BITSAT Chemistry Sample Paper – 9

Duration: 40 Minutes **Maximum Marks: 90**

Instructions

- This paper contains **30** Multiple Choice Questions (Single Correct Answer).
- Each correct answer carries **+3 marks**. Each incorrect answer carries -1 mark. Unattempted questions carry **0** marks.
- Only **one** option is correct for each question. Choose carefully.
- Use of mobile phones, smartwatches, calculators, or any electronic gadgets is strictly prohibited.

Q1. Chlorine has two naturally occurring isotopes: ^{35}Cl (75% abundance, $M = 35$) and ^{37}Cl (25% abundance, $M = 37$). The average atomic mass of chlorine is:

(A) 35.5

(B) 36.0

(C) 35.0

(D) 36.5

Q2. The work function of a metal is $3.0\,\text{eV}$. What is the minimum frequency of light needed to eject electrons from its surface? ($h = 6.626 \times 10^{-34}\,\text{J s}$; $1\,\text{eV} = 1.6 \times 10^{-19}\,\text{J}$)

(A) $7.25 \times 10^{14}\,\text{Hz}$

(B) $3.62 \times 10^{14}\,\text{Hz}$

(C) $1.45 \times 10^{15}\,\text{Hz}$

(D) $4.83 \times 10^{14}\,\text{Hz}$

Q3. The shape of XeF_4 (xenon tetrafluoride) is:

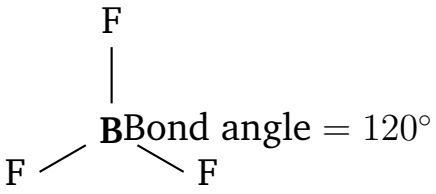
(A) Tetrahedral

(B) See-saw

(C) Square planar

(D) Octahedral

Q4. Consider the molecule below with formula $\mathrm{BF_3}$:



Which of the following is correct about $\mathrm{BF_3}$?

(A) It has a net dipole moment due to polar B–F bonds

(B) It is $\mathrm{sp^2}$ hybridised with zero net dipole moment (trigonal planar)

(C) Boron has a complete octet in $\mathrm{BF_3}$

(D) It is $\mathrm{sp^3}$ hybridised with a lone pair on B

Q5. According to the kinetic theory of gases, the root mean square (rms) speed of gas molecules is proportional to:

(A) T

(B) $1/\sqrt{T}$

(C) T^2

(D) $\sqrt{T}$

Q6. For the reaction $\mathrm{N_2(g) + 3H_2(g) \rightarrow 2NH_3(g)}$, $\Delta H^\circ_{298} = -92\,\mathrm{kJ\,mol^{-1}}$. The reaction is *exothermic*. At higher temperatures (e.g. $500\,\mathrm{K}$), $|\Delta H|$:

(A) Increases (becomes more negative) because $\Delta C_p < 0$

(B) Decreases (becomes less negative) because entropy increases

(C) Remains the same (ΔH is independent of temperature)

(D) Becomes zero at $500\,\mathrm{K}$

Q7. For the reaction $\mathrm{PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)}$, the relationship between K_p and K_c at temperature T is:

(A) $K_p = K_c$

(B) $K_p = K_c(RT)^{-1}$

(C) $K_p = K_c(RT)$

(D) $K_p = K_c(RT)^2$

Q8. A buffer contains $0.2\,\mathrm{M}$ $\mathrm{CH_3COOH}$ and $0.4\,\mathrm{M}$ $\mathrm{CH_3COONa}$. Given $\mathrm{p}K_a = 4.74$, the pH of the buffer is:

(A) 4.44

(B) 5.44

(C) 4.74

(D) 5.04

Q9. In $\mathrm{K_2FeO_4}$ (potassium ferrate), the oxidation state of iron is:

(A) $+3$

(B) $+4$

(C) $+5$

(D) $+6$

Q10. The molar conductance of a strong electrolyte at infinite dilution (Λ_m°) can be obtained by:

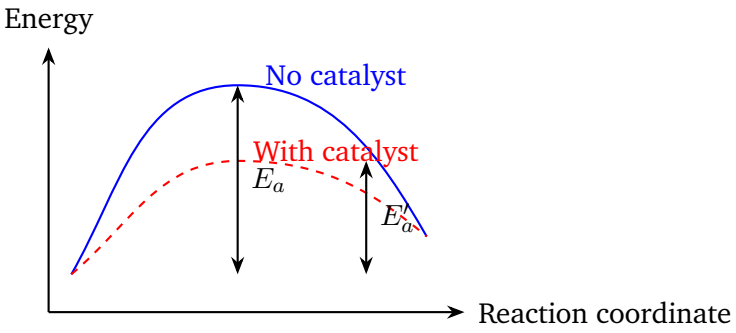
(A) Directly measuring conductance at very high dilution

(B) Extrapolating Λ_m vs $\sqrt{c}$ plot to zero concentration (Kohlrausch's law)

(C) Using the Henderson-Hasselbalch equation

(D) Measuring conductance at $1\,\mathrm{M}$ concentration

Q11. The following diagram shows two energy profiles for the same reaction with and without a catalyst:



Which statement is correct?

(A) The catalyst increases E_a to speed up the reaction

(B) The catalyst is consumed and must be regenerated externally

(C) The catalyst changes ΔH of the reaction

(D) The catalyst lowers E_a; both the forward and reverse rates increase equally; K_{eq} is unchanged

Q12. Which of the following plots is LINEAR for the Freundlich adsorption isotherm?

(A) x/m vs P

(B) $\log(x/m)$ vs $\log P$

(C) x/m vs $\log P$

(D) $1/(x/m)$ vs $1/P$

Q13. Which of the following is the correct order of **reducing power** of Group 15 hydrides?

(A) $NH_3 > PH_3 > AsH_3 > SbH_3$

(B) $SbH_3 > AsH_3 > PH_3 > NH_3$

(C) $NH_3 > AsH_3 > PH_3 > SbH_3$

(D) $PH_3 > NH_3 > AsH_3 > SbH_3$

Q14. Manganese shows the widest range of oxidation states among first-row transition metals. In $KMnO_4$, the oxidation state of Mn is:

(A) $+5$

(B) $+6$

(C) $+7$

(D) $+4$

Q15. According to Werner's theory, in $[Co(NH_3)_6]Cl_3$, the primary valence and secondary valence of Co are respectively:

(A) Primary = 3; Secondary = 3

(B) Primary = 6; Secondary = 3

(C) Primary = 3; Secondary = 6

(D) Primary = 6; Secondary = 6

Q16. Silver crystallises in an FCC lattice. Its unit cell edge length is $409\,\mathrm{pm}$ and $M(\mathrm{Ag}) = 108\,\mathrm{g\,mol^{-1}}$. The density of silver is approximately:

(A) $10.5\,\mathrm{g\,cm^{-3}}$

(B) $5.25\,\mathrm{g\,cm^{-3}}$

(C) $21.0\,\mathrm{g\,cm^{-3}}$

(D) $2.63\,\mathrm{g\,cm^{-3}}$

Q17. A $0.01\,\mathrm{m}$ aqueous solution of K_2SO_4 shows a freezing-point depression of $0.0519\,\mathrm{K}$ ($K_f = 1.86\,\mathrm{K\,kg\,mol^{-1}}$). The apparent degree of dissociation of K_2SO_4 is:

(A) 75%

(B) 100%

(C) 85%

(D) 90%

Q18. Which of the following alkyl halides undergoes SN2 reaction **fastest**?

(A) $(CH_3)_3CBr$ (tert-butyl bromide)

(B) $(CH_3)_2CHBr$ (isopropyl bromide)

(C) CH_3Br (methyl bromide)

(D) CH_3CH_2Br (ethyl bromide)

Q19. When ethanol undergoes acid-catalysed intermolecular dehydration at $140^\circ C$:

$$2\,C_2H_5OH \xrightarrow{H_2SO_4,\ 140^\circ C} \text{Product}$$

The product is:

(A) Ethylene ($CH_2 = CH_2$)

(B) Diethyl ether ($C_2H_5OC_2H_5$)

(C) Acetaldehyde (CH_3CHO)

(D) Ethyl hydrogen sulfate

Q20. Formaldehyde ($HCHO$), which has no α-hydrogen, undergoes a reaction with concentrated NaOH to give:

(A) Acetaldehyde only

(B) Methanol and sodium formate (Cannizzaro reaction)

(C) Formaldehyde polymers only

(D) Carbon dioxide and water

Q21. Which reagent converts a carboxylic acid directly to an acid anhydride?

(A) $SOCl_2$

(B) Acetic anhydride ($(CH_3CO)_2O$)

(C) P_2O_5

(D) $LiAlH_4$

Q22. In aqueous solution, which of the following is the correct order of **basicity**?

(A) $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$

(B) $NH_3 > CH_3NH_2 > (CH_3)_2NH > (CH_3)_3N$

(C) $CH_3NH_2 > (CH_3)_2NH > (CH_3)_3N > NH_3$

(D) $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$

Q23. The isoelectric point (pI) of glycine is approximately 6.0. At pH 3.0, glycine exists predominantly as:

(A) $\mathrm{H_2N-CH_2-COO^-}$ (anionic form)

(B) $\mathrm{H_3N^+-CH_2-COOH}$ (cationic form)

(C) $\mathrm{H_3N^+-CH_2-COO^-}$ (zwitterion)

(D) $\mathrm{H_2N-CH_2-COOH}$ (neutral form)

Q24. Natural rubber is a polymer of:

(A) 1,3-Butadiene

(B) Isoprene (2-methyl-1,3-butadiene)

(C) Chloroprene (2-chloro-1,3-butadiene)

(D) Styrene

Q25. Which of the following is used as an antiseptic in the form of 0.2% solution (Dettol component) and is also an antibiotic precursor?

(A) Chloroxylenol

(B) Tincture of iodine

(C) Phenol (2% solution)

(D) Boric acid

Q26. Sodium burns in excess oxygen to give:

(A) $\mathrm{Na_2O}$ (sodium oxide)

(B) $\mathrm{Na_2O_2}$ (sodium peroxide)

(C) NaO_2 (sodium superoxide)

(D) Na_2O_3 (sodium trioxide)

Q27. SO_2 acts as a bleaching agent by:

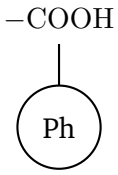
(A) Oxidising coloured compounds with nascent oxygen

(B) Reducing coloured compounds via hydrogen produced in situ

(C) Combining with water to form H_2SO_3 which reduces the coloured matter

(D) Direct chlorination of coloured substances

Q28. In the nitration of the compound shown:



(benzoic acid), the NO_2 group enters predominantly at:

(A) ortho and para positions

(B) meta position

(C) ipso position

(D) ortho position only

Q29. Which of the following gases is NOT a greenhouse gas?

(A) CO_2

(B) CH_4

(C) N_2

(D) N_2O

Q30. Which of the following is the most stable carbocation?

(A) CH_3^+ (methyl)

(B) $CH_3CH_2^+$ (ethyl, primary)

(C) $(CH_3)_2CH^+$ (isopropyl, secondary)

(D) $C_6H_5CH_2^+$ (benzyl)

Detailed Solutions

Q1.

Solution

Concept — Average atomic mass from isotopic abundances:

$$\bar{M} = \sum_i (\text{fractional abundance}_i \times M_i)$$

Step 1: $\bar{M} = 0.75 \times 35 + 0.25 \times 37 = 26.25 + 9.25 = \mathbf{35.5}$

Physical meaning: 35.5 is a weighted average; no single Cl atom has mass 35.5. The periodic table value of $35.5\,\text{g mol}^{-1}$ for Cl reflects this natural isotopic mixture.

Common trap: Taking the arithmetic mean $(35 + 37)/2 = 36$ ignores the unequal abundances (75:25, not 50:50).

Final Answer: $\bar{M}(\text{Cl}) = 35.5 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q1

Q2.

Solution

Concept — Photoelectric effect: threshold frequency: $h\nu_0 = \phi$ (work function), so $\nu_0 = \phi/h$.

Step 1 — Convert work function to joules: $\phi = 3.0\,\text{eV} \times 1.6 \times 10^{-19}\,\text{J eV}^{-1} = 4.8 \times 10^{-19}\,\text{J}$

Step 2 — Threshold frequency:

$$\nu_0 = \frac{\phi}{h} = \frac{4.8 \times 10^{-19}}{6.626 \times 10^{-34}} = 7.245 \times 10^{14}\,\text{Hz} \approx \mathbf{7.25 \times 10^{14}}\,\text{Hz}$$

Step 3 — Wavelength check: $\lambda_0 = c/\nu_0 = 3 \times 10^8/7.25 \times 10^{14} = 414\,\text{nm}$ (violet light, near UV). Any photon with $\lambda < 414\,\text{nm}$ (i.e. UV/violet) can eject electrons from this metal.

Physical significance: Below ν_0, no photoelectrons are emitted regardless of light intensity. Above ν_0, kinetic energy of emitted electrons $= h\nu - \phi$ (Einstein's photoelectric equation).

Final Answer: $\nu_0 = 7.25 \times 10^{14}\,\text{Hz} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q2

Q3.

Solution

Concept — VSEPR for XeF_4: Xe has 8 valence electrons. In XeF_4: 4 Xe–F bonds use 4 electrons; 4 remaining form 2 lone pairs. Total electron domains = 6 $\Rightarrow$ **octahedral** electron geometry $\Rightarrow$ sp^3d^2 hybridisation.

Step 1 — Lone pair placement: In octahedral geometry, the two lone pairs go to positions that maximise their separation. The two lone pairs occupy opposite (trans) positions (axial positions), giving minimum LP–LP repulsion (180° apart).

Step 2 — Molecular shape: The 4 F atoms are in the equatorial plane. The molecular shape (ignoring lone pairs) is **square planar**.

Step 3 — Dipole moment: The two lone pairs are opposite each other (trans) and cancel; the four F atoms are in a square with dipoles cancelling $\Rightarrow \mu = 0$ (non-polar molecule).

Other sp^3d^2 examples: SF_6 (octahedral, 0 lone pairs), IF_5 (square pyramidal, 1 lone pair), XeF_4 (square planar, 2 lone pairs).

Final Answer: Square planar $\Rightarrow$ C

Answer: (C) Go Back to Q3

Q4.

Solution

Concept — Hybridisation and dipole moment of BF_3: B has 3 valence electrons. In BF_3: 3 B–F bonds, no lone pairs on B. Electron domains = 3 $\Rightarrow$ sp^2 hybridisation $\Rightarrow$ trigonal planar.

Step 1 — Dipole moment: Each B–F bond is polar (δ^+ on B, δ^- on F, since F is much more electronegative). However, the three B–F bond dipoles are arranged symmetrically at $120°$. Their vector sum is exactly zero $\Rightarrow$ **net dipole moment = 0**.

Step 2 — Incomplete octet: B in BF_3 has only 6 electrons around it (3 bonding pairs) — an incomplete octet. This makes BF_3 a Lewis acid that can accept a lone pair from a Lewis base (e.g. $BF_3 + NH_3 \rightarrow BF_3 \cdot NH_3$).

Step 3 — Option B is correct: sp^2, trigonal planar, zero net dipole moment due to symmetric cancellation.

Final Answer: sp^2, trigonal planar, zero net dipole $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q4

Q5.

Solution

Concept — Kinetic theory: rms speed formula:

$$v_{\text{rms}} = \sqrt{\frac{3RT}{M}}$$

Step 1: $v_{\text{rms}} \propto \sqrt{T/M}$. At constant M, $v_{\text{rms}} \propto \sqrt{T}$.

Step 2 — Other speeds:

- Most probable speed: $v_p = \sqrt{2RT/M} \propto \sqrt{T}$
- Average speed: $\bar{v} = \sqrt{8RT/\pi M} \propto \sqrt{T}$
- All three are $\propto \sqrt{T}$

Step 3 — Physical insight: Doubling T (in Kelvin) increases v_{rms} by factor $\sqrt{2} \approx 1.41$, not by 2. This is why the speed distribution broadens gradually with temperature.

Final Answer: $v_{\text{rms}} \propto \sqrt{T} \Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q5

Q6.

Solution

Concept — Kirchhoff's equation: temperature dependence of ΔH: $\Delta H(T_2) = \Delta H(T_1) + \Delta C_p(T_2 - T_1)$, where $\Delta C_p = \sum C_p(\text{products}) - \sum C_p(\text{reactants})$.

Step 1 — Sign of ΔC_p for $\text{N}_2 + 3\text{H}_2 \rightarrow 2\text{NH}_3$: $\Delta C_p = 2C_p(\text{NH}_3) - C_p(\text{N}_2) - 3C_p(\text{H}_2)$ $= 2(35.1) - 29.1 - 3(28.8) = 70.2 - 29.1 - 86.4 = -45.3\,\text{J mol}^{-1}\text{K}^{-1} < 0$

Step 2 — Effect on ΔH at $500\,\text{K}$: $\Delta H_{500} = -92 + (-0.0453)(500 - 298)\,\text{kJ} = -92 - 9.15 = -101.15\,\text{kJ}$

Since $\Delta C_p < 0$, ΔH becomes *more negative* (larger magnitude) at higher temperatures.

Step 3 — Option A is correct: The reaction becomes more exothermic ($|\Delta H|$ increases) because $\Delta C_p < 0$: products have a lower total heat capacity than reactants, so as temperature rises, the energy gap widens.

Final Answer: $|\Delta H|$ increases (more negative) because $\Delta C_p < 0 \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q6

Q7.

Solution

Concept — $K_p = K_c(RT)^{\Delta n_g}$: For $\mathrm{PCl_5(g) \rightleftharpoons PCl_3(g) + Cl_2(g)}$: $\Delta n_g = (1+1)-1 = +1$.

Step 1: $K_p = K_c(RT)^{\Delta n_g} = K_c(RT)^{+1} = K_c(RT)$

Step 2 — Units check: K_c has units $\mathrm{mol\,L^{-1}}$ (for $\Delta n_g = +1$); K_p has units atm. Multiplying by RT $(\mathrm{L\,atm\,mol^{-1}})$ gives correct dimensions: $\mathrm{mol\,L^{-1}} \times \mathrm{L\,atm\,mol^{-1}} = \mathrm{atm}$ ✓.

Step 3 — Physical meaning: Since $\Delta n_g > 0$, $K_p > K_c$ (at normal temperatures where $RT > 1\,\mathrm{L\,atm\,mol^{-1}}$). The reaction produces more moles of gas, so partial pressures are amplified compared to concentrations.

Final Answer: $K_p = K_c(RT) \Rightarrow \boxed{\text{C}}$

Answer: (C) Go Back to Q7

Q8.

Solution

Concept — Henderson-Hasselbalch equation:

$$\mathrm{pH} = \mathrm{p}K_a + \log\frac{[\mathrm{salt}]}{[\mathrm{acid}]}$$

Step 1: $\mathrm{pH} = 4.74 + \log\frac{0.4}{0.2} = 4.74 + \log 2 = 4.74 + 0.301 = \mathbf{5.04}$

Step 2 — Interpretation: $[\mathrm{salt}] > [\mathrm{acid}]$ (ratio $= 2 > 1$) $\Rightarrow \mathrm{pH} > \mathrm{p}K_a$. The buffer is slightly basic compared to the pure acid's $\mathrm{p}K_a$, because there is more conjugate base than acid.

Step 3 — Buffer capacity: This buffer is effective in the range $\mathrm{p}K_a \pm 1 = 3.74$–$5.74$. Adding small amounts of strong acid or base changes pH by < 0.1 units.

Final Answer: pH = 5.04 $\Rightarrow \boxed{\text{D}}$

Answer: (D) Go Back to Q8

Q9.

Solution

Concept — Oxidation state in ferrate: In K_2FeO_4: $2(+1) + x + 4(-2) = 0 \Rightarrow 2 + x - 8 = 0 \Rightarrow x = +6$.

Physical significance: Fe(+6) in FeO_4^{2-} is isoelectronic with CrO_4^{2-} (Cr is +6). Ferrate is a powerful green oxidising agent used in water treatment (oxidises organic contaminants and reduces to non-toxic Fe^{3+}). It is considered an environmentally friendly oxidant.

Stability: K_2FeO_4 is only stable in strongly alkaline solution; it decomposes in acidic or neutral conditions: $4FeO_4^{2-} + 20H^+ \rightarrow 4Fe^{3+} + 3O_2 + 10H_2O$.

Final Answer: Fe is $+6$ in $K_2FeO_4 \Rightarrow \boxed{D}$

Answer: (D) Go Back to Q9

Q10.

Solution

Concept — Kohlrausch's law of independent migration of ions: For strong electrolytes, Λ_m decreases linearly with $\sqrt{c}$ (Debye-Hückel-Onsager equation): $\Lambda_m = \Lambda_m^\circ - K\sqrt{c}$

Step 1 — Obtaining Λ_m°: A plot of Λ_m vs $\sqrt{c}$ for a *strong electrolyte* is a straight line. Extrapolating to $c = 0$ ($\sqrt{c} = 0$) gives the y-intercept = Λ_m°.

Step 2 — Why not option A? At very high dilution, the conductance of a weak electrolyte changes steeply (not linearly), so direct measurement is impractical. For weak acids, Λ_m° is obtained using Kohlrausch's law of independent migration: $\Lambda_m^\circ(HA) = \lambda^\circ(H^+) + \lambda^\circ(A^-)$.

Step 3 — Kohlrausch's law of independent migration: $\Lambda_m^\circ = \sum \nu_+ \lambda_+^\circ + \sum \nu_- \lambda_-^\circ$ (ions migrate independently at infinite dilution, no interionic interactions).

Final Answer: Extrapolating Λ_m vs $\sqrt{c}$ to $c = 0 \Rightarrow \boxed{B}$

Answer: (B) Go Back to Q10

Q11.

Solution

Concept — Catalysis and activation energy: A catalyst provides an alternative reaction pathway with lower activation energy $E_a' < E_a$.

Step 1 — Effect on rates: $k = Ae^{-E_a/RT}$. Lowering E_a increases k exponentially. Both forward and reverse rates increase by the same factor (since ΔH is unchanged, $E_a(\text{rev})$ also decreases by the same amount as $E_a(\text{fwd})$).

Step 2 — Effect on equilibrium: Since both forward and reverse rates increase equally, the equilibrium constant $K_{eq} = k_f/k_r$ is unchanged. Equilibrium is reached faster, but at the same composition.

Step 3 — Option B is the full correct answer: The catalyst lowers $E_a \Rightarrow$ both rates increase $\Rightarrow$ equilibrium reached faster $\Rightarrow$ K_{eq} unchanged. It also does not change ΔH (option B is fully correct).

The catalyst is regenerated in the catalytic cycle (not consumed permanently). Exceptions: surface catalysts deactivate slowly by poisoning.

Final Answer: Catalyst lowers E_a; both rates increase equally; K_{eq} unchanged $\Rightarrow$ D

Answer: (D) Go Back to Q11

Q12.

Solution

Concept — Freundlich isotherm linearisation: Freundlich: $\frac{x}{m} = kP^{1/n}$.

Taking log: $\log\left(\frac{x}{m}\right) = \log k + \frac{1}{n}\log P$.

Step 1: This is a linear equation of the form $Y = c + mX$ where $Y = \log(x/m)$ and $X = \log P$. So a plot of $\log(x/m)$ vs $\log P$ gives a straight line with slope $= 1/n$ and intercept $= \log k$.

Step 2 — Other options: Option A (x/m vs P): curved (power law, not linear). Option C (x/m vs $\log P$): semi-log, not exactly Freundlich. Option D ($1/(x/m)$ vs $1/P$): this is the Langmuir linearised plot, not Freundlich.

Application: The slope $1/n$ tells us the intensity of adsorption. If $1/n < 1$: normal (favourable) adsorption. If $1/n > 1$: cooperative (unfavourable). If $1/n = 1$: linear (Henry's law).

Final Answer: $\log(x/m)$ vs $\log P$ is linear $\Rightarrow$ $\boxed{\text{B}}$

Answer: (B) Go Back to Q12

Q13.

Solution

Concept — Reducing power of Group 15 hydrides: Reducing power depends on the ease of releasing electrons (or H). Going down the group, M–H bond becomes weaker $\Rightarrow$ H is released more easily $\Rightarrow$ stronger reducing agent.

Step 1 — Bond energies (N–H to Sb–H): N–H: 391, P–H: 322, As–H: 297, Sb–H: $255\,\text{kJ}\,\text{mol}^{-1}$. Weakest bond = Sb–H $\Rightarrow$ SbH_3 is easiest to oxidise $\Rightarrow$ strongest reducing agent.

Step 2 — Order: $SbH_3 > AsH_3 > PH_3 > NH_3$ (option B).

Step 3 — Contrast with thermal stability: Thermal stability is the opposite: $NH_3 > PH_3 > AsH_3 > SbH_3$. Stronger bond $\Rightarrow$ more stable hydride but weaker reducing agent.

Note on NH_3: Despite NH_3 being the least reducing, it is a better ligand (stronger Lewis base) due to N's lone pair being more available (less diffuse than P, As, Sb lone pairs).

Final Answer: $SbH_3 > AsH_3 > PH_3 > NH_3 \Rightarrow$ B

Answer: (B) Go Back to Q13

Q14.

Solution

Concept — Oxidation state of Mn in permanganate: $KMnO_4$: $+1 + x + 4(-2) = 0 \Rightarrow x = +7$.

Mn oxidation states: Mn shows all OS from $+2$ to $+7$. MnO_4^- (+7, purple); MnO_4^{2-} (+6, green); MnO_2 (+4, brown); Mn_2O_3 (+3); MnO (+2, stable pink).

Application of $KMnO_4$: Under acidic conditions, MnO_4^- is reduced to Mn^{2+} (colourless); under neutral/alkaline, to MnO_2 (brown). Used in titrations, organic synthesis (oxidises alkenes, alcohols), and water treatment.

Final Answer: Mn is $+7$ in $KMnO_4 \Rightarrow$ C

Answer: (C) Go Back to Q14

Q15.

Solution

Concept — Werner's theory: primary and secondary valences:

- **Primary valence** (ionisable valence): the oxidation state of the metal. Satisfied by anions that appear in the outer sphere (ionisable in solution).
- **Secondary valence** (non-ionisable): the coordination number. Satisfied by ligands in the inner sphere (within the coordination sphere, not ionisable directly).

Step 1 — For $[Co(NH_3)_6]Cl_3$: Co is $+3$ (primary valence = 3). Six NH_3 ligands occupy the inner sphere (secondary valence = 6). Three Cl^- are in the outer sphere and ionise in solution.

Step 2 — Verify: $[Co(NH_3)_6]Cl_3 \rightarrow [Co(NH_3)_6]^{3+} + 3Cl^-$ in solution. Primary valence = charge on cation complex = 3 (= Co's OS). Secondary valence = coordination number = 6 (= number of NH_3).

Final Answer: Primary = 3; Secondary = 6 $\Rightarrow$ C

Answer: (C) Go Back to Q15

Q16.

Solution

Concept — Density of crystal from unit cell parameters:

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

where Z = atoms per unit cell, M = molar mass, a = edge length.

Step 1 — FCC: $Z = 4$**:** $a = 409\,\text{pm} = 409 \times 10^{-10}\,\text{cm} = 4.09 \times 10^{-8}\,\text{cm}$

$a^3 = (4.09)^3 \times 10^{-24} = 68.4 \times 10^{-24}\,\text{cm}^3$

Step 2 — Calculate ρ:

$$\rho = \frac{4 \times 108}{6.022 \times 10^{23} \times 68.4 \times 10^{-24}} = \frac{432}{6.022 \times 10^{23} \times 6.84 \times 10^{-23}} = \frac{432}{41.19} = \mathbf{10.49 \approx 10.5}\,\text{g cm}^{-3}$$

Verification: Experimental density of Ag $= 10.49\,\text{g cm}^{-3}$ — exact agreement.

Application: This formula lets us calculate: density from crystal structure, or lattice parameter from measured density (important in X-ray crystallography).

Final Answer: $\rho(\text{Ag}) \approx 10.5\,\text{g cm}^{-3} \Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q16

Q17.

Solution

Concept — van't Hoff factor from freezing-point depression: $\Delta T_f = i \cdot K_f \cdot m$, so $i = \Delta T_f / (K_f \cdot m)$.

Step 1 — Calculate i: $i = \frac{0.0519}{1.86 \times 0.01} = \frac{0.0519}{0.0186} = 2.79$

Step 2 — Relate i to degree of dissociation α: $\mathrm{K_2SO_4} \rightarrow 2\mathrm{K^+} + \mathrm{SO_4^{2-}}$; theoretical $i = 3$ for complete dissociation.

For partial dissociation: $i = 1 + (n-1)\alpha = 1 + 2\alpha$, where $n = 3$.

$2.79 = 1 + 2\alpha \Rightarrow 2\alpha = 1.79 \Rightarrow \alpha = 0.895 \approx \mathbf{90\%}$

Step 3 — Physical meaning: At $0.01\ \mathrm{m}$, $\mathrm{K_2SO_4}$ is about 90% dissociated. At higher concentrations, interionic attraction reduces this further. This is why colligative property measurements give apparent (not theoretical) van't Hoff factors.

Final Answer: $\alpha \approx 90\% \Rightarrow$ D

Answer: (D) Go Back to Q17

Q18.

Solution

Concept — SN2 rate and substrate structure: SN2 is a bimolecular, one-step reaction. The nucleophile attacks the backside of the carbon bearing the leaving group. Rate is critically dependent on steric hindrance.

Step 1 — Steric effects:

Substrate	Type	SN2 rate
CH_3Br	methyl	fastest (no steric hindrance)
CH_3CH_2Br	primary (1°)	fast
$(CH_3)_2CHBr$	secondary (2°)	slow
$(CH_3)_3CBr$	tertiary (3°)	negligible (SN1 instead)

Step 2 — Why methyl is fastest? Methyl bromide has no alkyl substituents on the reaction carbon. The nucleophile can attack without any steric obstruction. As substituents increase ($1° \rightarrow 2° \rightarrow 3°$), the backside becomes increasingly crowded, slowing SN2 dramatically.

Energy analogy: In SN2, the transition state places 5 groups around the carbon (3 original + nucleophile + leaving group). More bulky substituents raise this transition state energy, increasing E_a and slowing the reaction.

Final Answer: CH_3Br (methyl) — fastest SN2 (no steric hindrance) $\Rightarrow$ $\boxed{C}$

Answer: (C) Go Back to Q18

Q19.

Solution

Concept — Intermolecular vs intramolecular dehydration of ethanol: Temperature determines the product:

- $140^\circ C$: intermolecular dehydration $\rightarrow$ ether (two molecules of alcohol lose one molecule of water)
- $170^\circ C$: intramolecular dehydration $\rightarrow$ alkene (one molecule loses water, E1/E2)

Step 1 — Reaction at $140^\circ C$**:** $2\,C_2H_5OH \xrightarrow{H_2SO_4,\ 140^\circ C} C_2H_5 - O - C_2H_5 + H_2O$

Product: **diethyl ether** (ethoxyethane).

Step 2 — Mechanism: Protonation of one ethanol's OH $\rightarrow$ $C_2H_5OH_2^+$; second ethanol molecule attacks as a nucleophile (SN2-like) $\rightarrow$ protonated ether $\rightarrow$ deprotonation $\rightarrow$ diethyl ether.

Step 3 — Industrial use: Diethyl ether was the first widely used general anaesthetic (1846). Today it is used as a solvent in organic synthesis and as a fuel additive.

Final Answer: Diethyl ether (intermolecular dehydration at $140^\circ C$) $\Rightarrow \boxed{B}$

Answer: (B) Go Back to Q19

Q20.

Solution

Concept — Cannizzaro reaction (HCHO, no α-H): Formaldehyde has no α-H (the only H is the aldehydic H). In conc. NaOH, disproportionation occurs.

Step 1 — Mechanism:

(a) OH^- attacks carbonyl of HCHO $\rightarrow$ hydride-donor intermediate
(b) Hydride (H^-) transfers to a second HCHO molecule
(c) One HCHO is oxidised to formate ($HCOO^-$); the other is reduced to methanol (CH_3OH)

$$2\,HCHO + NaOH \rightarrow CH_3OH + HCOONa$$

Step 2 — Industrial application: The Cannizzaro reaction of formaldehyde produces methanol and sodium formate, both commercially valuable. This is related to the Tishchenko reaction (ester from aldehyde + alkoxide catalyst).

Cross-Cannizzaro: Mixing HCHO with benzaldehyde (also no α-H): HCHO is preferentially oxidised (more reactive) $\rightarrow$ formate; benzaldehyde is reduced $\rightarrow$ benzyl alcohol (selective).

Final Answer: Methanol + sodium formate (Cannizzaro reaction) $\Rightarrow$ $\boxed{B}$

Answer: (B) Go Back to Q20

Q21.

Solution

Concept — Formation of acid anhydride from carboxylic acid: Two molecules of a carboxylic acid can be converted to an acid anhydride by dehydration using a dehydrating agent.

Step 1 — Reagent: P_2O_5**:** P_2O_5 (phosphorus pentoxide) is a powerful dehydrating agent. It removes water from two RCOOH molecules: $2\,RCOOH \xrightarrow{P_2O_5} (RCO)_2O + H_2O$

Step 2 — Other options: $SOCl_2$: converts RCOOH to RCOCl (acid chloride), not anhydride. Acetic anhydride: reacts with RCOOH by acyl exchange to give the mixed anhydride RCO-O-$COCH_3$, then pure anhydride on heating. More useful for reactive acids but not the direct anhydride synthesis. $LiAlH_4$: reduces RCOOH to RCH_2OH (alcohol), not anhydride.

Step 3 — Best answer: P_2O_5 For simple fatty acids, P_2O_5 is the cleanest anhydride synthesis route. For aromatic acids, the anhydride route via acetic anhydride followed by distillation is used industrially.

Final Answer: P_2O_5 converts RCOOH to anhydride $\Rightarrow$ C

Answer: (C) Go Back to Q21

Q22.

Solution

Concept — Basicity of aliphatic amines in aqueous solution: In aqueous solution, basicity is determined by:

(a) Inductive effect of alkyl groups (all increase basicity: $+I$ effect)
(b) Steric effect (large groups hinder protonation and solvation, decrease basicity)
(c) Solvation of the conjugate acid (RNH_3^+): more H atoms on N $\Rightarrow$ better H-bonding $\Rightarrow$ more stable cation $\Rightarrow$ stronger base

Step 1 — Predict the order: In water, the net effect gives: $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$

- $(CH_3)_2NH$ (pK_b = 3.27): 2 alkyl groups donate electrons; N–H still present for solvation — best balance.
- CH_3NH_2 (pK_b = 3.36): 1 alkyl group; good solvation of cation ($CH_3NH_3^+$).
- $(CH_3)_3N$ (pK_b = 4.19): 3 alkyl groups donate electrons (should be strongest by induction), BUT the cation $(CH_3)_3NH^+$ has only 1 N–H $\Rightarrow$ poor solvation $\Rightarrow$ less stabilised $\Rightarrow$ weaker base in water.
- NH_3 (pK_b = 4.74): no alkyl donation; weakest.

Step 2 — Gas-phase order (pure inductive): $(CH_3)_3N > (CH_3)_2NH > CH_3NH_2 > NH_3$ (option A is the gas-phase order, not aqueous).

Final Answer: $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$ (aqueous solution) $\Rightarrow$ D

Answer: (D) Go Back to Q22

Q23.

Solution

Concept — Amino acid speciation vs pH: Below pI: amino acid carries net positive charge (both groups protonated). At pI: zwitterion (net charge = 0). Above pI: amino acid carries net negative charge (amino group deprotonated).

Step 1 — pI of glycine = 6.0; solution pH = 3.0: pH = 3.0 < pI = 6.0. The pH is below the isoelectric point, meaning the solution is more acidic than the pI. In acidic conditions, groups tend to be protonated.

Step 2 — At pH 3.0: Both the $-NH_2$ group is protonated to $-NH_3^+$, AND the $-COO^-$ is protonated to $-COOH$ (since pH $\ll$ p$K_{a1} \approx 2.3$ for the carboxyl). Form: $\mathbf{H_3N^+ - CH_2 - COOH}$ (cationic form, option B).

Step 3 — Electrophoresis: At pH 3.0, glycine migrates toward the cathode (negatively charged electrode) because the glycine molecule itself is positively charged.

Final Answer: $H_3N^+ - CH_2 - COOH$ (cationic, pH < pI) $\Rightarrow$ B

Answer: (B) Go Back to Q23

Q24.

Solution

Concept — Natural rubber (polyisoprene): Natural rubber is obtained from latex of the rubber tree (*Hevea brasiliensis*). It is the polymer of isoprene.

Step 1 — Monomer: Isoprene = 2-methyl-1,3-butadiene: $CH_2 = C(CH_3) - CH = CH_2$

Step 2 — Structure of natural rubber: $[-CH_2 - C(CH_3) = CH - CH_2-]_n$: 1,4-addition of isoprene with *cis* configuration at the double bond (all *cis*-polyisoprene). This cis-configuration allows the chains to coil, giving rubber its elasticity.

Step 3 — Vulcanisation: Heating with 2–3% sulfur cross-links the rubber chains via $-S-S-$ and $-S-$ bridges, improving strength, elasticity, and thermal resistance. Hard rubber (ebonite) uses 30–50% S.

Compare: Synthetic rubbers: Buna-S (butadiene + styrene), Buna-N (butadiene + acrylonitrile), Neoprene (chloroprene).

Final Answer: Isoprene (2-methyl-1,3-butadiene) $\Rightarrow$ B

Answer: (B) Go Back to Q24

Q25.

Solution

Concept — Antiseptics and disinfectants:

- **Antiseptic**: applied to living tissues (wounds, skin) to kill/inhibit microbes.
- **Disinfectant**: applied to non-living surfaces (floors, instruments) — too toxic for living tissue.

Step 1 — Evaluate options: *Chloroxylenol (Dettol component):* A chlorinated phenol derivative. Used as the active ingredient in Dettol antiseptic liquid ($\approx 4.8\%$ in Dettol). It is a broad-spectrum antimicrobial, effective against bacteria and fungi. Also used as a preservative in cosmetics.

Tincture of iodine: I_2 in ethanol/KI solution; used as a wound antiseptic but stronger and can stain skin. Not the Dettol component.

Phenol (2%): Used as a disinfectant at 2–5%; too irritant for skin at this concentration.

Boric acid: Very mild antiseptic (eye wash); not a Dettol component.

Step 2 — Chloroxylenol (4-chloro-3,5-dimethylphenol): It disrupts bacterial cell membranes and inactivates enzymes. It is the main active ingredient in Dettol, TCP, and Savlon (with benzalkonium chloride).

Final Answer: Chloroxylenol (Dettol component) $\Rightarrow \boxed{\text{A}}$

Answer: (A) Go Back to Q25

Q26.

Solution

Concept — Products of combustion of alkali metals in excess oxygen:

- Li: $4\text{Li} + \text{O}_2 \rightarrow 2\text{Li}_2\text{O}$ (normal oxide, O^{2-})
- Na: $2\text{Na} + \text{O}_2 \rightarrow \text{Na}_2\text{O}_2$ (**sodium peroxide**, O_2^{2-})
- K, Rb, Cs: $M + \text{O}_2 \rightarrow \text{MO}_2$ (superoxide, O_2^{-})

Step 1 — Na in excess O_2: Sodium reacts with excess oxygen to give sodium peroxide: $2\text{Na} + \text{O}_2 \xrightarrow{\text{excess O}_2} \text{Na}_2\text{O}_2$

Step 2 — Properties of Na_2O_2: Na_2O_2 is a pale yellow solid. It reacts with water: $2\text{Na}_2\text{O}_2 + 2\text{H}_2\text{O} \rightarrow 4\text{NaOH} + \text{O}_2$ (used in submarines as oxygen source). With CO_2: $2\text{Na}_2\text{O}_2 + 2\text{CO}_2 \rightarrow 2\text{Na}_2\text{CO}_3 + \text{O}_2$ (CO_2 scrubber).

Step 3 — Why K gives superoxide: K is larger and less polarising than Na; it stabilises the larger O_2^{-} ion better.

Final Answer: Na burns in excess O_2 to give Na_2O_2 (sodium peroxide) $\Rightarrow$ B

Answer: (B) Go Back to Q26

Q27.

Solution

Concept — Mechanism of bleaching by SO_2: SO_2 dissolves in water to form sulfurous acid (H_2SO_3), which is a mild reducing agent.

Step 1 — Bleaching mechanism: $SO_2 + H_2O \rightarrow H_2SO_3$

H_2SO_3 reduces coloured organic compounds to colourless forms by reducing the chromophore (colour-causing π system). The reduction disrupts conjugation, destroying the colour.

Step 2 — Key distinction:

- SO_2 bleaching: by **reduction** (temporary; colour returns on oxidation by air)
- Cl_2/H_2O_2 bleaching: by **oxidation** (permanent; chromophore destroyed)

Step 3 — Application: SO_2 is used to bleach: wool, silk, straw, paper (delicate materials that would be damaged by oxidative bleaching). It preserves some coloured pigments in food (wine, dried fruits) as a preservative.

Final Answer: SO_2 bleaches by forming H_2SO_3 which reduces the coloured matter $\Rightarrow$ C

Answer: (C) Go Back to Q27

Q28.

Solution

Concept — EAS directing effects: $-$COOH is a meta-director: The $-$COOH group is an electron-withdrawing group by both induction ($-I$) and resonance ($-M$, the lone pair on C=O draws electrons from ring). It deactivates the ring and directs incoming electrophiles to the meta position.

Step 1 — Resonance effect: $-\mathrm{COOH}$ withdraws electrons from ortho and para positions (through the conjugated $\mathrm{C=O}$ system), making these positions electron-poor. The meta position is relatively less electron-poor and is therefore the preferred site for electrophilic attack.

Step 2 — Products of nitration of benzoic acid: Main product: 3-nitrobenzoic acid (meta). This is consistent with industrial preparation of m-nitrobenzoic acid.

Step 3 — Other meta-directors: $-\mathrm{NO_2}$, $-\mathrm{CN}$, $-\mathrm{CHO}$, $-\mathrm{COR}$, $-\mathrm{SO_3H}$: all are $-I/-M$ groups $\Rightarrow$ meta directors + ring deactivators.

Final Answer: $-$COOH is a meta-director; $\mathrm{NO_2}$ enters meta position $\Rightarrow$ $\boxed{\mathrm{B}}$

Answer: (B) Go Back to Q28

Q29.

Solution

Concept — Greenhouse gases and their properties: Greenhouse gases absorb and re-emit infrared (IR) radiation from the Earth's surface, trapping heat in the atmosphere (greenhouse effect).

Step 1 — Why a gas is a greenhouse gas: A molecule absorbs IR radiation if it has a vibrational mode that changes the **dipole moment** during vibration (IR-active modes). Symmetric, homonuclear diatomic molecules (N_2, O_2) have *no* dipole moment and no change in dipole during vibration $\Rightarrow$ they are **IR-inactive** $\Rightarrow$ not greenhouse gases.

Step 2 — Evaluate options: CO_2: bent vibration changes dipole $\Rightarrow$ GHG (major). CH_4: C–H stretches change dipole $\Rightarrow$ GHG (potent, 25$\times$ CO_2 over 100 years). $\mathbf{N_2}$: symmetric homonuclear diatomic, no dipole change $\Rightarrow$ **NOT a GHG**. It makes up 78% of atmosphere but contributes nothing to the greenhouse effect. N_2O: asymmetric; has dipole change during vibration $\Rightarrow$ GHG (300$\times$ CO_2; also destroys ozone).

Final Answer: N_2 is NOT a greenhouse gas (no IR-active modes) $\Rightarrow$ $\boxed{C}$

Answer: (C) Go Back to Q29

Q30.

Solution

Concept — Carbocation stability: resonance vs hyperconjugation: Stability order: allylic/benzylic $>$ 3° $>$ 2° $>$ 1° $>$ methyl.

Step 1 — Evaluate options:

Methyl (CH_3^+)*:* No alkyl groups, no lone pairs; empty p-orbital completely exposed. Most unstable.

Primary ($CH_3CH_2^+$)*:* One alkyl group; limited hyperconjugation. Unstable.

Secondary ($(CH_3)_2CH^+$)*:* Two alkyl groups; better hyperconjugation. More stable than 1°.

Benzyl ($C_6H_5CH_2^+$): The empty p-orbital on CH_2^+ is conjugated with the benzene ring π system. Resonance delocalises the positive charge over 7 atoms (the CH_2 carbon and 3 ortho/para ring carbons). This extensive resonance stabilisation makes benzyl cation more stable than even a tertiary carbocation.

Step 2 — Stability order: Benzyl $>$ 3° $>$ 2° $>$ 1° $>$ methyl.

Note: Allyl cation ($CH_2 = CH - CH_2^+$) is also highly stabilised by resonance (over 3 atoms), similar in stability to benzyl.

Final Answer: Benzyl cation ($C_6H_5CH_2^+$) most stable due to resonance with ring $\Rightarrow$ $\boxed{D}$

Answer: (D) Go Back to Q30

Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	A	3	C	4	B	5	D
6	A	7	C	8	D	9	D	10	B
11	D	12	B	13	B	14	C	15	C
16	A	17	D	18	C	19	B	20	B
21	C	22	D	23	B	24	B	25	A
26	B	27	C	28	B	29	C	30	D