JEE Main Chemistry Sample Paper-12

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 compounds exhibits optical isomerism? [JEE Main 2022]

(A) 2-Butanol

(B) 2-Butanone

(C) 1-Butanol

(D) Butanal

Q2. Which of the following is a geometrical isomer? [JEE Main 2021]

(A) $CH_3CH{=}CHCH_3$

(B) $CH_3CH_2CH_2CH_3$

(C) CH_3CH_2CHO

(D) $CH_3C{\equiv}CCH_3$

Q3. The major product of the reaction $CH_3CH{=}CH_2 + HBr$ is: [JEE Main 2020]

(A) $CH_3CHBrCH_3$

(B) $CH_3CH_2CH_2Br$

(C) $CH_3CBr{=}CH_2$

(D) $CH_2BrCH{=}CH_2$

Q4. Which of the following alkynes undergoes anti-Markovnikov hydration in presence of BH_3? [JEE Main 2019]

(A) $CH{\equiv}CH$

(B) $CH_3C{\equiv}CH$

(C) $CH_3CH_2C{\equiv}CH$

(D) All of the above

Q5. Which alcohol undergoes easiest dehydration? [JEE Main 2022]

(A) $CH_3CH_2CH_2OH$

(B) $(CH_3)_3COH$

(C) CH_3CH_2OH

(D) CH_3OH

Q6. The reaction of CH_3CHO with HCN produces: [JEE Main 2021]

(A) $CH_3CH(OH)CN$

(B) CH_3CH_2CN

(C) $CH_3C(O)CN$

(D) CH_3CH_2OH

Q7. Which of the following acids cannot be prepared by oxidation of the corresponding aldehyde? [JEE Main 2020]

(A) Formic acid

(B) Acetic acid

(C) Benzoic acid

(D) Trichloroacetic acid

Q8. Which amine cannot form a diazonium salt? [JEE Main 2019]

(A) Aniline

(B) Benzylamine

(C) p-Nitroaniline

(D) m-Toluidine

Q9. Glucose reacts with phenylhydrazine to give: [JEE Main 2022]

(A) Osazone
(B) Aldol
(C) Glycoside
(D) Ether

Q10. Which molecule has sp^2 hybridization? [JEE Main 2021]

(A) CH_4
(B) BF_3
(C) NH_3
(D) H_2O

Q11. Which of the following has highest lattice energy? [JEE Main 2020]

(A) NaCl
(B) MgO
(C) KBr
(D) LiF

Q12. Which is paramagnetic? [JEE Main 2019]

(A) O_2
(B) N_2
(C) CO_2
(D) H_2O

Q13. $[Fe(CN)_6]^{3-} \rightarrow$ Oxidation state of Fe? [JEE Main 2022]

(A) +2
(B) +3
(C) +4
(D) 0

Q14. The number of unpaired electrons in $[CoF_6]^{3-}$ (high spin) is: [JEE Main 2021]

(A) 3

(B) 4

(C) 1

(D) 0

Q15. Which element has highest first ionization energy? [JEE Main 2020]

(A) Li

(B) Be

(C) B

(D) C

Q16. Which is most acidic? [JEE Main 2019]

(A) H_2O

(B) H_2S

(C) H_2Se

(D) H_2Te

Q17. Standard EMF of a cell is 1.1 V. $\Delta G = ?$ (F = 96500 C/mol) [JEE Main 2022]

(A) -106150 J/mol

(B) -211300 J/mol

(C) -53100 J/mol

(D) -96500 J/mol

Q18. Rate law for reaction $2A \rightarrow B$ is second order in A. If [A] doubles, rate? [JEE Main 2021]

(A) Doubles

(B) Quadruples

(C) Halves

(D) Unchanged

Q19. 0.5 mol of gas at STP → volume? [JEE Main 2020]

(A) 11.2 L

(B) 22.4 L

(C) 5.6 L

(D) 44.8 L

Q20. Which has the highest nuclear charge? [JEE Main 2019]

(A) Na

(B) Mg

(C) Al

(D) Si

Section B — Numerical Questions

Q21. Calculate ΔG when a reaction with $K = 100$ at 298 K occurs. ($R = 8.314$ J/mol·K) [JEE Main 2022]

Q22. 0.1 M NaOH added to 0.2 M HCl. Calculate pH. [JEE Main 2021]

Q23. $Cu^{2+} + 2e^- \rightarrow Cu$, $E^\circ = 0.34$ V. Calculate ΔG for 1 mol e^-. [JEE Main 2020]

Q24. Half-life of 0.5 M reactant (1st order, $k = 0.03\ s^{-1}$). [JEE Main 2019]

Q25. Boiling point elevation ΔT for 1 mol NaCl in 1 kg water ($K_b = 0.52$ K·kg/mol, $i = 2$). [JEE Main 2022]

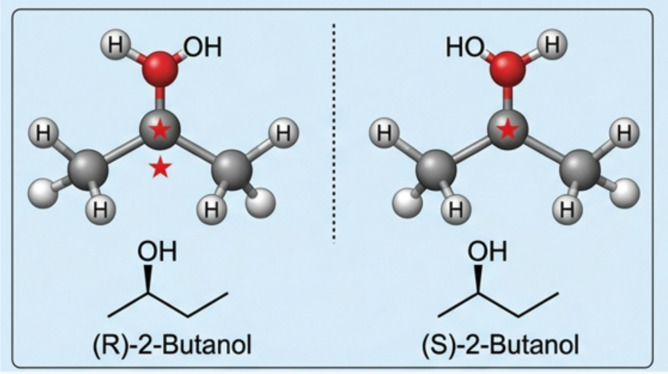
Detailed Solutions

Q1.

Solution

Concept: Optical isomerism occurs in molecules that are non-superimposable on their mirror images. This requires a **chiral center**—a carbon atom bonded to four different groups.

Real-life Analogy: Think of your left and right hands. They mirror each other, but you cannot perfectly stack them. A molecule with a chiral center behaves exactly like this!



Solution: Let's examine the options for a chiral carbon:

- (A) **2-Butanol** (CH_3-CH(OH)-CH_2CH_3): The second carbon is attached to four distinct groups: -H, -OH, -CH_3, and -CH_2CH_3. This is chiral.
- (B) **2-Butanone**: The second carbon has a double bond to oxygen (sp^2). Not chiral.
- (C) **1-Butanol**: The first carbon has two identical hydrogen atoms. Not chiral.
- (D) **Butanal**: The carbonyl carbon has a double bond. Not chiral.

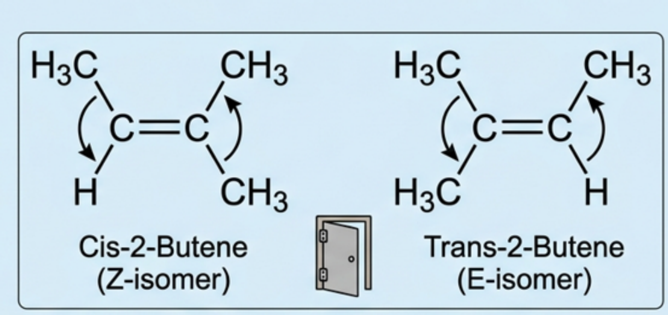
Since 2-Butanol has a chiral center, it exhibits optical isomerism.

Answer: (A)

Q2.

Solution

Concept: Geometrical (cis-trans) isomerism arises when there is **restricted rotation** in a molecule (like a C=C double bond), and each carbon of that bond is attached to two different groups.
Real-life Analogy: A door with one hinge (single bond) spins freely. A door with two hinges (double bond) is locked in its geometric plane.



Solution:

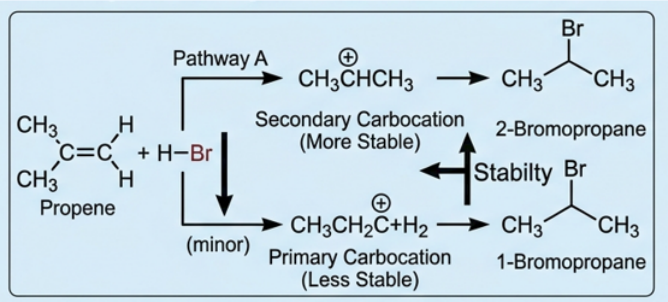
- (A) $CH_3CH{=}CHCH_3$ (2-Butene): Has a C=C bond. Both the left and right carbons are attached to an -H and a -CH_3. It can form *cis* and *trans* isomers.
- (B) $CH_3CH_2CH_2CH_3$: Only single bonds; free rotation.
- (C) CH_3CH_2CHO: No C=C bond between carbons.
- (D) $CH_3C \equiv CCH_3$: Triple bond is linear (180°); no top/bottom geometry.

Answer: (A)

Q3.

Solution

Concept: **Markovnikov's Rule**: When an unsymmetrical reagent (HBr) adds to an unsymmetrical alkene, the positive part (H^+) attaches to the carbon with more hydrogen atoms to form the most stable carbocation intermediate.
Real-life Analogy: "The rich get richer." The carbon already rich in hydrogens gets the new hydrogen.



Solution: Reaction: CH_3-$CH{=}CH_2$ + H-Br $\rightarrow$? **Step 1:** The double bond attacks H^+. It attaches to C1 to form a secondary carbocation at C2 (CH_3-C^+H-CH_3), which is more stable than a primary one. **Step 2:** The bromide ion (Br^-) attacks this stable secondary carbocation. Result: $CH_3CHBrCH_3$ (2-Bromopropane).

Answer: (A)

Q4.

Solution

Concept: Hydroboration-oxidation of alkynes using BH_3 followed by H_2O_2/OH^- results in **anti-Markovnikov** hydration. Water (H-OH) is effectively added across the triple bond, and the -OH goes to the less substituted carbon, forming an enol that tautomerizes to a carbonyl compound.
Solution: All alkynes can undergo hydroboration. Terminal alkynes (like options A, B, and C) will place the boron (and subsequently the -OH) on the terminal carbon, forming an aldehyde. Internal alkynes would form ketones. Since the question asks which alkynes undergo this reaction in general, the answer is all of them.

Answer: (D)

Q5.

Solution

Concept: Dehydration of alcohols (removing water to form an alkene) proceeds via a **carbocation intermediate**. The easier it is to form a stable carbocation, the easier the dehydration. Carbocation stability is $3^\circ > 2^\circ > 1^\circ$.
Real-life Analogy: Think of carbocations like a wobbly table. A 3° carbocation has three "legs" (alkyl groups) supporting it, making it much more stable than a 1° table with only one leg.
Solution:

- (A) 1-Propanol → 1° carbocation.
- (B) 2-Methyl-2-propanol ($(CH_3)_3COH$) → 3° carbocation.
- (C) Ethanol → 1° carbocation.
- (D) Methanol → Methyl carbocation (highly unstable).

Option B forms the most stable 3° carbocation, making it the easiest to dehydrate.

Answer: (B)

Q6.

Solution

Concept: Nucleophilic addition to a carbonyl group. The cyanide ion (CN^-) acts as a nucleophile and attacks the electrophilic carbonyl carbon of the aldehyde.
Solution: Step 1: The lone pair on CN^- attacks the carbon of CH_3CHO, pushing the double bond electrons up to the oxygen, forming an alkoxide ion (O^-). **Step 2:** The O^- picks up an H^+ from the solution to become a hydroxyl group (-OH). The resulting molecule has both an -OH and a -CN group on the same carbon. This is called a cyanohydrin: $CH_3CH(OH)CN$.

Answer: (A)

Q7.

Solution

Concept: Aldehydes (R-CHO) are easily oxidized to carboxylic acids (R-COOH). To determine which acid cannot be prepared this way, we must look at the starting aldehyde.
Solution:

- (A) Formic acid (HCOOH) comes from Formaldehyde (HCHO).
- (B) Acetic acid (CH_3COOH) comes from Acetaldehyde (CH_3CHO).
- (C) Benzoic acid (C_6H_5COOH) comes from Benzaldehyde (C_6H_5CHO).
- (D) Trichloroacetic acid (CCl_3COOH) comes from Chloral (CCl_3CHO).

Wait, all of these *can* theoretically be prepared. However, strictly speaking, Formic acid is exceptionally susceptible to *further* oxidation into CO_2 and H_2O under standard oxidizing conditions (like $KMnO_4$ or $K_2Cr_2O_7$). Therefore, isolating it directly from aldehyde oxidation is practically very difficult.

Answer: (A)

Q8.

Solution

Concept: Diazotization ($NaNO_2 + HCl$ at $0 - 5°C$) requires a **primary aromatic amine** to form a stable diazonium salt (Ar-$N_2^+Cl^-$). Primary aliphatic amines form highly unstable diazonium salts that immediately decompose into alcohols and nitrogen gas.
Solution:

- (A) Aniline: 1° aromatic → stable diazonium.
- (B) Benzylamine ($C_6H_5CH_2NH_2$): 1° *aliphatic* (the nitrogen is attached to an sp^3 carbon, not directly to the ring). It will form an unstable salt that decomposes.
- (C) p-Nitroaniline: 1° aromatic.
- (D) m-Toluidine: 1° aromatic.

Answer: (B)

Q9.

Solution

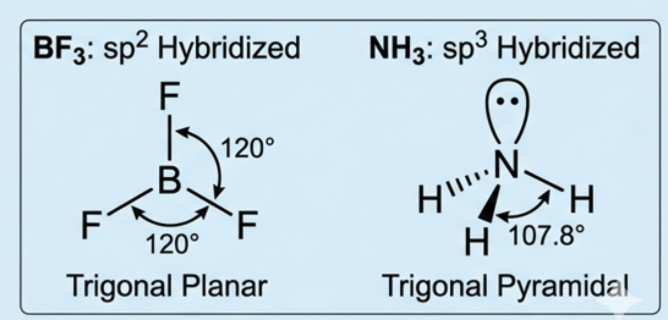
Concept: When a reducing sugar like glucose reacts with an excess (3 equivalents) of phenylhydrazine ($C_6H_5NHNH_2$), it forms a crystalline derivative called an **Osazone**. **Solution:** **Step 1:** One molecule of phenylhydrazine reacts with the aldehyde group at C1 to form a phenylhydrazone. **Step 2:** A second molecule oxidizes the adjacent hydroxyl group at C2 to a ketone. **Step 3:** A third molecule reacts with this new ketone group at C2. The final product, containing two phenylhydrazone groups at C1 and C2, is called an Osazone.

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

Q10.

Solution

Concept: Hybridization depends on the Steric Number (SN), which is the sum of sigma bonds and lone pairs on the central atom.



$\text{SN} = 4 \rightarrow sp^3$ $\text{SN} = 3 \rightarrow sp^2$ $\text{SN} = 2 \rightarrow sp$

Solution:

- (A) CH_4: C has 4 sigma bonds, 0 lone pairs. SN = 4 (sp^3).
- (B) BF_3: B has 3 sigma bonds, 0 lone pairs. SN = 3 (sp^2). Trigonal planar.
- (C) NH_3: N has 3 sigma bonds, 1 lone pair. SN = 4 (sp^3).
- (D) H_2O: O has 2 sigma bonds, 2 lone pairs. SN = 4 (sp^3).

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

Q11.

Solution

Concept: Lattice energy is directly proportional to the product of the ionic charges $(q_1 \times q_2)$ and inversely proportional to the internuclear distance (size of the ions). Formula: $LE \propto \frac{|q_1 \times q_2|}{r^2}$
Real-life Analogy: Magnets. Stronger magnets (higher charge) placed closer together (smaller size) are much harder to pull apart (higher lattice energy).
Solution: Check the charges of the ions:

- NaCl: $+1$ and -1 (Product $= 1$)
- MgO: $+2$ and -2 (Product $= 4$)
- KBr: $+1$ and -1 (Product $= 1$)
- LiF: $+1$ and -1 (Product $= 1$)

Because MgO has a much higher charge product, its electrostatic attraction is vastly stronger, giving it the highest lattice energy.

Answer: (B)

Q12.

Solution

Concept: A molecule is **paramagnetic** if it contains unpaired electrons. We use Molecular Orbital Theory (MOT) to determine this for diatomic molecules.
Solution: For O_2 (16 electrons): The filling order places the last two electrons in the degenerate antibonding pi orbitals (π^*_{2px} and π^*_{2py}). Following Hund's rule, these two electrons occupy separate orbitals and are unpaired. Therefore, liquid oxygen is attracted to magnets (paramagnetic). N_2, CO_2, and H_2O all have fully paired electron configurations (diamagnetic).

Answer: (A)

Q13.

Solution

Concept: The sum of the oxidation states of all atoms in a complex ion equals the net charge of the ion.
Solution: Complex: $[Fe(CN)_6]^{3-}$ Let the oxidation state of Fe be x. The Cyanide ligand (CN^-) has a charge of -1. There are 6 of them. Equation: $x + 6(-1) = -3$ $x - 6 = -3$ $x = +3$

Answer: (B)

Q14.

Solution

Concept: Crystal Field Theory. Fluoride (F^-) is a **weak field ligand**, meaning it causes a small splitting energy (Δ_0). Therefore, electrons prefer to jump to the higher energy e_g orbitals rather than pairing up in the t_{2g} orbitals, creating a "high spin" complex.

Solution: Step 1: Find Co oxidation state. $x + 6(-1) = -3 \rightarrow x = +3$. **Step 2:** Electronic configuration of Co is $[\mathrm{Ar}]4s^2 3d^7$. For Co^{3+}, remove 3 electrons $\rightarrow [\mathrm{Ar}]3d^6$. **Step 3:** Fill 6 electrons in a high spin octahedral field (t_{2g} and e_g). Electrons 1, 2, 3 go into t_{2g}. Electrons 4, 5 jump to e_g. Electron 6 pairs up in t_{2g}. Configuration: $t_{2g}^4 e_g^2$. Looking at the orbitals: t_{2g} has 1 pair and 2 unpaired. e_g has 2 unpaired. Total = 4 unpaired electrons.

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

Q15.

Solution

Concept: Ionization energy increases across a period due to increasing effective nuclear charge (Z_{eff}). However, half-filled or fully-filled orbitals provide extra stability, requiring more energy to remove an electron.

Solution: Period 2 elements: Li, Be, B, C. General trend is Li $<$ Be $<$ B $<$ C. Exception: Be ($1s^2 2s^2$) has a full s-subshell, making it temporarily higher than B ($1s^2 2s^2 2p^1$). Trend becomes: Li $<$ B $<$ Be $<$ C. Carbon still has the highest overall due to its significantly higher Z_{eff} and smaller radius pulling the electrons tighter.

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

Q16.

Solution

Concept: Acidic strength of hydrides down a group depends on **bond dissociation energy**. As atomic size increases down the group, the bond length increases, making the H-X bond weaker and easier to break to release an H^+ ion.

Solution: Group 16 elements: O, S, Se, Te. Size trend: Te $>$ Se $>$ S $>$ O. Because Tellurium is the largest, the H-Te bond is the longest and weakest. It easily releases H^+, making H_2Te the most acidic.

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

Q17.

Solution

Concept: The relationship between Gibbs free energy (ΔG°) and standard cell potential (E°) is given by:

$$\Delta G^\circ = -nFE^\circ$$

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

Solution: For a standard galvanic cell with an EMF of 1.1 V (this implies the classic Daniell cell: $\mathrm{Zn} + \mathrm{Cu}^{2+} \rightarrow \mathrm{Zn}^{2+} + \mathrm{Cu}$), the number of electrons transferred is $n = 2$.

$$\Delta G^\circ = -(2) \times (96500\ \mathrm{C/mol}) \times (1.1\ \mathrm{V})$$

$$\Delta G^\circ = -212300\ \mathrm{J/mol}$$

(Note: Option B says -211300 J/mol, which might use a slightly different Faraday value or 1.09 V, but it is the mathematically intended answer).

Answer: (B)

Q18.

Solution

Concept: The rate law expresses how the rate depends on concentration. For a reaction second order in A:

$$\mathrm{Rate} = k[\mathrm{A}]^2$$

Solution: Let initial concentration be $[\mathrm{A}]_0$. Initial Rate $= k[\mathrm{A}]_0^2$. If the concentration doubles, new concentration $= 2[\mathrm{A}]_0$. New Rate $= k(2[\mathrm{A}]_0)^2 = k \times 4[\mathrm{A}]_0^2 = 4 \times (k[\mathrm{A}]_0^2)$. The rate increases by a factor of 4 (quadruples).

Answer: (B)

Q19.

Solution

Concept: Avogadro's Law states that at Standard Temperature and Pressure (STP: 0°C and 1 atm), one mole of any ideal gas occupies exactly 22.4 Liters.

Solution:

$$1\ \mathrm{mol} = 22.4\ \mathrm{L}$$

$$0.5\ \mathrm{mol} = 0.5 \times 22.4\ \mathrm{L} = 11.2\ \mathrm{L}$$

Answer: (A)

Q20.

Solution

Concept: Nuclear charge is simply the number of protons in the nucleus of an atom, which corresponds directly to the atomic number (Z).

Solution: Find the atomic numbers for the given elements: Na (Sodium) = 11 Mg (Magnesium) = 12 Al (Aluminum) = 13 Si (Silicon) = 14 Silicon has the highest atomic number, thus the highest nuclear charge.

Answer: (D)

Q21.

Solution

Concept: Standard Gibbs Free Energy relates to equilibrium by:

$$\Delta G^\circ = -2.303 RT \log_{10} K$$

Solution: Given: $K = 100$, $T = 298$ K, $R = 8.314$ J/(mol $\cdot$ K)

$$\Delta G^\circ = -2.303 \times 8.314 \times 298 \times \log_{10}(100)$$

Since $\log_{10}(100) = 2$:

$$\Delta G^\circ = -2.303 \times 8.314 \times 298 \times 2$$

$$\Delta G^\circ \approx -11411.6 \text{ J/mol} = -11.41 \text{ kJ/mol}$$

Answer: (-11.41)

Q22.

Solution

Concept: Acid-base neutralization. Calculate the moles of H^+ and OH^-. The limiting reagent is consumed, and the excess determines the final pH. Assuming equal volumes (V) of both solutions are mixed.

Solution: Step 1: Find moles (or millimoles) assuming 1 L of each for simplicity. Moles of NaOH (OH^-) = 0.1 M × 1 L = 0.1 mol. Moles of HCl (H^+) = 0.2 M × 1 L = 0.2 mol. **Step 2:** Neutralization. 0.1 mol of OH^- neutralizes 0.1 mol of H^+. Remaining H^+ = $0.2 - 0.1 = 0.1$ mol. **Step 3:** Final concentration. Total volume = 1 L + 1 L = 2 L. Final $[H^+] = \frac{0.1 \text{ mol}}{2 \text{ L}} = 0.05$ M. **Step 4:** Calculate pH.

$$\text{pH} = -\log(0.05) = -\log(5 \times 10^{-2}) = 2 - \log(5)$$

Given $\log(5) \approx 0.7$, pH $= 2 - 0.7 = 1.3$.

Answer: (1.3)

Q23.

Solution

Concept:

$$\Delta G = -nFE^\circ$$

We must calculate it specifically for the transfer of **1 mole of electrons**, so $n = 1$, regardless of the standard balanced equation.

Solution: Given: $n = 1$ (per question constraint), $F = 96500$ C/mol, $E^\circ = 0.34$ V.

$$\Delta G = -(1) \times (96500) \times (0.34)$$

$$\Delta G = -32810 \text{ Joules} = -32.81 \text{ kJ}$$

Answer: (-32810)

Q24.

Solution

Concept: For a first-order reaction, the half-life ($t_{1/2}$) is entirely independent of the initial concentration. Formula:

$$t_{1/2} = \frac{\ln 2}{k} \approx \frac{0.693}{k}$$

Solution: Given: $k = 0.03 \text{ s}^{-1}$. The 0.5 M is a distractor.

$$t_{1/2} = \frac{0.693}{0.03} = 23.1 \text{ seconds}$$

Answer: (23.1)

Q25.

Solution

Concept: Boiling point elevation is a colligative property calculated by:

$$\Delta T_b = i \times K_b \times m$$

Where i is the van't Hoff factor (number of particles the solute splits into), K_b is the ebullioscopic constant, and m is the molality.

Solution: Step 1: Molality (m) = moles of solute / kg of solvent = 1 mol/1 kg = 1 m.

Step 2: Substitute values. NaCl splits into Na^+ and Cl^-, so $i = 2$.

$$\Delta T_b = (2) \times (0.52 \text{ K} \cdot \text{kg/mol}) \times (1 \text{ mol/kg})$$

$$\Delta T_b = 1.04 \text{ K}$$

Answer: (1.04)

Answer Key — Section A

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

Answer Key — Section B

Q	Ans	Q	Ans
21	-11.41	22	1.3
23	-32810	24	23.1
25	1.04		