# AME CET Chemistry Sample Paper-12

**Duration: 20 Minutes** **Maximum Marks: 80**

## Instructions

- This paper contains **20** Multiple Choice Questions (Single Correct).
- Each correct answer carries **+4 marks**.
- Each incorrect answer carries: **−1 marks**.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

**Q1.** For a given first-order reaction, the time required for 75% completion is exactly twice the time required for 50% completion. If the rate constant for this reaction is $k$, what is the time required for 87.5% completion of the same reaction?

(A) $\frac{3\ln 2}{k}$

(B) $\frac{2\ln 2}{k}$

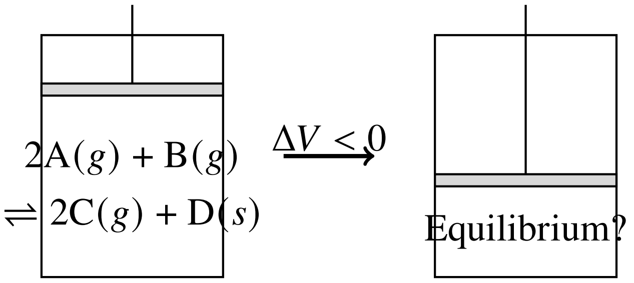
(C) $\frac{\ln 2}{k}$

(D) $\frac{\ln 2}{k}$

**Q2.** Consider the following gaseous equilibrium reaction occurring in a closed container:

$$2\mathrm{A}(g) + \mathrm{B}(g) \rightleftharpoons 2\mathrm{C}(g) + \mathrm{D}(s)$$

If the volume of the reaction vessel is suddenly halved at constant temperature, what will happen to the equilibrium position and the value of $K_c$?



(A) Shifts to the right; $K_c$ increases

(B) Shifts to the right; $K_c$ remains unchanged

(C) Shifts to the left; $K_c$ decreases

(D) Shifts to the left; $K_c$ remains unchanged

**Q3.** The standard reduction potentials for three metallic cations $X^{2+}$, $Y^{3+}$, and $Z^{+}$ are $-0.44$ V, $+0.34$ V, and $-0.80$ V respectively. What is the correct relative order of their reducing power as neutral metals?

(A) Y > X > Z

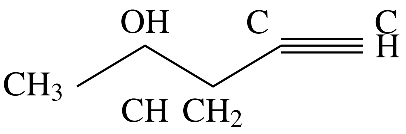
(B) Z > X > Y

(C) X > Y > Z

(D) Z > Y > X

**Q4.** What is the correct IUPAC name for the following organic compound?

$$CH_3 - CH(OH) - CH_2 - C \equiv CH$$



(A) Pent-4-yn-2-ol

(B) Pent-1-yn-4-ol

(C) Hydroxypent-4-yne

(D) Pent-2-ol-4-yne

**Q5.** An ideal solution is prepared by mixing two volatile liquids, P and Q. At 300 K, the vapor pressures of pure P and pure Q are 120 mm Hg and 160 mm Hg, respectively. If the mole fraction of P in the liquid phase is 0.4, what is the mole fraction of P in the vapor phase at equilibrium?

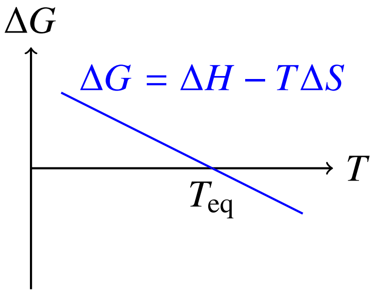
(A) 0.30

(B) 0.40

(C) 0.33

(D) 0.67

**Q6.** For a particular chemical reaction, the values of $\Delta H$ and $\Delta S$ are both positive numbers. Under which of the following conditions will this reaction become strictly spontaneous?



(A) At all temperatures

(B) Only at low temperatures where $T < \frac{\Delta H}{\Delta S}$

(C) Only at high temperatures where $T > \frac{\Delta H}{\Delta S}$

(D) It can never be spontaneous regardless of temperature

**Q7.** Which of the following elements forms a stable, solid oxide that dissolves in aqueous sodium hydroxide to yield an aluminate-like complex, demonstrating clear amphoteric behavior?

(A) B

(B) Al

(C) Tl

(D) In

**Q8.** An organic compound W undergoes a reaction with $CHCl_3$ and aqueous KOH to give an offensive-smelling compound R. When W is treated with nitrous acid ($HNO_2$) at 0 – 5°C, it forms a stable diazonium salt. Identify compound W.

(A) Benzylamine

(B) Aniline

(C) N-Methylaniline

(D) Nitrobenzene

**Q9.** For the reaction $M_2(g) + 3N_2(g) \rightleftharpoons 2MN_3(g)$, the value of $K_p$ is found to be $4.5 \times 10^{-5}$ at a temperature of 450 K. What is the value of $K_c$ for this reaction at the same temperature? (Take $R = 0.0821$ L atm mol$^{-1}$ K$^{-1}$)

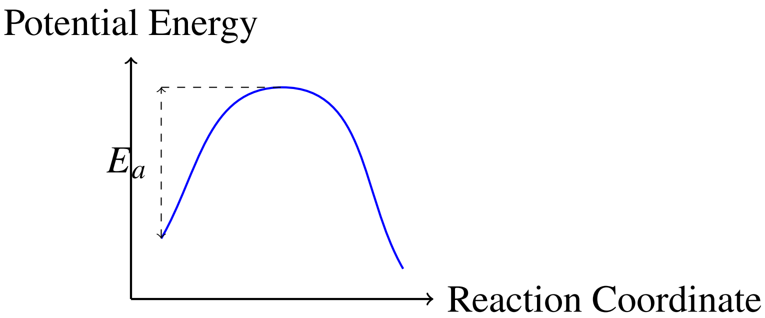
(A) $4.5 \times 10^{-5} \times (0.0821 \times 450)^2$

(B) $4.5 \times 10^{-5} \times (0.0821 \times 450)^{-2}$

(C) $4.5 \times 10^{-5} \times (0.0821 \times 450)^{-1}$

(D) $4.5 \times 10^{-5} \times (0.0821 \times 450)^1$

**Q10.** The activation energy of a certain reaction is 83.14 kJ mol$^{-1}$. By what factor does the rate constant $k$ increase when the temperature is raised from 300 K to 310 K? (Given: $R = 8.314$ J mol$^{-1}$ K$^{-1}$ and $e^{1.07} \approx 2.9$)



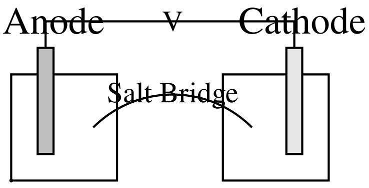
(A) 1.5

(B) 2.9

(C) 4.2

(D) 9.8

**Q11.** The standard EMF of a galvanic cell involving the cell reaction with $n = 2$ electrons transferred is found to be 0.59 V at 298 K. What is the value of the equilibrium constant ($K_{eq}$) for this cell reaction? (Assume $\frac{2.303RT}{F} = 0.059$ V at 298 K)



(A) $1.0 \times 10^{10}$

(B) $1.0 \times 10^{20}$

(C) $2.0 \times 10^{10}$

(D) $1.0 \times 10^{-20}$

**Q12.** When 2-bromobutane is treated with alcoholic KOH under reflux conditions, a mixture of isomeric alkenes is obtained. Which of the following statements is entirely correct regarding the products?

(A) But-1-ene is the major product according to Hofmann's rule.

(B) trans-But-2-ene is the major product according to Saytzeff's rule.

(C) cis-But-2-ene is the major product because it has higher steric stability.

(D) An equimolar mixture of But-1-ene and But-2-ene is produced.

**Q13.** Two dilute solutions, a 0.1 M aqueous solution of $BaCl_2$ and a 0.1 M aqueous solution of glucose ($C_6H_{12}O_6$), are compared at the same ambient temperature. Which statement correctly relates their colligative behavior?

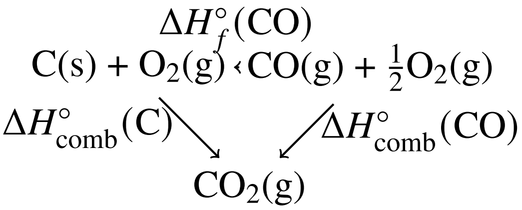
(A) Both solutions will exhibit the exact same osmotic pressure.

(B) The boiling point of the glucose solution will be higher than that of the $BaCl_2$ solution.

(C) The freezing point depression of the $BaCl_2$ solution will be approximately three times that of the glucose solution.

(D) The vapor pressure of the $BaCl_2$ solution will be higher than that of the glucose solution.

**Q14.** The standard enthalpy of combustion of solid carbon (graphite) and gaseous carbon monoxide (CO) are $-393.5$ kJ $mol^{-1}$ and $-283.0$ kJ $mol^{-1}$ respectively. What is the standard enthalpy of formation ($\Delta H_f^\circ$) of gaseous carbon monoxide per mole?



(A) $-110.5$ kJ mol$^{-1}$

(B) $+110.5$ kJ mol$^{-1}$

(C) $-676.5$ kJ mol$^{-1}$

(D) $+676.5$ kJ mol$^{-1}$

**Q15.** Which of the following arrangements accurately represents the correct increasing order of electron gain enthalpy (with negative sign) among the given p-block elements?

(A) I < Br < F < Cl

(B) Cl < F < Br < I

(C) F < Cl < Br < I

(D) I < Br < Cl < F

**Q16.** An organic compound containing an aldehyde functional group undergoes a self-condensation reaction in the presence of dilute sodium hydroxide (NaOH) to yield a $\beta$-hydroxyaldehyde. When heated, this product easily dehydrates to give an $\alpha,\beta$-unsaturated carbonyl compound. Which of the following compounds will successfully undergo this exact transformation?

(A) Benzaldehyde

(B) Formaldehyde

(C) Propanal

(D) 2,2-Dimethylpropanal

**Q17.** The solubility product ($K_{sp}$) of a sparingly soluble salt $MX_2$ in water is $4.0\times10^{-12}$ at 298 K. What is the molar solubility of this salt in a 0.01 M aqueous solution of $X^-$ ions?

(A) $4.0 \times 10^{-10}$ M

(B) $1.0 \times 10^{-4}$ M

(C) $4.0 \times 10^{-8}$ M

(D) $2.0 \times 10^{-6}$ M

**Q18.** Consider a chemical reaction A + B $\longrightarrow$ Products. Experimental data shows that doubling the concentration of A alone quadruples the rate of the reaction. However, doubling the concentration of B alone leaves the initial rate completely unchanged. What is the overall order of this reaction?

(A) 1

(B) 2

(C) 3

(D) 0

**Q19.** A current of 2.0 A is passed through an aqueous solution of $CuSO_4$ for exactly 965 seconds. What is the mass of copper metal deposited at the cathode? (Atomic mass of Cu = 63.5 g $mol^{-1}$, 1 F = 96500 C $mol^{-1}$)

(A) 0.3175 g

(B) 0.6350 g

(C) 1.2700 g

(D) 3.1750 g

**Q20.** Which of the following chemical species exhibits an anomalous, highly stable +4 oxidation state despite belonging to a group where the +2 oxidation state becomes increasingly stable down the group due to the inert pair effect?

(A) Pb

(B) Sn

(C) Ge

(D) Si

## Detailed Solutions

## Q1.

### Solution

**Concept:**
For a first-order chemical reaction, the integrated rate equation relates the rate constant $k$, the initial concentration $[A]_0$, and the remaining concentration $[A]_t$ at any time $t$. The formula is expressed as:

$$t = \frac{1}{k}\ln\left(\frac{[A]_0}{[A]_t}\right)$$

We can utilize the properties of fractional or percentage completion to establish a linear relationship for time intervals based on the half-life period $t_{1/2}$.

**Solution:**
Step 1: Understand the given data for the first-order reaction. The time taken for 50% completion of a first-order reaction is defined as its half-life, denoted as $t_{50\%}$ or $t_{1/2}$. According to the properties of first-order kinetics, the remaining concentration after 50% completion is half of the initial concentration. Thus, we have:

$$t_{50\%} = \frac{\ln 2}{k}$$

Step 2: Analyze the time taken for 75% completion. After 75% completion, the amount of reactant left is 25% of the original concentration, which is exactly one-quarter of $[A]_0$. This can be viewed as two successive half-lives. Therefore, the time required is:

$$t_{75\%} = \frac{1}{k}\ln\left(\frac{100}{25}\right) = \frac{\ln 4}{k} = \frac{2\ln 2}{k} = 2 \times t_{50\%}$$

Step 3: Calculate the time taken for 87.5% completion. When a reaction reaches 87.5% completion, the amount of unreacted starting material remaining in the system is calculated as:

$$100\% - 87.5\% = 12.5\%$$

Expressing 12.5% as a fraction of the initial 100% gives $\frac{12.5}{100} = \frac{1}{8} = \left(\frac{1}{2}\right)^3$. This signifies that the reaction has proceeded through exactly three consecutive half-life periods.
Step 4: Substitute the remaining concentration value back into our integrated first-order rate law equation:

$$t_{87.5\%} = \frac{1}{k}\ln\left(\frac{100}{12.5}\right) = \frac{\ln 8}{k}$$

Step 5: Simplify the logarithmic term using standard mathematical exponents, knowing that $8 = 2^3$:

$$t_{87.5\%} = \frac{\ln(2^3)}{k} = \frac{3\ln 2}{k}$$

**Final Answer:** $\boxed{3\ln 2_{\overline{k}}}$

**Answer: (A)**

**Go Back to Question 1**

## Q2.

### Solution

**Concept:**
Le Chatelier's principle states that if a dynamic equilibrium is disturbed by changing the conditions, the position of equilibrium shifts to counteract the change. For volume variations in gaseous systems, decreasing the volume increases the total pressure, driving the equilibrium toward the side with fewer moles of gas. The equilibrium constant $K_c$ is temperature-dependent and remains invariant unless temperature changes.

**Solution:**
Step 1: Examine the phases of the reactants and products involved in the balanced chemical equation:

$$2\mathrm{A}(g) + \mathrm{B}(g) \rightleftharpoons 2\mathrm{C}(g) + \mathrm{D}(s)$$

Identify that A, B, and C are in the gaseous phase, while D is a pure solid. Pure solids do not contribute to the gaseous mole count or pressure adjustments.

Step 2: Count the total number of stoichiometric moles of gaseous species on both sides of the system. On the reactant side, we have 2 moles of A and 1 mole of B, giving $\Delta n_{\text{reactants}}(g) = 2+1 = 3$. On the product side, we have only 2 moles of C gas, giving $\Delta n_{\text{products}}(g) = 2$.

Step 3: Determine the effect of halving the reaction vessel volume. Decreasing the volume causes an immediate increase in the partial pressures and concentrations of all gaseous components. To alleviate this pressure stress, the system shifts toward the side containing a lower total number of gas moles.

Step 4: Compare the gaseous moles of both sides. Since 2 moles on the product side is less than 3 moles on the reactant side, the net forward reaction is favored. Thus, the equilibrium position shifts to the right.

Step 5: Evaluate the effect on the equilibrium constant $K_c$. By definition, $K_c$ is a true thermodynamic constant at a given temperature. Because the process is carried out at a constant temperature, the numerical value of $K_c$ does not change.

**Final Answer:** $\boxed{\text{Shifts to the right; K}_c remainsunchanged}$

**Answer: (B)**

**Go Back to Question 2**

# Q3.

## Solution

**Concept:**

The standard reduction potential ($E^\circ$) measures the tendency of a chemical species to gain electrons and be reduced. A lower or more negative standard reduction potential indicates a weaker tendency to undergo reduction, which conversely means a stronger tendency for the neutral metal atom to lose electrons and undergo oxidation. Therefore, a more negative reduction potential corresponds to a stronger reducing power of the metal.

**Solution:**

Step 1: List and categorize the given standard reduction potentials for each of the metallic cations:

$$E^\circ(\mathrm{X}^{2+}/\mathrm{X}) = -0.44\ \mathrm{V}$$

$$E^\circ(\mathrm{Y}^{3+}/\mathrm{Y}) = +0.34\ \mathrm{V}$$

$$E^\circ(\mathrm{Z}^{+}/\mathrm{Z}) = -0.80\ \mathrm{V}$$

Step 2: Understand the relationship between reducing capability and reduction potential. The neutral metal with the lowest (most negative) reduction potential will release electrons most readily, making it the most potent reducing agent.

Step 3: Compare the values systematically. Among the given potentials, $-0.80$ V is the most negative value, followed by $-0.44$ V, while $+0.34$ V is positive and represents the highest value.

Step 4: Arrange the metal ions in increasing order of their standard reduction potentials:

$$-0.80\ \mathrm{V} < -0.44\ \mathrm{V} < +0.34\ \mathrm{V}$$

This numerical sequence corresponds directly to the elements in the order: $\mathrm{Z} < \mathrm{X} < \mathrm{Y}$.

Step 5: Invert this order to find the relative strength of the neutral metals as reducing agents. Since reducing power is inversely related to the standard reduction potential, the final sequence for decreasing reducing power is:

$$\mathrm{Z} > \mathrm{X} > \mathrm{Y}$$

**Final Answer:** $\boxed{\mathrm{Z} > \mathrm{X} > \mathrm{Y}}$

**Answer: (B)**

**Go Back to Question 3**

# Q4.

## Solution

**Concept:**

According to IUPAC nomenclature guidelines for polyfunctional organic molecules, the principal carbon chain must be selected to include the maximum number of principal functional groups, multiple bonds, and substituents. When a chain contains both a hydroxyl group (−OH) and an alkyne triple bond ($-C \equiv C-$), the hydroxyl group takes higher priority as the principal functional group, dictates the suffix, and receives the lowest possible locant during numbering.

**Solution:**

Step 1: Identify the structural formula provided in the question:

$$CH_3 - CH(OH) - CH_2 - C \equiv CH$$

The continuous carbon backbone contains a total of 5 carbon atoms, establishing "pent" as the parent root word.

Step 2: Identify all functional groups attached to the chain. We observe a principal secondary suffix group, which is the hydroxyl (−OH) group on one side, and a primary unsaturation suffix, which is the alkyne triple bond.

Step 3: Determine the correct numbering direction for the chain. Numbering from left-to-right places the −OH group at carbon-2 and the alkyne at carbon-4. Numbering from right-to-left places the alkyne at carbon-1 and the −OH group at carbon-4.

Step 4: Apply IUPAC priority rules. Because the alcohol group possesses a higher nomenclatural priority over the carbon-carbon triple bond, the chain must be numbered from left to right to assign the lower locant (2) to the −OH group. Thus, the numbering is:

$$\overset{5}{C}H_3 - \overset{4}{C}H(OH) - \overset{3}{C}H_2 - \overset{2}{C} \equiv \overset{1}{C}H$$

Step 5: Combine the root word, unsaturation position, and functional group suffix. The 5-carbon chain with a triple bond starting at position 4 yields "pent-4-yn". Appending the alcohol functional group at position 2 gives the systematic name: Pent-4-yn-2-ol.

**Final Answer:** $\boxed{\text{Pent-4-yn-2-ol}}$

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

**Go Back to Question 4**

# Q5.

## Solution

**Concept:**

For an ideal solution composed of volatile components, Raoult's law states that the partial vapor pressure of each component in the vapor phase is proportional to its mole fraction in the liquid phase ($p_i = x_i \cdot p_i^\circ$). Dalton's law of partial pressures relates the mole fraction of a component in the vapor phase ($y_i$) to its partial pressure and the total pressure of the system ($y_i = p_i / P_{\text{total}}$).

**Solution:**

Step 1: Extract the parameters provided for the binary liquid mixture. Let the mole fraction of liquid P in the solution phase be $x_P = 0.4$. The vapor pressures of the isolated pure components are given as $p_P^\circ = 120$ mm Hg and $p_Q^\circ = 160$ mm Hg.

Step 2: Calculate the liquid phase mole fraction of component Q, designated as $x_Q$. Since the sum of mole fractions in a binary mixture is equal to unity:

$$x_Q = 1 - x_P = 1 - 0.4 = 0.6$$

Step 3: Determine the individual partial vapor pressures exerted by each component above the liquid solution using Raoult's law calculations:

$$p_P = x_P \cdot p_P^\circ = 0.4 \times 120 \text{ mm Hg} = 48 \text{ mm Hg}$$

$$p_Q = x_Q \cdot p_Q^\circ = 0.6 \times 160 \text{ mm Hg} = 96 \text{ mm Hg}$$

Step 4: Compute the total combined vapor pressure ($P_{\text{total}}$) exerted by the ideal system by summing the partial pressures:

$$P_{\text{total}} = p_P + p_Q = 48 + 96 = 144 \text{ mm Hg}$$

Step 5: Apply Dalton's law to find the mole fraction of component P in the vapor phase ($y_P$):

$$y_P = \frac{p_P}{P_{\text{total}}} = \frac{48}{144} = \frac{1}{3} \approx 0.33$$

**Final Answer:** $\boxed{0.33}$

**Answer: (C)**

Go Back to Question 5

# Q6.

## Solution

**Concept:**

The spontaneity of a chemical reaction under conditions of constant temperature and pressure is dictated by the change in Gibbs free energy ($\Delta G$), as defined by the Gibbs-Helmholtz equation:

$$\Delta G = \Delta H - T\Delta S$$

A reaction is strictly spontaneous if and only if $\Delta G < 0$. When both enthalpy change ($\Delta H$) and entropy change ($\Delta S$) are positive, the sign of $\Delta G$ depends on the temperature $T$.

**Solution:**

Step 1: Analyze the signs of the thermodynamic parameters given. We are given that $\Delta H > 0$ (an endothermic process) and $\Delta S > 0$ (an entropy-driven process increasing molecular disorder).

Step 2: Substitute these positive parameters into the expression for Gibbs free energy:

$$\Delta G = (+\text{value}) - T(+\text{value})$$

The first term ($\Delta H$) is positive and opposes spontaneity, while the second term ($-T\Delta S$) is negative and favors spontaneity.

Step 3: Set up the mathematical inequality required to achieve a spontaneous process. For spontaneity, we require $\Delta G$ to be strictly less than zero:

$$\Delta H - T\Delta S < 0$$

Step 4: Rearrange the inequality to isolate the temperature variable $T$:

$$\Delta H < T\Delta S$$

Since $\Delta S$ is positive, dividing both sides by $\Delta S$ preserves the direction of the inequality:

$$T > \frac{\Delta H}{\Delta S}$$

Step 5: Conclude based on the derived condition. The reaction remains non-spontaneous at low temperatures because the positive $\Delta H$ term dominates. It becomes spontaneous only at high temperatures where the magnitude of $T\Delta S$ exceeds $\Delta H$.

**Final Answer:** $\boxed{\text{Only at high temperatures where T > } \Delta H_{\overline{\Delta S}}}$

**Answer: (C)**

Go Back to Question 6

# Q7.

## Solution

**Concept:**

The periodic properties of Group 13 elements show trends in metallic character and oxide behavior. Boron is a non-metal that forms an acidic oxide ($B_2O_3$). Aluminum is a metal with significant covalent character, and its oxide ($Al_2O_3$) is amphoteric, reacting with both acids and bases. Elements further down the group, such as Indium and Thallium, are more metallic and form basic oxides.

**Solution:**

Step 1: Identify the chemical behaviors of the oxides of Group 13 elements. The oxides are $B_2O_3$, $Al_2O_3$, $Ga_2O_3$, $In_2O_3$, and $Tl_2O_3$.

Step 2: Evaluate boron oxide ($B_2O_3$). Boron is a metalloid/non-metal, and its oxide reacts with water and bases to form borates, behaving as an acidic oxide. Thus, it is not amphoteric.

Step 3: Evaluate aluminum oxide ($Al_2O_3$). Aluminum exhibits amphoterism. Its solid oxide reacts with aqueous strong acids to form aluminum salts and with strong bases like sodium hydroxide (NaOH) to form soluble aluminate complexes:

$$\mathrm{Al_2O_3}(s) + 2\mathrm{NaOH}(aq) + 3\mathrm{H_2O}(l) \longrightarrow 2\mathrm{Na[Al(OH)_4]}(aq)$$

This matches the criteria given in the prompt.

Step 4: Evaluate indium (In) and thallium (Tl) oxides. As metallic character increases down Group 13, their oxides ($In_2O_3$ and $Tl_2O$) become predominantly basic and do not readily dissolve in aqueous sodium hydroxide to yield complex aluminate-like anions.

Step 5: Conclude that aluminum is the element that matches all parts of the description.

**Final Answer:** $\boxed{\mathrm{Al}}$

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

**Go Back to Question 7**

# Q8.

## Solution

**Concept:**

The carbylamine reaction (or Hofmann's isocyanide test) serves as a diagnostic chemical test for primary amines. When heated with chloroform ($CHCl_3$) and alcoholic potassium hydroxide (KOH), primary aliphatic or aromatic amines yield an intensely foul, offensive-smelling isocyanide (carbylamine) product. Furthermore, primary aromatic amines react with nitrous acid at low temperatures ($0-5^\circ$C) to form stable arenediazonium salts via diazotization.

**Solution:**

Step 1: Analyze the first chemical test described. The reaction of compound W with $CHCl_3$ and base to produce an offensive odor indicates that W must contain a primary amino group ($-NH_2$). This eliminates N-methylaniline (a secondary amine) and nitrobenzene.

Step 2: Narrow down the remaining possibilities containing a primary amino group: benzylamine ($C_6H_5CH_2NH_2$) and aniline ($C_6H_5NH_2$). Both are primary amines and give positive carbylamine tests.

Step 3: Analyze the second chemical test. When treated with nitrous acid ($HNO_2$) at a low temperature range of $0 - 5^\circ$C, compound W forms a stable diazonium salt.

Step 4: Compare the stability of diazonium salts derived from aliphatic versus aromatic primary amines. Benzylamine is an aliphatic primary amine; its diazonium salt is highly unstable and decomposes immediately to release nitrogen gas, forming a carbocation.

Step 5: Evaluate aniline. Aniline is a primary aromatic amine. At $0 - 5^\circ$C, it undergoes diazotization to form benzenediazonium chloride, which is stable in solution due to resonance stabilization of the diazonium group with the aromatic $\pi$-system. Thus, compound W is aniline.

**Final Answer:** $\boxed{\text{Aniline}}$

**Answer: (B)**

Go Back to Question 8

# Q9.

## Solution

**Concept:**

The mathematical relationship connecting the partial pressure equilibrium constant ($K_p$) and the molar concentration equilibrium constant ($K_c$) for a reversible gaseous chemical reaction is given by the following equation:

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

Here, $R$ represents the ideal gas constant, $T$ is the absolute temperature in Kelvin, and $\Delta n_g$ is the change in the number of moles of gaseous components, calculated as $\Delta n_g = \Sigma n_{\text{products}}(g) - \Sigma n_{\text{reactants}}(g)$.

**Solution:**

Step 1: Write down the balanced equilibrium chemical equation provided:

$$M_2(g) + 3N_2(g) \rightleftharpoons 2MN_3(g)$$

Verify that all participating reactants and products are in the gaseous phase.

Step 2: Calculate the value of $\Delta n_g$ by subtracting the sum of the stoichiometric coefficients of gaseous reactants from those of gaseous products:

$$\Delta n_g = 2 - (1 + 3) = 2 - 4 = -2$$

Step 3: Substitute $\Delta n_g = -2$ into the general formula linking the two equilibrium constants:

$$K_p = K_c(RT)^{-2}$$

Step 4: Rearrange the equation to isolate the target variable, $K_c$:

$$K_c = \frac{K_p}{(RT)^{-2}} = K_p \cdot (RT)^2$$

Step 5: Substitute the numerical values given into the rearranged expression ($K_p = 4.5 \times 10^{-5}$ and $T = 450$ K):

$$K_c = 4.5 \times 10^{-5} \times (0.0821 \times 450)^2$$

**Final Answer:** $\boxed{4.5 \times 10^{-5} \times (0.0821 \times 450)^2}$

**Answer: (A)**

**Go Back to Question 9**

# Q10.

## Solution

**Concept:**

The temperature dependence of chemical reaction rate constants is quantified by the Arrhenius equation. When comparing rate constants $k_1$ and $k_2$ at two different absolute temperatures $T_1$ and $T_2$, the logarithmic form of the equation is expressed as:

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{E_a}{R}\left[\frac{1}{T_1} - \frac{1}{T_2}\right] = \frac{E_a}{R}\left[\frac{T_2 - T_1}{T_1 \cdot T_2}\right]$$

where $E_a$ represents the activation energy and $R$ is the universal gas constant.

**Solution:**

Step 1: Identify and record the given values from the problem statement:

$$E_a = 83.14 \text{ kJ mol}^{-1} = 83140 \text{ J mol}^{-1}$$

$$R = 8.314 \text{ J mol}^{-1} \text{ K}^{-1}$$

$$T_1 = 300 \text{ K}, \quad T_2 = 310 \text{ K}$$

Step 2: Substitute these values into the Arrhenius expression to set up the calculation:

$$\ln\left(\frac{k_2}{k_1}\right) = \frac{83140}{8.314} \times \left[\frac{310 - 300}{300 \times 310}\right]$$

Step 3: Simplify the numerical terms step by step:

$$\frac{83140}{8.314} = 10000$$

$$\frac{310 - 300}{300 \times 310} = \frac{10}{93000} = \frac{1}{9300}$$

Step 4: Multiply the simplified factors to determine the value of the natural logarithm:

$$\ln\left(\frac{k_2}{k_1}\right) = 10000 \times \frac{1}{9300} = \frac{100}{93} \approx 1.075$$

Step 5: Convert the logarithmic equation to exponential form to find the ratio $\frac{k_2}{k_1}$:

$$\frac{k_2}{k_1} = e^{1.075}$$

Using the given approximation $e^{1.07} \approx 2.9$, we find that the rate constant increases by a factor of approximately 2.9.

**Final Answer:** $\boxed{2.9}$

**Answer: (B)**

Go Back to Question 10

# Q11.

## Solution

**Concept:**

The Nernst equation establishes the relationship between cell electromotive force ($E_{\text{cell}}$) and the reaction quotient under non-standard state parameters. At thermodynamic equilibrium, the net cell EMF ($E_{\text{cell}}$) drops to zero, and the reaction quotient equals the equilibrium constant ($K_{\text{eq}}$). Under these conditions, the standard cell potential ($E^\circ_{\text{cell}}$) is related to $K_{\text{eq}}$ by:

$$E^\circ_{\text{cell}} = \frac{2.303RT}{nF} \log K_{\text{eq}}$$

**Solution:**

Step 1: Identify the given standard electrochemical parameters at 298 K:

$$E^\circ_{\text{cell}} = 0.59 \text{ V}$$

$$n = 2 \text{ (number of electrons transferred)}$$

$$\frac{2.303RT}{F} = 0.059 \text{ V}$$

Step 2: Substitute these terms into the equilibrium form of the Nernst relationship:

$$0.59 = \frac{0.059}{2} \log K_{\text{eq}}$$

Step 3: Isolate the term containing the logarithm by multiplying both sides by 2:

$$2 \times 0.59 = 0.059 \log K_{\text{eq}}$$

$$1.18 = 0.059 \log K_{\text{eq}}$$

Step 4: Solve for $\log K_{\text{eq}}$ by dividing both sides by 0.059:

$$\log K_{\text{eq}} = \frac{1.18}{0.059} = 20$$

Step 5: Convert the logarithmic expression from base-10 to its exponential equivalent to determine $K_{\text{eq}}$:

$$K_{\text{eq}} = 10^{20} = 1.0 \times 10^{20}$$

**Final Answer:** $\boxed{1.0 \times 10^{20}}$

**Answer: (B)**

**Go Back to Question 11**

## Q12.

### Solution

**Concept:**

The dehydrohalogenation of alkyl halides using a strong, sterically unhindered base like alcoholic potassium hydroxide (KOH) proceeds via an E2 elimination mechanism. This reaction follows Saytzeff's rule, which states that the preferred product is the more highly substituted alkene because it is thermodynamically more stable. When multiple internal alkene isomers can form, the trans-alkene is favored over the cis-alkene due to minimized steric hindrance.

**Solution:**

Step 1: Sketch the molecular structure of the starting reactant, 2-bromobutane:

$$CH_3 - CH(Br) - CH_2 - CH_3$$

Identify the $\alpha$-carbon bearing the bromine atom (Carbon-2) and the adjacent $\beta$-carbons (Carbon-1 and Carbon-3).

Step 2: Evaluate elimination paths from the two different $\beta$-carbon environments. Elimination involving the hydrogen atoms on Carbon-1 ($\beta_1$) yields a terminal alkene:

$$CH_2 = CH - CH_2 - CH_3 \quad \text{(But-1-ene)}$$

Step 3: Evaluate elimination involving the hydrogen atoms on Carbon-3 ($\beta_2$). This pathway gives an internal, 2-substituted alkene system:

$$CH_3 - CH = CH - CH_3 \quad \text{(But-2-ene)}$$

Step 4: Apply Saytzeff's rule to predict regioselectivity. But-2-ene is a disubstituted alkene, whereas but-1-ene is monosubstituted. Therefore, But-2-ene is the major product, which rules out Option A.

Step 5: Evaluate the stereochemical configurations of But-2-ene. It exists as cis and trans diastereomers. The trans isomer (trans-but-2-ene) positions the bulky methyl groups on opposite sides of the double bond, reducing steric strain compared to the cis isomer. Thus, trans-but-2-ene is the major product.

**Final Answer:** $\boxed{\text{trans-But-2-ene is the major product according to Saytzeff's rule.}}$

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

**Go Back to Question 12**

# Q13.

## Solution

**Concept:**

Colligative properties depend on the total concentration of dissolved solute particles (ions or molecules) in a solution rather than their chemical identity. The effective particle concentration is determined by multiplying the molar concentration by the van 't Hoff factor ($i$). For a non-electrolyte solute that does not dissociate, $i = 1$. For an electrolyte solute that dissociates completely into ions, $i$ equals the total number of ions produced per formula unit.

**Solution:**

Step 1: Analyze the first solution, 0.1 M glucose ($C_6H_{12}O_6$). Glucose is a non-electrolyte organic carbohydrate that does not dissociate into smaller ions when dissolved in water. Its van 't Hoff factor is $i = 1$. The effective particle concentration is:

$$i \times C = 1 \times 0.1 \text{ M} = 0.1 \text{ M}$$

Step 2: Analyze the second solution, 0.1 M barium chloride ($BaCl_2$). Barium chloride is a strong soluble electrolyte that dissociates completely in aqueous solution according to the following equation:

$$\text{BaCl}_2(aq) \rightarrow \text{Ba}^{2+}(aq) + 2\text{Cl}^-(aq)$$

Each formula unit yields 3 ions, so its van 't Hoff factor is $i = 3$. The effective particle concentration is:

$$i \times C = 3 \times 0.1 \text{ M} = 0.3 \text{ M}$$

Step 3: Compare the effective concentrations. The effective particle count of the $BaCl_2$ solution is exactly three times larger than that of the glucose solution (0.3 M versus 0.1 M).

Step 4: Relate this particle concentration ratio to the freezing point depression ($\Delta T_f = i \cdot K_f \cdot m$). Assuming molarity is approximately equal to molality in dilute solutions, the freezing point depression ($\Delta T_f$) of the $BaCl_2$ solution will be three times greater than that of the glucose solution.

Step 5: Evaluate the remaining choices. Barium chloride has a higher boiling point and lower vapor pressure than glucose due to its higher particle concentration, which validates Option C.

**Final Answer:** $\boxed{\text{The freezing point depression of the BaCl}_2\text{ solution will be approximately three times that of the glucose solution.}}$

**Answer: (C)**

**Go Back to Question 13**

# Q14.

## Solution

**Concept:**

Hess's Law of Constant Heat Summation states that the total enthalpy change for a chemical reaction is the same whether the reaction occurs in a single step or in multiple steps. The standard enthalpy of formation ($\Delta H_f^\circ$) of a compound is the enthalpy change for the formation of one mole of the substance from its constituent elements in their standard reference states. We can determine this value by combining equations with known enthalpies of combustion.

**Solution:**

Step 1: Write out the balanced thermochemical equations corresponding to the given enthalpies of combustion. For the combustion of solid graphite:

$$(1) \quad \text{C(graphite)} + \text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H_1^\circ = -393.5 \text{ kJ mol}^{-1}$$

For the combustion of gaseous carbon monoxide:

$$(2) \quad \text{CO}(g) + \frac{1}{2}\text{O}_2(g) \rightarrow \text{CO}_2(g) \quad \Delta H_2^\circ = -283.0 \text{ kJ mol}^{-1}$$

Step 2: Target the objective chemical equation. The standard enthalpy of formation of gaseous carbon monoxide (CO) describes the production of 1 mole of CO($g$) from element state graphite and oxygen gas:

$$(3) \quad \text{C(graphite)} + \frac{1}{2}\text{O}_2(g) \rightarrow \text{CO}(g) \quad \Delta H_f^\circ = ?$$

Step 3: Manipulate the combustion equations using Hess's law to match the target equation. Keep equation (1) as written and reverse equation (2) to place CO($g$) on the product side:

$$\text{CO}_2(g) \rightarrow \text{CO}(g) + \frac{1}{2}\text{O}_2(g) \quad \Delta H^\circ_{\text{reversed}} = +283.0 \text{ kJ mol}^{-1}$$

Step 4: Sum equation (1) and the reversed equation (2). The intermediate $\text{CO}_2(g)$ cancels out from both sides:

$$\text{C(graphite)} + \text{O}_2(g) + \text{CO}_2(g) \rightarrow \text{CO}_2(g) + \text{CO}(g) + \frac{1}{2}\text{O}_2(g)$$

This simplifies to the target equation:

$$\text{C(graphite)} + \frac{1}{2}\text{O}_2(g) \rightarrow \text{CO}(g)$$

Step 5: Calculate the final enthalpy change by summing the individual enthalpy components:

$$\Delta H_f^\circ = \Delta H_1^\circ + \Delta H^\circ_{\text{reversed}} = -393.5 \text{ kJ mol}^{-1} + 283.0 \text{ kJ mol}^{-1} = -110.5 \text{ kJ mol}^{-1}$$

**Final Answer:** $\boxed{\text{-110.5 kJ mol}^{-1}}$

**Answer: (A)**

**Go Back to Question 14**

# Q15.

## Solution

**Concept:**

Electron gain enthalpy ($\Delta_{eg}H$) is the energy change that occurs when an electron is added to a neutral gaseous atom. For halogens (Group 17), releasing energy results in a negative value. Generally, electron gain enthalpy becomes less negative down a group as atomic radius increases. However, chlorine exhibits an anomaly: its electron gain enthalpy is more negative than that of fluorine due to minimized inter-electronic repulsions in chlorine's larger $3p$ subshell compared to fluorine's compact $2p$ subshell.

**Solution:**

Step 1: Recall the general periodic trend for electron gain enthalpy down Group 17 (Halogens: F, Cl, Br, I). As atomic size increases down the column, the incoming electron is shielded from the nucleus, which typically makes the electron gain enthalpy less negative. Based on size alone, the expected trend would be F > Cl > Br > I.

Step 2: Identify the exception between fluorine (F) and chlorine (Cl). Fluorine has a compact $2p$ valence subshell with high electron density. Adding an electron introduces significant inter-electronic repulsion, which decreases the energy released.

Step 3: Evaluate chlorine (Cl). Chlorine has a larger $3p$ subshell that accommodates the extra electron with less repulsion. Consequently, more energy is released when an electron is added to chlorine, making its electron gain enthalpy the most negative in the group.

Step 4: Order the halogens by their negative electron gain values. Chlorine is more negative than fluorine (Cl > F). Below chlorine, the normal trend resumes due to the larger atomic radii of bromine and iodine, giving: F > Br > I.

Step 5: Combine these observations into an increasing order of magnitude (with negative sign):

$$\mathrm{I} < \mathrm{Br} < \mathrm{F} < \mathrm{Cl}$$

**Final Answer:** $\boxed{\mathrm{I} < \mathrm{Br} < \mathrm{F} < \mathrm{Cl}}$

**Answer: (A)**

**Go Back to Question 15**

# Q16.

## Solution

**Concept:**

The Aldol condensation reaction occurs in aldehydes or ketones that possess at least one $\alpha$-hydrogen atom. Under the influence of a dilute base, the $\alpha$-carbon is deprotonated to form a nucleophilic enolate ion. This ion attacks the carbonyl carbon of another monomer unit, yielding a $\beta$-hydroxycarbonyl compound. Subsequent dehydration upon heating forms an $\alpha, \beta$-unsaturated product. Compounds lacking $\alpha$-hydrogens cannot undergo self-aldol condensation.

**Solution:**

Step 1: Analyze the specific structural requirement for a self-aldol condensation reaction. The reactant aldehyde must possess a carbon atom directly adjacent to the carbonyl group (the $\alpha$-carbon) that bears at least one hydrogen atom (an $\alpha$-hydrogen).

Step 2: Evaluate Choice A, benzaldehyde ($C_6H_5CHO$). The carbonyl carbon is attached directly to an aromatic benzene ring carbon that lacks any hydrogen atoms. Because it has no $\alpha$-hydrogens, benzaldehyde cannot undergo self-aldol condensation.

Step 3: Evaluate Choice B, formaldehyde (HCHO). This molecule contains only a single carbon atom and lacks an $\alpha$-carbon entirely, meaning it has no $\alpha$-hydrogens and cannot undergo self-aldol condensation.

Step 4: Evaluate Choice C, propanal ($CH_3 - CH_2 - CHO$). The $\alpha$-carbon (Carbon-2) is a $-CH_2-$ methylene group that possesses two $\alpha$-hydrogen atoms. Propanal readily undergoes base-catalyzed deprotonation to form an enolate intermediate, satisfying the reaction criteria.

Step 5: Evaluate Choice D, 2,2-dimethylpropanal ($(CH_3)_3C\text{-}CHO$). The $\alpha$-carbon is fully substituted with three methyl groups and carries zero hydrogen atoms, preventing self-aldol condensation.

**Final Answer:** $\boxed{\text{Propanal}}$

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

**Go Back to Question 16**

# Q17.

## Solution

**Concept:**

The common ion effect describes the reduction in solubility of an ionic precipitate when a soluble compound containing a common ion is introduced into the solution. For a sparingly soluble salt $MX_2$, the solubility equilibrium is written as:

$$MX_2(s) \rightleftharpoons M^{2+}(aq) + 2X^{-}(aq)$$

The solubility product expression is given by $K_{sp} = [M^{2+}][X^{-}]^2$. When a common ion is present, its total concentration must account for contributions from both sources.

**Solution:**

Step 1: Set up the equilibrium concentrations for the dissociation of $MX_2$ in the presence of an existing common ion. Let $S$ represent the molar solubility of $MX_2$ in this solution. The dissociation yields:

$$[M^{2+}] = S$$

$$[X^{-}] = 2S + C_{\text{common}}$$

Here, $C_{\text{common}} = 0.01$ M is the concentration of $X^{-}$ ions provided by the fully soluble secondary source.

Step 2: Write out the explicit mathematical expression for the solubility product constant ($K_{sp}$):

$$K_{sp} = [S] \cdot [2S + 0.01]^2 = 4.0 \times 10^{-12}$$

Step 3: Simplify the equation using physical approximations. Since $MX_2$ is a sparingly soluble salt with a small equilibrium constant ($K_{sp} = 4.0 \times 10^{-12}$), its solubility $S$ will be very small relative to the common ion concentration ($2S \ll 0.01$). Therefore, we can approximate:

$$2S + 0.01 \approx 0.01 \text{ M}$$

Step 4: Substitute this approximation back into the simplified $K_{sp}$ equation:

$$4.0 \times 10^{-12} = S \cdot (0.01)^2$$

$$4.0 \times 10^{-12} = S \cdot (10^{-2})^2 = S \cdot 10^{-4}$$

Step 5: Isolate and solve for the molar solubility $S$ by dividing by $10^{-4}$:

$$S = \frac{4.0 \times 10^{-12}}{10^{-4}} = 4.0 \times 10^{-8} \text{ M}$$

**Final Answer:** $\boxed{4.0 \times 10^{-8} \text{ M}}$

**Answer: (C)**

**Go Back to Question 17**

## Q18.

### Solution

**Concept:**

The rate law for a general chemical reaction expresses the reaction rate as a function of the concentrations of its reactants raised to specific powers, known as partial orders. For the reaction A + B $\longrightarrow$ Products, the rate law is given by:

$$\text{Rate} = k[\text{A}]^x[\text{B}]^y$$

where $x$ is the order with respect to reactant A, and $y$ is the order with respect to reactant B. The overall reaction order is the sum of these partial orders $(x + y)$.

**Solution:**

Step 1: Write down the general algebraic rate law equation for the given reaction system:

$$\text{Rate}_1 = k[\text{A}]^x[\text{B}]^y$$

Step 2: Analyze the experimental effect of changing the concentration of reactant A. The prompt states that doubling [A] while keeping [B] constant causes the initial rate to quadruple ($4 \times \text{Rate}_1$):

$$\text{Rate}_2 = k[2\text{A}]^x[\text{B}]^y = 2^x \cdot k[\text{A}]^x[\text{B}]^y = 4 \cdot \text{Rate}_1$$

By comparing the coefficients, we find $2^x = 4 = 2^2$, which means the partial order with respect to A is $x = 2$.

Step 3: Analyze the experimental effect of changing the concentration of reactant B. Doubling [B] while keeping [A] constant leaves the initial rate completely unchanged ($\text{Rate}_3 = \text{Rate}_1$):

$$\text{Rate}_3 = k[\text{A}]^x[2\text{B}]^y = 2^y \cdot k[\text{A}]^x[\text{B}]^y = 1 \cdot \text{Rate}_1$$

Comparing the coefficients gives $2^y = 1 = 2^0$, which means the partial order with respect to B is $y = 0$.

Step 4: Substitute the values of $x$ and $y$ back into the rate law expression:

$$\text{Rate} = k[\text{A}]^2[\text{B}]^0 = k[\text{A}]^2$$

Step 5: Calculate the overall order of the chemical reaction by summing the partial orders:

$$\text{Overall Order} = x + y = 2 + 0 = 2$$

**Final Answer:** $\boxed{2}$

**Answer: (B)**

**Go Back to Question 18**

# Q19.

## Solution

**Concept:**

Faraday's First Law of Electrolysis states that the mass ($m$) of a substance altered at an electrode during electrolysis is directly proportional to the quantity of electric charge ($Q$) passed through the cell. The relationship is given by:

$$Q = I \cdot t \quad \text{and} \quad m = \frac{\text{Atomic Mass} \cdot Q}{n \cdot F}$$

where $I$ is the electric current in amperes, $t$ is the time in seconds, $n$ is the number of moles of electrons transferred per mole of product, and $F$ is Faraday's constant.

**Solution:**

Step 1: Calculate the total electrical charge ($Q$) passed through the aqueous $CuSO_4$ solution using the current and time values provided:

$$I = 2.0\text{ A}, \quad t = 965\text{ s}$$

$$Q = I \cdot t = 2.0\text{ A} \times 965\text{ s} = 1930\text{ C}$$

Step 2: Write down the reduction half-reaction occurring at the cathode for copper deposition to determine the valence factor ($n$):

$$\text{Cu}^{2+}(aq) + 2e^- \longrightarrow \text{Cu}(s)$$

This equation shows that 2 moles of electrons are required to deposit 1 mole of metallic copper, so $n = 2$. Step 3: State the mass of copper corresponding to one Faraday of charge. Depositing 1 mole of Cu (63.5 g) requires 2 F of charge ($2 \times 96500$ C). Therefore, the mass of copper deposited per Coulomb of charge is:

$$\text{Mass deposited per Coulomb} = \frac{63.5}{2 \times 96500}$$

Step 4: Multiply this factor by the total charge $Q$ passed through the system to calculate the total mass ($m$) of copper deposited:

$$m = \frac{63.5 \times 1930}{2 \times 96500}$$

Step 5: Simplify the fraction to find the final numerical value:

$$\frac{1930}{96500} = \frac{1}{50}$$

$$m = \frac{63.5}{2 \times 50} = \frac{63.5}{100} = 0.3175\text{ g}$$

**Final Answer:** $\boxed{0.3175\text{ g}}$

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

**Go Back to Question 19**

## Q20.

### Solution

**Concept:**

The inert pair effect describes the reluctance of the outermost s-electrons to participate in chemical bonding due to poor shielding by intervening d and f electrons. In Group 14 (Si, Ge, Sn, Pb), this effect becomes progressively stronger down the group, making the +2 oxidation state more stable than the +4 oxidation state for heavier elements like lead (Pb). Conversely, lighter elements in the group form highly stable compounds in the +4 oxidation state.

**Solution:**

Step 1: Analyze the elements listed in the options, which all belong to Group 14 of the periodic table: Silicon (Si), Germanium (Ge), Tin (Sn), and Lead (Pb).

Step 2: Understand the trend in oxidation state stability within Group 14. The elements have a valence shell electron configuration of $ns^2np^2$. They can exhibit oxidation states of +4 (involving all valence electrons) and +2 (involving only the $p$ electrons).

Step 3: Evaluate the impact of the inert pair effect down the group. As the atomic number increases, the $ns^2$ electrons become more tightly bound by the nucleus due to poor shielding by internal d and f orbitals. Consequently, the +2 oxidation state becomes increasingly dominant for heavier elements, while the +4 oxidation state becomes strongly oxidizing.

Step 4: Analyze Lead (Pb), the heaviest element listed. For lead, the +2 state is much more stable than the +4 state. Compounds of $Pb^{4+}$ are unstable and act as strong oxidizing agents to return to the preferred $Pb^{2+}$ form.

Step 5: Evaluate Silicon (Si). Silicon is a light second-period element where the inert pair effect is entirely absent. The energy required to unpair the $3s^2$ electrons is easily compensated for by the energy released during bond formation. As a result, Silicon forms highly stable covalent networks exclusively in the +4 oxidation state, making it the correct match.

**Final Answer:** $\boxed{\text{Si}}$

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

**Go Back to Question 20**

# Answer Key

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