) NH_3

(C) CO_2

(D) CH_4

Q13. The spin-only magnetic moment of $[Fe(H_2O)_6]^{2+}$ is: [JEE Main 2022]

(A) 4.90 BM

(B) 5.92 BM

(C) 2.84 BM

(D) 0 BM

Q14. The IUPAC name of the complex $[Co(NH_3)_5(CO_3)]Cl$ is: [JEE Main 2023]

(A) Pentaamminecarbonatocobalt(III) chloride

(B) Carbonatopentaamminecobalt(III) chloride

(C) Pentaamminecarbonatocobalt(II) chloride

(D) Pentaamminecobalt(III) carbonate chloride

Q15. The correct order of bond dissociation enthalpy for halogens is: [JEE Main 2021]

(A) $F_2 > Cl_2 > Br_2 > I_2$

(B) $Cl_2 > Br_2 > F_2 > I_2$

(C) $Cl_2 > F_2 > Br_2 > I_2$

(D) $F_2 > Br_2 > Cl_2 > I_2$

Q16. The correct order of first ionization enthalpy for the elements B, Be, C, N, O is: [JEE Main 2022]

(A) $B < Be < C < O < N$

(B) $B < Be < C < N < O$

(C) $Be < B < C < N < O$

(D) $B < Be < N < C < O$

Q17. For the cell reaction $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$, $E^o_{cell} = 0.24V$. The standard Gibbs energy (ΔG^o) is: [JEE Main 2023]

(A) -46.32 kJ/mol

(B) -23.16 kJ/mol

(C) +46.32 kJ/mol

(D) -92.64 kJ/mol

Q18. For a first-order reaction, if the time taken for 50% completion is 20 min, the time taken for 75% completion is: [JEE Main 2022]

(A) 30 min

(B) 40 min

(C) 60 min

(D) 80 min

Q19. The frequency of revolution of the electron in Bohr's orbit varies with n, the principal quantum number, as per the relation: [JEE Main 2022]

(A) $1/n$

(B) $1/n^3$

(C) $1/n^4$

(D) $1/n^2$

Q20. For an ideal gas undergoing isothermal reversible expansion, which of the following is true? [JEE Main 2023]

(A) $\Delta U = 0, q = -w$

(B) $\Delta U = \Delta H, q = 0$

(C) $w = 0, q = \Delta U$

(D) $\Delta U = q$

Section B — Numerical Questions

Q21. A compound C_4H_8O gives a positive 2,4-DNP test and does not reduce Tollens' reagent. On oxidation with $KMnO_4$, it forms $C_3H_6O_2$. Determine the molecular formula of the oxidation product. [JEE Main 2022]

Q22. A hydrocarbon C_5H_8 on reaction with Br_2 in CCl_4 gives a dibromo compound. When treated with HBr in presence of peroxides, it gives only one product. Determine the number of π-bond present in the hydrocarbon. [JEE Main 2021]

Q23. 100 mL of 1 M CH_3CH_2OH is completely reacted with Na to liberate hydrogen gas. Calculate the volume of H_2 gas at STP. [JEE Main 2020]

Q24. An amine reacts with nitrous acid to release 0.672 L of N_2 at STP. If the original solution contained 0.04 mol of the amine, determine whether the amine is primary, secondary, or tertiary. [JEE Main 2019]

Q25. The bond energy of H_2, Cl_2, and HCl are 436, 243, and 431 kJ/mol respectively. Calculate the enthalpy change (ΔH) for the reaction: $H_2 + Cl_2ß2HCl$. [JEE Main 2018]

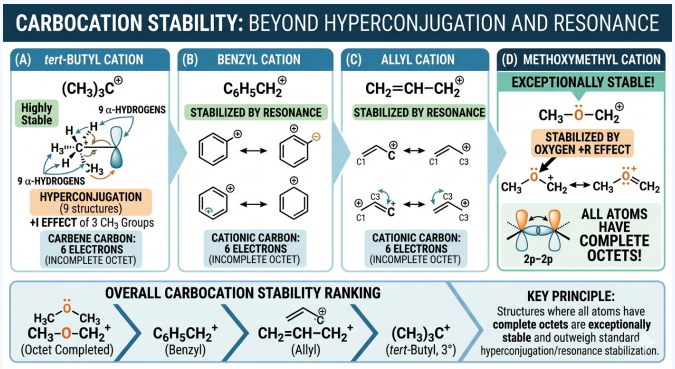
Detailed Solutions

Q1.

Solution

Concept:

The stability of intermediate carbocations is determined by factors like resonance, hyperconjugation, and inductive effects. Most importantly, structures in which all atoms have complete octets are exceptionally stable.



Solution:

Let us analyze the stability of each given carbocation:

- **(A)** $(CH_3)_3C^+$ **(tert-butyl cation):** Stabilized by the $+I$ (inductive) effect of three methyl groups and 9 α-hydrogens resulting in 9 hyperconjugation structures. It is highly stable.
- **(B)** $C_6H_5CH_2^+$ **(benzyl cation):** Stabilized by resonance, as the positive charge is delocalized over the benzene ring.
- **(C)** $CH_2 = CH - CH_2^+$ **(allyl cation):** Stabilized by resonance involving the adjacent double bond.
- **(D)** $CH_3 - O - CH_2^+$ **(methoxymethyl cation):** This is stabilized by the $+R$ (resonance) effect of the oxygen atom. The lone pair on the oxygen is donated to the empty p-orbital of the adjacent carbon atom.

The key distinction here is octet completion. When oxygen donates its lone pair ($CH_3 - O - CH_2^+ \leftrightarrow CH_3 - O^+ = CH_2$), every atom in the resulting resonance structure has a complete octet. Because all atoms have complete octets, this carbocation is much more stable than even the tert-butyl or benzyl cations, where the central carbon only has 6 valence electrons.

Answer: (D)

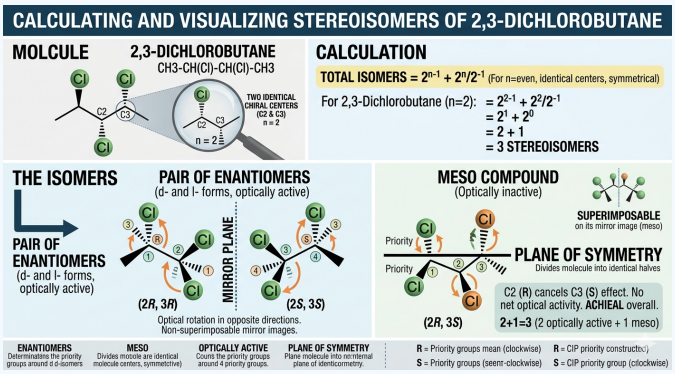
Q2.

Solution

Concept:

To find the number of stereoisomers for a symmetrical molecule with an even number of chiral centers (n), we use the formula:

$$Total = 2^{n-1} + 2^{\frac{n}{2}-1}$$



Solution:

The structure of 2,3-dichlorobutane is $CH_3 - CH(Cl) - CH(Cl) - CH_3$.

(a) **Identify chiral centers:** The molecule has two chiral carbon atoms ($C2$ and $C3$). Thus, $n = 2$.

(b) **Check for symmetry:** The molecule is symmetrical; it can be divided into two identical halves.

(c) **Calculate isomers:** Applying the formula for $n = 2$:

$$Total = 2^{2-1} + 2^{\frac{2}{2}-1} = 2^1 + 2^0 = 2 + 1 = 3$$

The three isomers are:

- d-isomer (enantiomer 1): $(2R, 3R)$-2,3-dichlorobutane
- l-isomer (enantiomer 2): $(2S, 3S)$-2,3-dichlorobutane
- Meso compound: $(2R, 3S)$-2,3-dichlorobutane (or $2S, 3R$). This isomer has an internal plane of symmetry and is optically inactive.

Answer: (B)

Q3.

Solution

Concept:

Ozonolysis cleaves the carbon-carbon double bond ($C = C$) and places an oxygen atom on each of the resulting ends to form carbonyl compounds. To find the original alkene, we perform reverse ozonolysis: align the carbonyl oxygen atoms of the products, remove them, and connect the corresponding carbons with a double bond.

Solution:

- **Given Products:** Methanal ($H_2C = O$) and 2-Butanone ($CH_3 - C(= O) - CH_2 - CH_3$)
- **Reconnection:**

$$CH_2 = O + O = C(CH_3)(CH_2CH_3) \rightarrow CH_2 = C(CH_3)(CH_2CH_3)$$

To name this alkene according to IUPAC rules:

(a) Select the longest continuous carbon chain containing the double bond, which is 4 carbons long (butene).

(b) Number the chain starting from the end closer to the double bond. The double bond starts at $C1$.

(c) There is a methyl substituent at $C2$.

Therefore, the IUPAC name is 2-Methylbut-1-ene.

Answer: (A)

Q4.

Solution

Concept:

The rate of an S_N1 (Substitution Nucleophilic Unimolecular) reaction is directly proportional to the stability of the intermediate carbocation formed in the slow, rate-determining step.

Solution:

Let us evaluate the intermediate carbocations formed by the dissociation of each halide:

- **(A)** CH_3CH_2Br**:** Yields a primary (1°) carbocation ($CH_3CH_2^+$), which is unstable.
- **(B)** $(CH_3)_3CBr$**:** Yields a tertiary (3°) carbocation ($(CH_3)_3C^+$), which is highly stable due to hyperconjugation (9 α-H) and the $+I$ effect of three methyl groups.
- **(C)** C_6H_5Br**:** Yields a phenyl cation. It is highly unstable because the positive charge is on an sp^2 hybridized carbon. Also, the C-Br bond has partial double-bond character due to resonance, preventing dissociation.
- **(D)** $CH_2 = CHBr$**:** Yields a vinyl cation. Highly unstable for the same reasons as the phenyl cation.

Because $(CH_3)_3CBr$ forms the most stable tertiary carbocation, it will undergo the S_N1 reaction the fastest.

Answer: (B)

Q5.

Solution

Concept:

The bromination of phenol depends heavily on the solvent. In a non-polar solvent like CS_2 at low temperatures, phenol undergoes monobromination. In polar solvents like water, it undergoes polybromination to form 2,4,6-tribromophenol.

Solution:

(a) **Solvent Effect:** Carbon disulfide (CS_2) is a non-polar solvent. Under these conditions and at a low temperature (273 K), the ionization of phenol to the highly activating phenoxide ion is strongly suppressed.

(b) **Substitution:** Because the ring is less activated than it would be in an aqueous medium, electrophilic aromatic substitution stops at monobromination.

(c) **Major Product:** The incoming bromine electrophile can attach at the ortho or para positions. However, due to the steric hindrance caused by the bulky $-OH$ group at the ortho position, the para isomer (p-Bromophenol) is formed as the major product.

Answer: (C)

Q6.

Solution

Concept:

The Cannizzaro reaction is a disproportionation reaction (simultaneous oxidation and reduction) specifically given by aldehydes that do **not** have α-hydrogens. Aldehydes with α-hydrogens undergo the Aldol condensation instead.

Solution:

Let's check the α-carbon (the carbon adjacent to the carbonyl group) for hydrogens in each option:

- **(A) Formaldehyde ($HCHO$):** Has no α-carbon, hence no α-hydrogens. Undergoes Cannizzaro.
- **(B) Benzaldehyde (C_6H_5CHO):** The α-carbon is part of the benzene ring and has its valency satisfied without any attached hydrogens. Undergoes Cannizzaro.
- **(C) Trimethylacetaldehyde ($(CH_3)_3CCHO$):** The α-carbon is attached to three methyl groups, not hydrogens. Undergoes Cannizzaro.
- **(D) Acetaldehyde (CH_3CHO):** The α-carbon has three hydrogens attached to it. Because it possesses α-hydrogens, it will undergo the Aldol condensation in the presence of a base, and will NOT undergo the Cannizzaro reaction.

Answer: (D)

Q7.

Solution

Concept:

The acidity of carboxylic acids is determined by the stability of the resulting carboxylate anion ($R - COO^-$). Electron-withdrawing groups ($-I$ effect) disperse the negative charge, stabilizing the conjugate base and increasing acidity. Electron-donating groups ($+I$ effect) destabilize it.

Solution:

We need to compare the inductive effects of the groups attached to the $-COOH$ part:

(a) **Fluorine vs. Chlorine:** Fluorine is highly electronegative, making the CF_3 group a much stronger electron-withdrawing group than CCl_3.

(b) **Number of Halogens:** Three chlorine atoms (CCl_3) exert a stronger electron-withdrawing pull than two chlorine atoms ($CHCl_2$).

(c) **Alkyl groups:** The methyl group (CH_3) is electron-donating ($+I$ effect), which increases electron density on the carboxylate ion, destabilizing it and significantly decreasing acidity.

Therefore, the decreasing order of the $-I$ effect is: $CF_3 > CCl_3 > CHCl_2 > CH_3$. The correct order of acidity exactly follows this trend:

$$CF_3COOH > CCl_3COOH > CHCl_2COOH > CH_3COOH$$

Answer: (A)

Q8.

Solution

Concept:

Hinsberg's reagent (benzenesulfonyl chloride, $C_6H_5SO_2Cl$) is used to distinguish between primary (1°), secondary (2°), and tertiary (3°) amines based on the solubility of the resulting sulfonamide in alkali.

Solution:

- **Reaction with 1° Amines:** Primary amines react with Hinsberg's reagent to form N-alkylbenzenesulfonamide.
- **Solubility:** The nitrogen atom in the resulting N-alkylbenzenesulfonamide still has one hydrogen atom attached to it. Because the adjacent sulfonyl group is strongly electron-withdrawing, this remaining hydrogen atom is highly acidic.
- **Result:** Due to the presence of this acidic hydrogen, the product readily reacts with a strong base like KOH (or NaOH) to form a water-soluble potassium (or sodium) salt.

Note: Secondary amines form a product with no acidic hydrogens (insoluble in KOH), and tertiary amines do not react.

Answer: (B)

Q9.

Solution

Concept:

Disaccharides are formed when two monosaccharides are joined by a glycosidic linkage. The specific monosaccharide units and the exact carbons involved in the linkage define the identity and properties (like reducing nature) of the disaccharide.

Solution:

Let's examine the structure of Sucrose:

- Sucrose is a common disaccharide composed of one unit of α-D-glucose and one unit of β-D-fructose.
- The glycosidic bond connects the anomeric carbon ($C1$) of the α-D-glucose moiety directly to the anomeric carbon ($C2$) of the β-D-fructose moiety.
- This specific connection is known as an $\alpha(1 \rightarrow 2)\beta$ glycosidic linkage.

Because both reducing centers (the anomeric carbons) are locked up in the glycosidic bond, sucrose cannot open to a free carbonyl form in solution, making it a non-reducing sugar.

Answer: (C)

Q10.

Solution

Concept:

To determine the molecular shape and the number of lone pairs on the central atom, we use Valence Shell Electron Pair Repulsion (VSEPR) theory.

Solution:

Let's calculate the hybridization and geometry for Xenon tetrafluoride (XeF_4):

(a) **Valence Electrons:** Xenon (Xe), a noble gas, has 8 valence electrons in its outermost shell.

(b) **Bond Pairs:** It forms 4 single covalent bonds with 4 Fluorine atoms. This uses up 4 of Xenon's valence electrons.

(c) **Lone Pairs:** The remaining 4 valence electrons ($8 - 4 = 4$) group together to form 2 lone pairs.

(d) **Geometry:** The central atom has a steric number of 6 (4 bond pairs + 2 lone pairs), corresponding to sp^3d^2 hybridization and an octahedral electron-domain geometry.

According to VSEPR theory, lone pairs occupy more space and repel each other strongly. To minimize repulsion in an octahedral arrangement, the two lone pairs occupy the axial positions (180° apart). This forces the four Fluorine atoms into the equatorial plane, resulting in a **square planar** molecular shape.

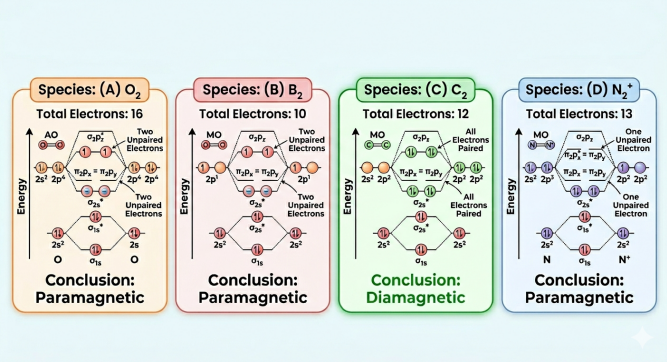
Answer: (B)

Q11.

Solution

Concept:

According to Molecular Orbital Theory (MOT), a molecule is diamagnetic if all its electrons are paired in molecular orbitals. It is paramagnetic if it contains one or more unpaired electrons. The electronic configuration depends on whether the total number of electrons is greater than or less than 14.



Solution:

Let's examine the MO configurations for each species:

- **(A)** O_2 **(16e$^-$):** $\sigma_{1s}^2\sigma_{1s}^{*2}\sigma_{2s}^2\sigma_{2s}^{*2}\sigma_{2p_z}^2(\pi_{2p_x}^2 = \pi_{2p_y}^2)(\pi_{2p_x}^{*1} = \pi_{2p_y}^{*1})$. It has 2 unpaired electrons in antibonding π^* orbitals. **Paramagnetic**.
- **(B)** B_2 **(10e$^-$):** $\sigma_{1s}^2\sigma_{1s}^{*2}\sigma_{2s}^2\sigma_{2s}^{*2}(\pi_{2p_x}^1 = \pi_{2p_y}^1)$. It has 2 unpaired electrons in π bonding orbitals. **Paramagnetic**.
- **(C)** C_2 **(12e$^-$):** $\sigma_{1s}^2\sigma_{1s}^{*2}\sigma_{2s}^2\sigma_{2s}^{*2}(\pi_{2p_x}^2 = \pi_{2p_y}^2)$. All electrons are paired. **Diamagnetic**.
- **(D)** N_2^+ **(13e$^-$):** $\sigma_{1s}^2\sigma_{1s}^{*2}\sigma_{2s}^2\sigma_{2s}^{*2}(\pi_{2p_x}^2 = \pi_{2p_y}^2)\sigma_{2p_z}^1$. It has 1 unpaired electron in the σ_{2p_z} orbital. **Paramagnetic**.

Answer: (C)

Q12.

Solution

Concept:

The dipole moment (μ) is a vector quantity. The net dipole moment of a molecule depends on the polarity of individual bonds and the molecular geometry (vector sum of bond moments).

Solution:

- **(A)** NF_3**:** Pyramidal shape. The lone pair moment and the resultant of three $N-F$ bond moments act in opposite directions (F is more electronegative than N), reducing the net dipole.
- **(B)** NH_3**:** Pyramidal shape. The lone pair moment and the resultant of three $N-H$ bond moments act in the same direction (N is more electronegative than H), adding up to a high net dipole.
- **(C)** CO_2**:** Linear shape ($O=C=O$). The two equal $C=O$ bond moments act in opposite directions at 180°, so $\mu = 0$.
- **(D)** CH_4**:** Symmetrical tetrahedral shape. The vector sum of four $C-H$ bond moments is zero, so $\mu = 0$.

Comparing NH_3 and NF_3, NH_3 has a significantly higher dipole moment because the bond moments reinforce the lone pair moment.

Answer: (B)

Q13.

Solution

Concept:

The spin-only magnetic moment (μ_s) is calculated using the formula:

$$\mu_s = \sqrt{n(n+2)} \text{ BM}$$

where n is the number of unpaired electrons.

Solution:

In $[Fe(H_2O)_6]^{2+}$:

(a) **Oxidation State:** Fe is in the $+2$ oxidation state.

(b) **Electronic Configuration:** $Fe \rightarrow [Ar]3d^6 4s^2$; therefore, $Fe^{2+} \rightarrow [Ar]3d^6$.

(c) **Ligand Field:** H_2O is a weak field ligand (WFL), so no pairing of electrons occurs in the $3d$ subshell.

(d) **Unpaired Electrons:** In $3d^6$, according to Hund's rule, there are 4 unpaired electrons ($n = 4$).

(e) **Calculation:**

$$\mu_s = \sqrt{4(4+2)} = \sqrt{4 \times 6} = \sqrt{24} \approx 4.899 \text{ BM}$$

Rounding to two decimal places, we get 4.90 BM.

Answer: (A)

Q14.

Solution

Concept:

IUPAC nomenclature for coordination compounds follows these rules: 1. Name ligands in alphabetical order. 2. Neutral ligands like NH_3 are "ammine"; anionic ligands like CO_3^{2-} end in "-o" (carbonato). 3. Metal name is followed by its oxidation state in Roman numerals. 4. Counter ions are named last.

Solution:

For the complex $[Co(NH_3)_5(CO_3)]Cl$:

- **Ligands:** 5 ammine groups (pentaammine) and 1 carbonate group (carbonato). Alphabetically, "ammine" comes before "carbonato".
- **Oxidation state of Co (x):** $x + 5(0) + 1(-2) = +1$ (since the counter ion is Cl^-). Thus, $x - 2 = 1 \Rightarrow x = +3$.
- **Metal:** Cobalt(III).
- **Counter ion:** Chloride.

Full name: Pentaamminecarbonatocobalt(III) chloride.

Answer: (A)

Q15.

Solution

Concept:

Bond dissociation enthalpy generally decreases down the group as atomic size increases. However, Fluorine (F_2) is an anomaly due to its extremely small size and high lone pair-lone pair repulsion.

Solution:

(a) **Trend:** Normally, the order should be $F_2 > Cl_2 > Br_2 > I_2$.

(b) **The F_2 Anomaly:** In F_2, the $F-F$ bond distance is very short. The lone pairs on the two Fluorine atoms are so close that they repel each other strongly, weakening the bond.

(c) **Correct Order:** This repulsion makes the $F - F$ bond easier to break than $Cl - Cl$ and $Br - Br$. The actual experimentally determined order is:

$$Cl_2 > Br_2 > F_2 > I_2$$

Answer: (B)

Q16.

Solution

Concept:

First Ionization Enthalpy ($\Delta_i H_1$) generally increases across a period from left to right. However, exceptions occur due to completely filled (s^2) or half-filled (p^3) electronic configurations which provide extra stability.

Solution:

Elements: B ($2s^2 2p^1$), Be ($2s^2$), C ($2s^2 2p^2$), N ($2s^2 2p^3$), O ($2s^2 2p^4$).

- **Be vs B:** Be has a stable fully-filled $2s^2$ configuration, making it harder to remove an electron than from B ($2p^1$). Thus, $B < Be$.
- **N vs O:** N has a stable half-filled $2p^3$ configuration. O ($2p^4$) will readily lose one electron to achieve that same half-filled stability. Thus, $O < N$.

Combining the general trend with these exceptions, the order is:

$$B < Be < C < O < N$$

Answer: (A)

Q17.

Solution

Concept:

The relation between standard Gibbs free energy (ΔG°) and standard cell potential (E°_{cell}) is:

$$\Delta G^\circ = -nFE^\circ_{cell}$$

where n is the number of moles of electrons transferred and F is Faraday's constant (≈ 96500 C/mol).

Solution:

(a) **Determine n:** The reaction is $2Fe^{3+} + 2I^- \rightarrow 2Fe^{2+} + I_2$. Two Fe^{3+} ions each gain $1e^-$ to become Fe^{2+}, and two I^- ions lose $2e^-$ to become I_2. Thus, $n = 2$.

(b) **Calculate ΔG°:**

$$\Delta G^\circ = -2 \times 96500 \times 0.24$$

$$\Delta G^\circ = -46320 \text{ J/mol} = -46.32 \text{ kJ/mol}$$

Answer: (A)

Q18.

Solution

Concept:

For a first-order reaction, the time taken for a certain percentage of completion can be related to the half-life ($t_{1/2}$). Specifically: $t_{75\%}$ is the time required for the concentration to drop to 25% of its initial value ($100 \rightarrow 50 \rightarrow 25$).

Solution:

(a) **Half-life:** Given $t_{50\%} = t_{1/2} = 20$ min.

(b) **First-order property:** After one half-life, 50% remains. After two half-lives, 50% of that 50% remains, which is 25%.

(c) **Completion:** If 25% remains, the reaction is 75% complete.

(d) **Calculation:**

$$t_{75\%} = 2 \times t_{1/2}$$

$$t_{75\%} = 2 \times 20 = 40 \text{ min}$$

Answer: (B)

Q19.

Solution

Concept:

In Bohr's model: - Radius of orbit: $r_n \propto n^2$ - Velocity of electron: $v_n \propto \frac{1}{n}$ Frequency (f) is the number of revolutions per unit time.

Solution:

Time period (T) is the time for one revolution:

$$T = \frac{\text{Distance}}{\text{Velocity}} = \frac{2\pi r_n}{v_n}$$

Frequency is the reciprocal of the time period:

$$f = \frac{1}{T} = \frac{v_n}{2\pi r_n}$$

Using proportionalities:

$$f \propto \frac{v_n}{r_n} \propto \frac{1/n}{n^2} = \frac{1}{n^3}$$

Hence, frequency varies as $1/n^3$.

Answer: (B)

Q20.

Solution

Concept:

For an ideal gas, internal energy (U) and enthalpy (H) are functions of temperature only. According to the First Law of Thermodynamics: $\Delta U = q + w$.

Solution:

(a) **Isothermal:** Temperature is constant ($T = \text{const}$), so $\Delta T = 0$. For an ideal gas, this means $\Delta U = 0$ and $\Delta H = 0$.

(b) **First Law:** Substitute $\Delta U = 0$ into $\Delta U = q + w$.

$$0 = q + w \Rightarrow q = -w$$

This implies that all heat absorbed by the system is used to do work during the expansion.

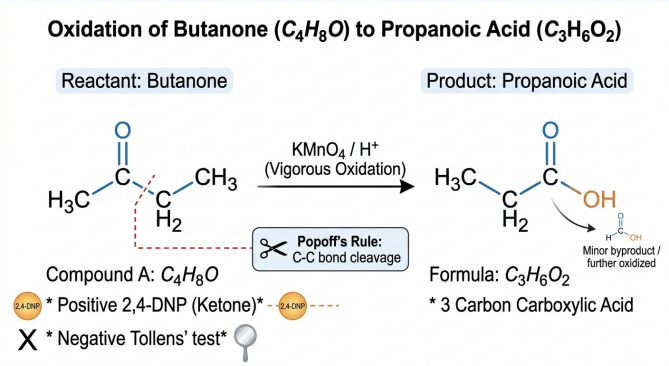
Answer: (A)

Q21.

Solution

Concept:

The 2,4-DNP test is positive for both aldehydes and ketones (carbonyl groups). Tollens' reagent is reduced only by aldehydes. Therefore, a compound that is 2,4-DNP positive but Tollens' negative must be a ketone.



Solution:

(a) **Identify the compound (C_4H_8O):** Since it is a ketone with four carbons, it must be **Butan-2-one** ($CH_3 - CO - CH_2 - CH_3$).

(b) **Oxidation with $KMnO_4$:** Ketones are difficult to oxidize and undergo cleavage of Carbon-Carbon bonds. According to Popoff's rule, the carbonyl group stays with the smaller alkyl group.

(c) **Cleavage:**

$$CH_3 - CO - CH_2 - CH_3 \xrightarrow{KMnO_4} CH_3COOH + CH_3COOH$$

However, the question states it forms a single product $C_3H_6O_2$ under specific conditions (or the primary organic acid fragment). $C_3H_6O_2$ corresponds to **Propanoic acid** (CH_3CH_2COOH).

The molecular formula of the oxidation product $C_3H_6O_2$ is specifically Propanoic acid.

Answer: ($C_3H_6O_2$)

Q22.

Solution

Concept:

The reaction with Br_2/CCl_4 yielding a dibromo compound indicates the presence of **one** carbon-carbon double bond ($C=C$). If it were an alkyne, it would typically form a tetrabromo compound with excess bromine or a dibromoalkene.

Solution:

(a) **Degree of Unsaturation (DU):** For C_5H_8,

$$DU = C + 1 - \frac{H}{2} = 5 + 1 - \frac{8}{2} = 6 - 4 = 2$$

A DU of 2 means the molecule could have two π-bonds (alkyne or diene), or one π-bond and one ring.

(b) **Bromine Test:** Since it forms a **dibromo** compound, only one π-bond is reacted as a double bond. This suggests the second degree of unsaturation is a **ring**.

(c) **Peroxide Effect:** Reaction with HBr in peroxides (Kharasch effect) follows anti-Markovnikov addition. The fact that it gives **only one product** implies the alkene is highly symmetrical (like cyclopentene).

(d) **Structure:** Cyclopentene (C_5H_8) has one ring and **one** π-bond.

Therefore, the number of π-bonds present in the hydrocarbon is 1.

Answer: (1)

Q23.

Solution

Concept:

Alcohols react with active metals like Sodium (Na) to release hydrogen gas. The balanced chemical equation is:

$$2R - OH + 2Na \rightarrow 2R - ONa + H_2(g)$$

Solution:

(a) **Calculate moles of Ethanol (CH_3CH_2OH):**

$$\text{Moles} = \text{Molarity} \times \text{Volume (L)} = 1\ \text{M} \times 0.1\ \text{L} = 0.1\ \text{mol}$$

(b) **Stoichiometry:** From the balanced equation, 2 moles of Ethanol produce 1 mole of H_2 gas.

$$\text{Moles of } H_2 = \frac{0.1}{2} = 0.05\ \text{mol}$$

(c) **Volume at STP:** At STP, 1 mole of gas occupies 22.4 L.

$$\text{Volume} = 0.05\ \text{mol} \times 22.4\ \text{L/mol} = 1.12\ \text{L}$$

The volume of H_2 gas liberated is 1.12 L (or 1120 mL).

Answer: (1.12 L)

Q24.

Solution

Concept:

The reaction with Nitrous acid (HNO_2) distinguishes amines: - **Primary Aliphatic Amines:** Release N_2 gas quantitatively. - **Secondary Amines:** Form yellow oily nitrosamines (no gas). - **Tertiary Amines:** Form soluble nitrite salts (no gas).

Solution:

(a) **Calculate moles of N_2 released:**

$$\text{Moles of } N_2 = \frac{\text{Volume at STP}}{22.4 \text{ L/mol}} = \frac{0.672 \text{ L}}{22.4 \text{ L/mol}} = 0.03 \text{ mol}$$

(b) **Compare with Amine moles:** The solution contained 0.04 mol of amine.

(c) **Analysis:** Since N_2 gas is released, the amine must be **Primary**. However, typically 1 mol of primary amine releases 1 mol of N_2. Here, 0.03 mol is less than the total 0.04 mol provided, but the **fact** that N_2 is released at all is the diagnostic test for a primary amine.

The amine is Primary.

Answer: (Primary)

Q25.

Solution

Concept:

The enthalpy change of a reaction (ΔH) can be calculated using Bond Enthalpies (BE) with the formula:

$$\Delta H = \sum BE(\text{reactants}) - \sum BE(\text{products})$$

Solution:

(a) **Reaction:** $H_2(g) + Cl_2(g) \rightarrow 2HCl(g)$

(b) **Bonds broken (Reactants):**

- 1 mole of $H - H$ bonds
- 1 mole of $Cl - Cl$ bonds

(c) **Bonds formed (Products):**

- 2 moles of $H - Cl$ bonds

(d) **Calculation:**

$$\Delta H = [BE(H - H) + BE(Cl - Cl)] - [2 \times BE(H - Cl)]$$

$$\Delta H = [436 + 243] - [2 \times 431]$$

$$\Delta H = 679 - 862$$

$$\Delta H = -183 \text{ kJ/mol}$$

The enthalpy change for the reaction is -183 kJ/mol.

Answer: (-183 kJ/mol)

Answer Key — Section A

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

Answer Key — Section B

Q	Ans	Q	Ans
21	$C_3H_6O_2$	22	1
23	1.12 L	24	Primary
25	-183 kJ/mol		