JEE Main Chemistry

Sample Paper – 18

Duration: 60 Minutes **Maximum Marks: 100**

Instructions

- This paper contains **30 questions** modelled on the Chemistry portion of **JEE Main** entrance examination.
- **Section A** (Q1–Q20): 20 Single Correct Multiple Choice Questions. **+4 marks** for correct answer; **−1 mark** for wrong answer; **0** for unattempted.
- **Section B** (Q21–Q30): 10 Numerical Value Questions. Attempt **any 5**. **+4 marks** for correct answer; **0 marks** for incorrect or unattempted.
- Syllabus: Class 11 & 12 NCERT Chemistry (JEE Main official syllabus).
- Personal calculators, log tables, and electronic gadgets are strictly prohibited. A simple on-screen virtual calculator is provided in the CBT interface.
- Rough sheets will be provided at the examination centre. Write your roll number on every sheet.

Section A — Single Correct
MCQ (Q1–Q20) [+4 / −1]

Q1. Which of the following statements **correctly** interprets the Heisenberg uncertainty principle for an electron whose position is known to within $\Delta x = 1\,\text{Å}$ ($= 1 \times 10^{-10}\,\text{m}$)?

(A) The electron is at rest at a precisely known location; only its energy is uncertain.

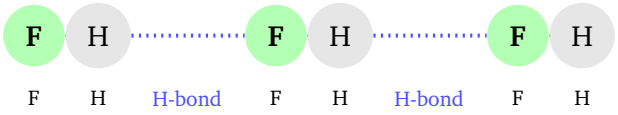
(B) It is impossible to simultaneously determine the position and momentum of the electron with arbitrary precision; the minimum un-

certainty in momentum is $\Delta p \geq \dfrac{h}{4\pi\,\Delta x}$.

(C) The uncertainty principle applies only to macroscopic objects; for an electron the position and momentum can both be measured exactly.

(D) Knowing $\Delta x = 1\,\text{Å}$ implies $\Delta p = 0$, since a smaller position uncertainty means the electron's momentum is better defined.

Q2. The boiling point of HF is $+19.5\,^{\circ}\text{C}$, which is anomalously high compared to HCl ($-85\,^{\circ}\text{C}$), HBr ($-67\,^{\circ}\text{C}$), and HI ($-35\,^{\circ}\text{C}$), despite HF having the lowest molar mass in the series. The diagram below shows the intermolecular interaction responsible.



Which statement **correctly** explains the anomalously high boiling point of HF?

(A) HF has the highest molar mass in the halogen hydride series, so van der Waals forces are strongest.

(B) The H–F covalent bond is the weakest in the series; therefore less energy is needed to vaporise HF.

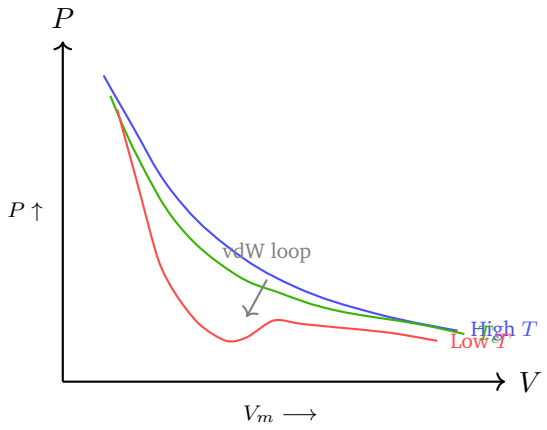
(C) HF molecules associate strongly through intermolecular hydrogen bonds (F is the most electronegative element and has a small atomic radius), greatly increasing the energy needed for vaporisation.

(D) HF is ionic in the liquid phase, requiring high energy to separate the ions.

Q3. The van der Waals equation for a real gas is:

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

The diagram below shows isotherms for a real gas, including the characteristic van der Waals loop at low temperature.



Which statement **correctly** describes the physical significance of the constants a and b in the van der Waals equation?

(A) a corrects for the finite volume of the gas molecules (excluded volume); b corrects for intermolecular attractive forces that reduce the pressure.

(B) Both a and b are correction terms for intermolecular repulsions only; they become negligible at high pressure.

(C) a accounts for the kinetic energy of molecules; b accounts for the molecular mass.

(D) a accounts for intermolecular attractive forces (reduces the observed pressure below the ideal value); b accounts for the excluded (finite) volume of the molecules (reduces the available volume below V).

Q4. The lattice energy of NaCl can be determined using the Born-Haber cycle (an application of Hess's law). Given the following data:

$\Delta H_f^\circ(\text{NaCl}) = -411\,\text{kJ/mol}$	(enthalpy of formation)
$\Delta H_{\text{sub}}(\text{Na}) = +108\,\text{kJ/mol}$	(sublimation of Na)
$IE_1(\text{Na}) = +496\,\text{kJ/mol}$	(first ionisation energy of Na)
$\frac{1}{2}D(\text{Cl}_2) = +121\,\text{kJ/mol}$	(bond dissociation of $\frac{1}{2}\,\text{Cl}_2$)
$EA(\text{Cl}) = -349\,\text{kJ/mol}$	(electron affinity of Cl)

What is the lattice energy U of NaCl?

(A) $-787\,\text{kJ/mol}$

(B) $+787\,\text{kJ/mol}$

(C) $-411\,\text{kJ/mol}$

(D) $-349\,\text{kJ/mol}$

Q5. A buffer solution is prepared from acetic acid (CH_3COOH) and sodium acetate (CH_3COONa) with $[CH_3COO^-]/[CH_3COOH] = 2.0$. Given $\text{p}K_a(CH_3COOH)$ 4.74 and $\log 2 = 0.30$, what is the pH of this buffer using the Henderson-Hasselbalch equation?

(A) 4.44

(B) 5.04

(C) 4.74

(D) 5.74

Q6. A current of 2 A is passed through a $CuSO_4$ solution for 965 s. Using Faraday's first law of electrolysis ($m = ZIt = \dfrac{M}{nF} \cdot It$), what mass of copper (atomic mass $= 63.5$ g/mol, $n = 2$, $F = 96500$ C/mol) is deposited at the cathode?

(A) 1.27 g

(B) 6.35 g

(C) 0.635 g

(D) 0.318 g

Q7. The following data were collected for the reaction $\text{A} + \text{B} \rightarrow$ Products:

Experiment	[A] (mol/L)	[B] (mol/L)	Rate ($\text{mol L}^{-1}\text{s}^{-1}$)
1	0.10	0.10	1.0×10^{-3}
2	0.20	0.10	4.0×10^{-3}
3	0.20	0.20	8.0×10^{-3}

What is the rate law for this reaction and its overall order?

(A) Rate $= k[\text{A}][\text{B}]$; second order overall.

(B) Rate $= k[\text{A}]^2$; second order overall.

(C) Rate $= k[\mathrm{A}][\mathrm{B}]^2$; third order overall.

(D) Rate $= k[\mathrm{A}]^2[\mathrm{B}]$; third order overall.

Q8. Ethylene glycol ($\mathrm{HOCH_2CH_2OH}$, molar mass $= 62\,\mathrm{g/mol}$) is used as antifreeze. If 62 g of ethylene glycol is dissolved in 1.0 kg of water ($K_f = 1.86\,\mathrm{K\,kg/mol}$), what is the freezing point of the resulting solution?

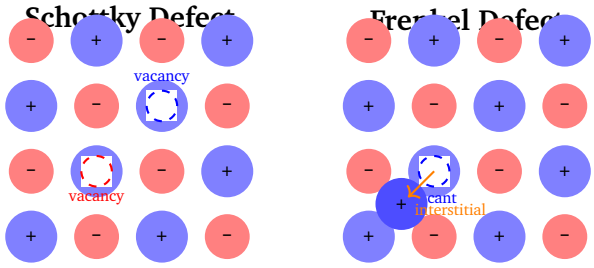
(A) $-1.86\,^\circ\mathrm{C}$

(B) $-3.72\,^\circ\mathrm{C}$

(C) $0.00\,^\circ\mathrm{C}$

(D) $+1.86\,^\circ\mathrm{C}$

Q9. Which of the following statements **correctly** distinguishes between Schottky and Frenkel defects in ionic crystals?



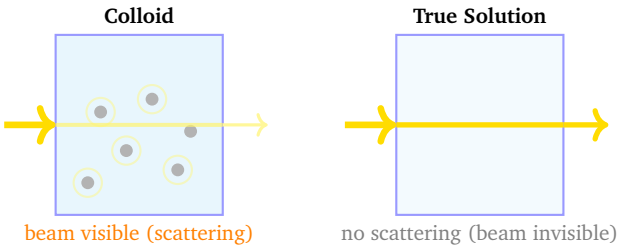
(A) In both defects, equal numbers of cations and anions are missing, so density decreases in both cases.

(B) In a Schottky defect, equal numbers of cation and anion vacancies are created (density decreases); in a Frenkel defect, a cation is displaced to an interstitial site (no change in density). Frenkel defects are common when the cation is much smaller than the anion (e.g. AgCl, ZnS).

(C) Frenkel defects involve the removal of both ions from the lattice surface; Schottky defects involve migration of a cation to an interstitial site.

(D) Schottky defects are found only in covalent crystals; Frenkel defects are found only in molecular crystals.

Q10. Which of the following **correctly** describes the Tyndall effect and its use in distinguishing a colloid from a true solution?



(A) Both colloids and true solutions scatter light; the Tyndall effect cannot be used to distinguish between them.

(B) True solutions show the Tyndall effect because dissolved molecules are larger than colloidal particles.

(C) Colloidal particles (diameter 1–1000 nm) scatter a beam of light, making it visible inside the medium (Tyndall effect); true solutions (particle diameter < 1 nm) do not scatter light and the beam passes through invisibly. This distinguishes a colloid from a true solution.

(D) The Tyndall effect is caused by the absorption of light by colloidal particles; it has nothing to do with scattering.

Q11. In the flame test, characteristic colours are observed due to emission of specific wavelengths when electrons return from excited states to ground states. Which of the following **correctly** matches the element to its observed flame colour?

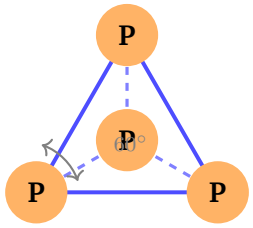
(A) Na: lilac; K: golden yellow; Li: apple green

(B) Ca: crimson red; Sr: apple green; Ba: scarlet red

(C) Li: golden yellow; Na: crimson red; K: brick red

(D) Na: golden yellow; K: lilac/violet; Li: crimson red

Q12. White phosphorus consists of discrete P_4 molecules. Which of the following **correctly** describes the structure of a P_4 molecule?



P_4 — tetrahedral structure

(A) P_4 is a tetrahedral molecule with four P atoms at the vertices; each P is bonded to three others with a P-P-P bond angle of $60°$; the extreme ring strain makes white phosphorus highly reactive. Each P atom is sp^3 hybridised.

(B) P_4 is a planar square arrangement of four P atoms with P-P-P bond angles of $90°$.

(C) P_4 is a linear molecule, similar to the structure of acetylene.

(D) P_4 consists of a benzene-like ring of six phosphorus atoms.

Q13. Transition metals exhibit variable oxidation states. Which of the following **correctly** explains this property, using manganese (Mn, $Z = 25$) as an example?

(A) Transition metals have variable oxidation states because their atoms have no defined electron configuration; electrons can be added or removed randomly.

(B) Because the energies of $3d$ and $4s$ orbitals in transition metals are very close, electrons can be removed from both subshells in stages; Mn can lose 2 electrons (giving Mn^{2+}, ox. state $+2$) up to 7 electrons (giving Mn^{7+}, ox. state $+7$ in permanganate $KMnO_4$).

(C) Variable oxidation states arise only because transition metals react with fluorine; with other halogens only the $+2$ state is possible.

(D) The variable oxidation states are due to the instability of the nucleus of transition metal atoms.

Q14. Which of the following pairs of complexes are **ionisation isomers**, and what is a simple chemical test to distinguish them?

(A) $[Co(NH_3)_6][Cr(CN)_6]$ and $[Cr(NH_3)_6][Co(CN)_6]$ — they are linkage isomers; distinguished by IR spectroscopy.

(B) $[Co(NH_3)_5Cl]Cl_2$ and $[Co(NH_3)_5Cl_2]Cl$ — they are coordination isomers; distinguishing test: conductivity measurement.

(C) $[Co(NH_3)_5Cl]Cl_2$ and $[Co(NH_3)_5Cl_2]Cl$ — they are **ionisation isomers** (same molecular formula, different ions in the coordination sphere vs counter-ion position); $[Co(NH_3)_5Cl]Cl_2$ gives **2 moles** of Cl^- per mole with $AgNO_3$, while $[Co(NH_3)_5Cl_2]Cl$ gives only **1 mole** of Cl^-.

(D) $[Co(NH_3)_4Cl_2]^+$ in its *cis* and *trans* forms are ionisation isomers; the test is reaction with $AgNO_3$.

Q15. Which of the following statements **correctly** describes the S_N2 mechanism of nucleophilic substitution?

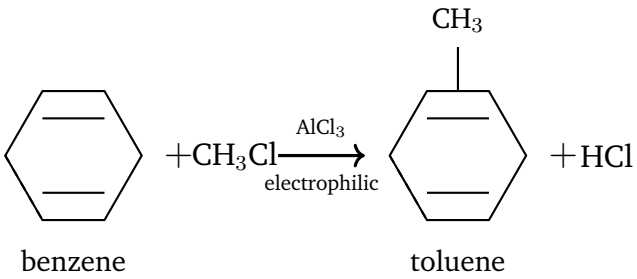
(A) S_N2 is a two-step mechanism proceeding via a carbocation intermediate; the rate depends only on the concentration of the substrate.

(B) S_N2 involves a carbanion intermediate and is favoured by tertiary substrates and polar protic solvents.

(C) S_N2 is a unimolecular mechanism; the rate $= k[\text{substrate}]$ and configuration is retained.

(D) S_N2 is a bimolecular, concerted (one-step) mechanism; the nucleophile attacks the carbon from the backside simultaneously with departure of the leaving group, causing complete **inversion of configuration** (Walden inversion); rate $= k[\text{substrate}][\text{nucleophile}]$; favoured by primary substrates, strong nucleophiles, and polar aprotic solvents.

Q16. Benzene undergoes Friedel-Crafts alkylation when treated with chloromethane (CH_3Cl) and aluminium chloride ($AlCl_3$) as a Lewis acid catalyst. What is the **major organic product**, and what acts as the electrophile?



(A) Toluene (methylbenzene) is the major product; $AlCl_3$ generates the electrophilic CH_3^+ (or $[CH_3–AlCl_4]^-$ complex) which attacks the π-ring of benzene.

(B) Benzyl chloride ($C_6H_5CH_2Cl$) is the product; $AlCl_3$ acts as a base abstracting H^+.

(C) No reaction occurs because benzene is too stable to undergo electrophilic attack.

(D) The major product is chlorobenzene formed by substitution of H by Cl via a free-radical mechanism.

Q17. The Lucas test uses anhydrous $ZnCl_2$/concentrated HCl to distinguish between primary, secondary, and tertiary alcohols. Which observation **correctly** matches the alcohol class?

(A) Primary alcohol gives immediate cloudiness (turbidity); tertiary alcohol does not react at room temperature.

(B) Tertiary alcohol gives immediate turbidity (cloudiness) upon mixing at room temperature; secondary alcohol gives turbidity within about 5 minutes; primary alcohol shows no turbidity at room temperature (requires heating).

(C) Secondary alcohol gives immediate turbidity; primary and tertiary alcohols do not react at all.

(D) All three classes give turbidity at the same rate because $ZnCl_2$ is a strong Lewis acid that activates all alcohols equally.

Q18. Benzene undergoes nitration when treated with a mixture of concentrated HNO_3 and concentrated H_2SO_4 at about $55\,^\circ$C. Which species acts

as the **electrophile** in this electrophilic aromatic substitution (EAS) reaction, and what is the product?

(A) NO_3^- (nitrate ion) acts as the nucleophile; the product is phenol.

(B) H^+ (proton) from H_2SO_4 is the electrophile; the product is benzenesulfonic acid.

(C) NO_2^+ (nitronium ion), generated by $HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$, is the electrophile; the product is **nitrobenzene** ($C_6H_5NO_2$).

(D) N_2O_4 acts as the electrophile; the product is azobenzene.

Q19. (Z)-But-2-ene is subjected to ozonolysis followed by oxidative workup (O_3 then H_2O_2). What are the organic product(s)?

(A) Two equivalents of acetaldehyde (CH_3CHO) only.

(B) One equivalent of butanedioic acid (succinic acid).

(C) Formaldehyde (HCHO) and propanal (CH_3CH_2CHO).

(D) Two equivalents of acetic acid (CH_3COOH).

Q20. In the Haworth projection of α-D-glucopyranose (the cyclic α form of D-glucose), which of the following **correctly** describes the position of the hydroxyl group at the anomeric carbon (C-1) compared to β-D-glucopyranose?

(A) In α-D-glucose, the OH at C-1 (anomeric carbon) is on the *same side* as the ring oxygen when drawn in the Haworth projection (below the plane of the ring); in β-D-glucose, the C-1 OH is on the opposite side (above the plane). They are called anomers.

(B) In α-D-glucose, the OH at C-1 is above the plane of the ring; in β-D-glucose it is below the plane.

(C) α- and β-D-glucose have identical configurations at all carbon atoms and differ only in the number of OH groups.

(D) The anomeric carbon in glucose is C-6, not C-1; the OH at C-6 determines the α/β designation.

Section B — Numerical Value Questions (Q21–Q30) [Attempt Any 5]

Q21. How many σ (sigma) bonds are present in one molecule of benzene (C_6H_6)?

(Enter the exact numerical value as your answer.)

Q22. What is the oxidation state of nitrogen in dinitrogen pentoxide (N_2O_5)?

(Enter the exact numerical value as your answer.)

Q23. How many electrons are present in the $3s$ subshell of a ground-state sodium atom (Na, $Z = 11$)?

(Enter the exact numerical value as your answer.)

Q24. What is the pH of a 0.001 M aqueous solution of hydrochloric acid (HCl), assuming complete dissociation?

(Enter the exact numerical value as your answer.)

Q25. What is the F-B-F bond angle (in degrees) in boron trifluoride (BF_3), which has a trigonal planar geometry?

(Enter the exact numerical value as your answer.)

Q26. How many atoms are present per unit cell in a face-centred cubic (FCC) crystal structure?

(Enter the exact numerical value as your answer.)

Q27. For a first-order reaction, the rate constant $k = 0.693\,\text{min}^{-1}$. What is the half-life ($t_{1/2}$, in minutes) of this reaction? (Use $t_{1/2} = 0.693/k$ for first-order reactions.)

(Enter the exact numerical value as your answer.)

Q28. How many geometrical (cis/trans) isomers does but-2-ene (CH_3-CH=CH-CH_3) have?

(Enter the exact numerical value as your answer.)

Q29. How many lone pairs of electrons are present on the sulfur (S) atom in sulfur hexafluoride (SF_6)? (S has 6 valence electrons; all are used to form 6 S–F bonds via expanded octet.)

(Enter the exact numerical value as your answer.)

Q30. How many equivalent resonance structures can be drawn for sulfur trioxide (SO_3)?

(Enter the exact numerical value as your answer.)

Detailed Solutions

Q1.

Solution

Concept — Heisenberg Uncertainty Principle: The Heisenberg uncertainty principle states that it is impossible to simultaneously determine the exact position and exact momentum (or velocity) of a subatomic particle. Mathematically:

$$\Delta x \cdot \Delta p \geq \frac{h}{4\pi}$$

where Δx is the uncertainty in position, Δp is the uncertainty in momentum, and h is Planck's constant ($6.626 \times 10^{-34}\,\text{J s}$).

Step 1 — Interpretation: The principle does NOT say we are merely ignorant of these values; it says that the act of measurement itself disturbs the system and nature fundamentally limits the precision with which both quantities can be simultaneously known.

Step 2 — Numerical illustration: For $\Delta x = 1\,\text{Å} = 1 \times 10^{-10}\,\text{m}$:

$$\Delta p \geq \frac{h}{4\pi\,\Delta x} = \frac{6.626 \times 10^{-34}}{4\pi \times 10^{-10}} \approx 5.27 \times 10^{-25}\,\text{kg m/s}$$

This is the minimum uncertainty in momentum — a very large uncertainty for an electron.

Why other options are wrong:

- Option A: The electron is not at rest; "at rest" would imply $\Delta p = 0$, which violates the principle.
- Option C: The uncertainty principle applies to all quantum particles; it is a fundamental law, not a classical limitation.
- Option D: A smaller Δx actually means a *larger* Δp (they are inversely related), not $\Delta p = 0$.

Final Answer: $\Delta x \cdot \Delta p \geq h/(4\pi)$; it is impossible to simultaneously know position and momentum with arbitrary precision $\Rightarrow$ Option B

Answer: (B) Go Back to Q#1

Q2.

Solution

Concept — Hydrogen Bonding in HF: Hydrogen bonding is a strong electrostatic interaction between a hydrogen atom covalently bonded to a highly electronegative atom (F, O, N) and a lone pair on another electronegative atom. In HF, fluorine is the most electronegative element ($\chi = 3.98$) and has a very small atomic radius, making the H-bond exceptionally strong.

Step 1 — Trend in boiling points of hydrogen halides:

- HCl: $-85\,^\circ$C, HBr: $-67\,^\circ$C, HI: $-35\,^\circ$C — boiling points increase due to increasing van der Waals (dispersion) forces with molar mass.
- HF: $+19.5\,^\circ$C — anomalously high; **does not follow** the van der Waals trend.

Step 2 — Reason for anomaly in HF: HF molecules form strong intermolecular hydrogen bonds (F$\cdots$H-F) due to the high electronegativity and small size of F. These H-bonds must be broken during vaporisation, requiring much more energy than predicted from its low molar mass. In liquid HF, chains/clusters of $(HF)_n$ units form via these hydrogen bonds.

Why other options are wrong:

- Option A: HF has the *lowest* molar mass in the halide series; dispersion forces are smallest, not largest.
- Option B: H-F is actually the *strongest* H-X covalent bond in the halide series ($\sim$568 kJ/mol), which does not explain the high boiling point; the intermolecular H-bond is the key.
- Option D: HF is a molecular (covalent) compound in the liquid phase, not ionic; it does not exist as F^- and H^+ ions in bulk liquid HF.

Final Answer: Strong intermolecular H-bonding due to high electronegativity and small size of F raises the boiling point of HF anomalously $\Rightarrow$ Option C

Answer: (C) Go Back to Q#2

Q3.

Solution

Concept — van der Waals Equation and the Significance of Constants a and b: The ideal gas law $PV = nRT$ assumes (i) no intermolecular forces and (ii) molecules have zero volume. The van der Waals equation corrects for both:

$$\left(P + \frac{an^2}{V^2}\right)(V - nb) = nRT$$

Step 1 — Physical meaning of a: In a real gas, molecules attract each other. Molecules in the bulk experience more attractions than those near the container wall, so the actual pressure hitting the wall is *less* than the ideal pressure. The term an^2/V^2 (called the internal pressure or cohesion pressure) is added back to the measured pressure to correct for this: a **corrects for intermolecular attractive forces**.

Step 2 — Physical meaning of b: Real molecules have finite size; they cannot occupy the same space. The actual volume available to a molecule is $(V - nb)$, where nb is the volume excluded by n moles of molecules: b **corrects for the finite (excluded) volume of gas molecules**. $b \approx 4\times$ actual molecular volume per mole.

Step 3 — The van der Waals loop: At temperatures below the critical temperature (T_c), the equation yields an S-shaped oscillation in the P-V curve (van der Waals loop), which corresponds physically to the coexistence of liquid and vapour phases.

Why other options are wrong:

- Option A: The roles of a and b are swapped; a is for attractions, b for excluded volume.
- Option B: Both constants involve different corrections (a for attractions, b for repulsions/volume), not only repulsions.
- Option C: a and b are not related to kinetic energy or molar mass; those are separate quantities.

Final Answer: a accounts for intermolecular attractions (pressure correction); b accounts for excluded volume (volume correction) $\Rightarrow$ Option D

Answer: (D) Go Back to Q#3

Q4.

Solution

Concept — Born-Haber Cycle for NaCl: The Born-Haber cycle applies Hess's law to relate the standard enthalpy of formation of an ionic compound to a series of steps:

$$\Delta H_f^\circ = \Delta H_{\text{sub}} + IE_1 + \tfrac{1}{2}D + EA + U$$

where U is the lattice energy (enthalpy of the ionic crystal formation from gaseous ions).

Step 1 — Rearrange to solve for U:

$$U = \Delta H_f^\circ - \Delta H_{\text{sub}} - IE_1 - \tfrac{1}{2}D - EA$$

Step 2 — Substitute given values:

$$U = (-411) - (+108) - (+496) - (+121) - (-349)$$

$$U = -411 - 108 - 496 - 121 + 349$$

$$U = (-411 - 108 - 496 - 121) + 349$$

$$U = -1136 + 349 = \mathbf{-787}\,\text{kJ/mol}$$

Step 3 — Interpretation: The lattice energy is large and negative, indicating that formation of the NaCl crystal from gaseous Na^+ and Cl^- ions releases a large amount of energy. This is the main thermodynamic driving force for the stability of ionic compounds.

Why other options are wrong:

- Option B ($+787$ kJ/mol): This would be the lattice dissociation energy (energy to separate the lattice into gaseous ions), which is the reverse process; the lattice formation energy is negative.
- Option C (-411 kJ/mol): This is ΔH_f°, not U.
- Option D (-349 kJ/mol): This is the electron affinity of Cl, not the lattice energy.

Final Answer: $U = -787$ kJ/mol $\Rightarrow$ Option A

Answer: (A) Go Back to Q#4

Q5.

Solution

Concept — Henderson-Hasselbalch Equation for Buffer pH: For a weak acid buffer:

$$\text{pH} = \text{p}K_a + \log\frac{[\text{A}^-]}{[\text{HA}]}$$

Step 1 — Identify given quantities:

- $\text{p}K_a(\text{CH}_3\text{COOH}) = 4.74$
- $[\text{CH}_3\text{COO}^-]/[\text{CH}_3\text{COOH}] = 2.0$

Step 2 — Calculate pH:

$$\text{pH} = 4.74 + \log(2.0) = 4.74 + 0.30 = \mathbf{5.04}$$

Step 3 — Check reasonableness: Since the ratio $[\text{A}^-]/[\text{HA}] > 1$, the pH is above the $\text{p}K_a$ (more base than acid), which is consistent: $\text{pH} = 5.04 > 4.74$. ✓

Why other options are wrong:

- Option A (4.44): This would result from $4.74 + \log(0.5)$, i.e., if the ratio were 0.5 not 2.0; the log is subtracted, not added.
- Option C (4.74): This is the $\text{p}K_a$ itself, which is the pH only when $[\text{A}^-] = [\text{HA}]$ (ratio = 1).
- Option D (5.74): This would require $\log(10) = 1$, i.e., a 10-fold excess of conjugate base.

Final Answer: $\text{pH} = 4.74 + \log 2 = 5.04 \Rightarrow$ Option B

Answer: (B) Go Back to Q#5

Q6.

Solution

Concept — Faraday's First Law of Electrolysis: The mass of substance deposited (or dissolved) at an electrode during electrolysis is directly proportional to the charge passed:

$$m = \frac{M}{nF} \cdot I \cdot t$$

where M = molar mass, n = number of electrons transferred per ion, F = Faraday constant, I = current (A), t = time (s).

Step 1 — Data for Cu deposition:

- Cathode reaction: $Cu^{2+} + 2e^- \rightarrow Cu$, so $n = 2$.
- $M(\text{Cu}) = 63.5\,\text{g/mol}$, $F = 96500\,\text{C/mol}$.
- $I = 2\,\text{A}$, $t = 965\,\text{s}$.

Step 2 — Calculate:

$$m = \frac{63.5}{2 \times 96500} \times 2 \times 965$$

$$m = \frac{63.5}{193000} \times 1930 = 63.5 \times \frac{1930}{193000} = 63.5 \times 0.01 = 0.635\,\text{g}$$

Why other options are wrong:

- Option A (1.27 g): This would result if $n = 1$ instead of 2 (using the wrong number of electrons for Cu^{2+}).
- Option B (6.35 g): This would require $10\times$ more charge or incorrect formula application.
- Option D (0.318 g): This would result if $n = 4$ (incorrect valency for Cu).

Final Answer: $m = 0.635\,\text{g}$ of Cu deposited $\Rightarrow$ Option C

Answer: (C) Go Back to Q#6

Q7.

Solution

Concept — Determining the Rate Law from Experimental Data: To find the order with respect to each reactant, compare experiments where only one concentration is varied.

Step 1 — Order in [A] (compare Experiments 1 and 2; [B] constant):

$$\frac{\text{Rate}_2}{\text{Rate}_1} = \frac{4.0 \times 10^{-3}}{1.0 \times 10^{-3}} = 4 = \left(\frac{[\text{A}]_2}{[\text{A}]_1}\right)^m = \left(\frac{0.20}{0.10}\right)^m = 2^m$$

$$2^m = 4 \implies m = 2 \quad \text{(second order in A)}$$

Step 2 — Order in [B] (compare Experiments 2 and 3; [A] constant):

$$\frac{\text{Rate}_3}{\text{Rate}_2} = \frac{8.0 \times 10^{-3}}{4.0 \times 10^{-3}} = 2 = \left(\frac{[\text{B}]_3}{[\text{B}]_2}\right)^n = \left(\frac{0.20}{0.10}\right)^n = 2^n$$

$$2^n = 2 \implies n = 1 \quad \text{(first order in B)}$$

Step 3 — Rate law and overall order:

$$\text{Rate} = k[\text{A}]^2[\text{B}]^1 = k[\text{A}]^2[\text{B}]$$

Overall order $= 2 + 1 = 3$ (third order).

Why other options are wrong:

- Option A: Rate $= k[\text{A}][\text{B}]$ would give rate quadruple only if both [A] and [B] doubled, not just [A].
- Option B: Rate $= k[\text{A}]^2$ ignores the dependence on [B] (from Expts 2 and 3, rate doubles when [B] doubles).
- Option C: Rate $= k[\text{A}][\text{B}]^2$ would predict rate quadruples when [B] doubles (from Expt 2 to 3), but rate only doubles.

Final Answer: Rate $= k[\text{A}]^2[\text{B}]$; overall third-order $\Rightarrow$ Option D

Answer: (D) Go Back to Q#7

Q8.

Solution

Concept — Depression of Freezing Point (Cryoscopy): When a non-volatile, non-electrolyte solute is dissolved in a solvent, the freezing point of the solution is lowered by:

$$\Delta T_f = K_f \times m$$

where K_f is the cryoscopic constant of the solvent (1.86 K kg/mol for water) and m is the molality (mol of solute per kg of solvent).

Step 1 — Calculate molality:

$$m = \frac{\text{moles of solute}}{\text{kg of solvent}} = \frac{62\,\text{g}/62\,\text{g/mol}}{1.0\,\text{kg}} = \frac{1.0\,\text{mol}}{1.0\,\text{kg}} = 1.0\,\text{mol/kg}$$

Step 2 — Calculate ΔT_f:

$$\Delta T_f = 1.86 \times 1.0 = 1.86\,\text{K}$$

Step 3 — Find new freezing point:

$$T_f(\text{solution}) = 0.00 - 1.86 = -1.86\,^\circ\text{C}$$

Why other options are wrong:

- Option B ($-3.72\,^\circ$C): This would require $m = 2.0$ mol/kg (e.g., 124 g of ethylene glycol), twice the given amount.
- Option C ($0.00\,^\circ$C): This implies no freezing point depression; the solute clearly depresses the freezing point.
- Option D ($+1.86\,^\circ$C): Freezing point depression always lowers the freezing point; it cannot rise.

Final Answer: Freezing point $= -1.86\,^\circ$C $\Rightarrow$ Option A

Answer: (A) Go Back to Q#8

Q9.

Solution

Concept — Schottky and Frenkel Defects: Both are point defects in ionic crystals but differ fundamentally.

Step 1 — Schottky Defect:

- Equal numbers of cation vacancies and anion vacancies are created (ions are missing from their lattice sites and migrate to the surface).
- Electrical neutrality is maintained.
- Density **decreases** because the same mass is spread over a slightly larger effective volume (missing ions reduce mass while lattice parameters remain similar).
- Common in crystals where cation and anion are of similar size (e.g. NaCl, KCl, KBr).

Step 2 — Frenkel Defect:

- A cation (usually the smaller ion) is displaced from its normal lattice site to an interstitial (non-lattice) position. No ions are removed from the crystal.
- Density is **unchanged** (same number of ions, just rearranged).
- Common when cation is much smaller than anion (large radius ratio difference): e.g. AgCl (Ag^+ small), ZnS (Zn^{2+} small).

Why other options are wrong:

- Option A: Density does not decrease in both; Frenkel defect leaves density unchanged.

- Option C: Descriptions are reversed; Frenkel involves migration to an *interstitial* site (not removal from surface); Schottky involves surface migration (not interstitial).
- Option D: Both types of defects occur in ionic crystals, not exclusively covalent or molecular crystals.

Final Answer: Schottky: equal ion vacancies, density decreases; Frenkel: cation to interstitial, density unchanged; Frenkel common when cation $\ll$ anion (AgCl, ZnS) $\Rightarrow$ Option B

Answer: (B) Go Back to Q#9

Q10.

Solution

Concept — Tyndall Effect and Colloidal Systems: The Tyndall effect is the scattering of light by colloidal particles, making the path of a light beam visible through the medium. It is named after John Tyndall.

Step 1 — Why colloids scatter light: Colloidal particles have diameters in the range 1–1000 nm. These dimensions are comparable to the wavelengths of visible light ($\sim$400–700 nm), so the particles scatter light effectively (Mie scattering or Rayleigh-type scattering for this size range). The beam becomes visible as a bright cone inside the colloid.

Step 2 — Why true solutions do not show the Tyndall effect: In a true solution, dissolved species (ions or small molecules) have dimensions < 1 nm, far smaller than visible wavelengths. They do not scatter visible light significantly; the beam passes through invisibly.

Step 3 — Practical use: The Tyndall effect is used in: (a) distinguishing colloids from true solutions, (b) detection of colloids in natural water bodies, (c) checking purity of solutions.

Why other options are wrong:

- Option A: True solutions do *not* show the Tyndall effect; the two cannot be interchanged.
- Option B: Dissolved molecules in a true solution are *smaller* than colloidal particles, not larger; this is a reversal of the fact.
- Option D: The Tyndall effect is caused by *scattering* (not absorption) of light; absorption would cause colour changes, not a visible beam.

Final Answer: Colloidal particles scatter light (Tyndall effect visible); true solution particles too small to scatter (beam invisible) $\Rightarrow$ Option C

Answer: (C) Go Back to Q#10

Q11.

Solution

Concept — Flame Test Colours: Flame tests exploit the characteristic emission spectra of metal cations when thermally excited. Key colours to remember:

Step 1 — Standard flame test colours:

Element	Symbol	Flame Colour
Lithium	Li	Crimson red
Sodium	Na	Golden (intense) yellow
Potassium	K	Lilac / violet
Calcium	Ca	Brick red
Strontium	Sr	Scarlet / crimson red
Barium	Ba	Apple green
Copper	Cu	Blue-green

Step 2 — Verify Option D: Na $\rightarrow$ golden yellow ✓, K $\rightarrow$ lilac/violet ✓, Li $\rightarrow$ crimson red ✓. All three are correctly stated in Option D.

Why other options are wrong:

- Option A: Na gives golden yellow (not lilac); K gives lilac (not golden yellow); Li gives crimson red (not apple green). All three are wrong.
- Option B: Ca gives brick red (not crimson); Sr gives scarlet (not apple green); Ba gives apple green (not scarlet). The Ca and Ba assignments are the correct colours but assigned to the wrong elements.
- Option C: Li gives crimson red (not golden yellow); Na gives golden yellow (not crimson); the assignments for Li and Na are swapped.

Final Answer: Na: golden yellow; K: lilac; Li: crimson red $\Rightarrow$ Option D

Answer: (D) Go Back to Q#11

Q12.

Solution

Concept — Structure of White Phosphorus (P_4): White phosphorus is the most reactive allotrope of phosphorus. It consists of discrete P_4 molecules in the solid, liquid, and vapour states.

Step 1 — Geometry of P_4:

- Four P atoms sit at the four vertices of a regular tetrahedron.
- Each P atom is covalently bonded to the other three P atoms.
- Each P-P-P bond angle is exactly 60° (angle at a vertex of a regular tetrahedron formed by the *edges* of the tetrahedron).

Step 2 — Hybridisation and reactivity: Each phosphorus in P_4 uses pure $3p$ orbitals (or equivalently is described as approximately sp^3 hybridised) to form bonds. The 60° P-P-P bond angle is far below the normal tetrahedral angle of 109.5° or the preferred 90° for p orbitals, resulting in very high ring strain. This extreme angular strain makes white phosphorus highly reactive and spontaneously flammable in air.

Why other options are wrong:

- Option B: A planar square with 90° angles would be a different, less strained geometry; P_4 is *not* planar.
- Option C: P_4 is a cage molecule, not a linear chain; linear P would be an entirely different allotrope (not characterised as white phosphorus).
- Option D: A benzene-like six-membered ring would be P_6, not P_4; white phosphorus is P_4.

Final Answer: P_4 is a tetrahedron with P-P-P angles of 60°; highly reactive due to ring strain; P atoms are sp^3 hybridised $\Rightarrow$ Option A

Answer: (A) Go Back to Q#12

Q13.

Solution

Concept — Variable Oxidation States in Transition Metals: Transition metals (d-block elements) are characterised by their ability to exhibit multiple oxidation states. This is a direct consequence of the electronic structure of d-block elements.

Step 1 — Electronic configuration of Mn ($Z = 25$):

$$\text{Mn} : [\text{Ar}]\, 3d^5\, 4s^2$$

The energies of the $3d$ and $4s$ subshells are very close to each other across the transition series.

Step 2 — Successive removal of electrons:

- Mn^{2+}: lose $4s^2 \Rightarrow$ oxidation state $+2$ (most stable; half-filled $3d^5$, extra stability).
- Mn^{3+}: lose $4s^2 + 1\,3d \Rightarrow$ oxidation state $+3$.
- Mn^{4+}: oxidation state $+4$ (e.g. MnO_2).
- Mn^{7+}: lose $4s^2 + 5\,3d$ (all d electrons) $\Rightarrow$ oxidation state $+7$ in MnO_4^- (permanganate ion in $KMnO_4$).

Because both $3d$ and $4s$ electrons can participate in bonding/oxidation, a wide range of oxidation states is accessible.

Why other options are wrong:

- Option A: Transition metals have well-defined electron configurations; the variable oxidation states are not due to random electron removal.
- Option C: Variable oxidation states are not limited to fluorine compounds; transition metals show multiple states with all common ligands and anions.
- Option D: Nuclear instability is a property of radioactive isotopes and is unrelated to chemical oxidation states.

Final Answer: Close energy of $3d$ and $4s$ orbitals allows step-wise electron removal; Mn shows $+2$ to $+7 \Rightarrow$ Option B

Answer: (B) Go Back to Q#13

Q14.

Solution

Concept — Ionisation Isomerism: Ionisation isomers are coordination compounds that have the same molecular formula but differ in the ions present *inside* the coordination sphere versus outside as counter-ions. They produce different ions when dissolved in water.

Step 1 — The pair in Option C:

- $[Co(NH_3)_5Cl]Cl_2$: the coordination sphere is $[Co(NH_3)_5Cl]^{2+}$; 2 Cl^- are counter-ions.
- $[Co(NH_3)_5Cl_2]Cl$: the coordination sphere is $[Co(NH_3)_5Cl_2]^+$; 1 Cl^- is a counter-ion.

Both have molecular formula $[CoCl_3(NH_3)_5]$, but differ in how Cl is distributed. These are **ionisation isomers**.

Step 2 — $AgNO_3$ test (distinguishing test): Adding $AgNO_3$ solution precipitates only free Cl^- ions (as AgCl):

- $[Co(NH_3)_5Cl]Cl_2$: releases 2 Cl^- per formula unit $\Rightarrow$ 2 moles AgCl precipitate per mole.
- $[Co(NH_3)_5Cl_2]Cl$: releases 1 Cl^- per formula unit $\Rightarrow$ 1 mole AgCl precipitate per mole.

The Cl^- inside the coordination sphere is not precipitated by $AgNO_3$ (at room temperature).

Why other options are wrong:

- Option A: The pair described are *coordination isomers* (metal centres swapped), not ionisation isomers; and the test stated is incorrect.
- Option B: The pair is the same as Option C (correct compounds) but misidentified as "coordination isomers."
- Option D: cis and trans isomers of $[Co(NH_3)_4Cl_2]^+$ are *geometrical isomers*, not ionisation isomers.

Final Answer: $[Co(NH_3)_5Cl]Cl_2$ and $[Co(NH_3)_5Cl_2]Cl$ are ionisation isomers; $AgNO_3$ test distinguishes them by the moles of AgCl precipitated $\Rightarrow$ Option C

Answer: (C) Go Back to Q#14

Q15.

Solution

Concept — S_N2 Mechanism: The S_N2 (Substitution, Nucleophilic, Bimolecular) mechanism is a concerted, one-step process for nucleophilic substitution at a saturated carbon centre.

Step 1 — Key features of S_N2:

- **One-step, concerted**: no intermediate; the nucleophile attacks as the leaving group departs, via a single transition state.
- **Bimolecular**: both the substrate and nucleophile are involved in the rate-determining step. Rate $= k$[substrate][Nu].
- **Backside attack**: the nucleophile attacks the electrophilic carbon from directly opposite the leaving group (180°).
- **Inversion of configuration** (Walden inversion): the three substituents on the carbon "umbrella-flip," converting R to S or S to R.
- **Substrate preference**: primary $>$ secondary; tertiary substrates are essentially inert to S_N2 due to steric hindrance.
- **Solvent**: polar aprotic solvents (e.g. DMF, DMSO, acetone) favour S_N2 by not solvating (and thus not deactivating) the nucleophile.

Why other options are wrong:

- Option A: S_N2 is one-step (no carbocation); rate depends on *both* substrate and nucleophile concentrations.
- Option B: S_N2 involves no carbanion; it is favoured by primary (not tertiary) substrates; polar *protic* solvents hinder S_N2.
- Option C: S_N2 is *bi*molecular; the rate $= k$[substrate][Nu]; and configuration is *inverted*, not retained.

Final Answer: S_N2 is bimolecular, concerted, backside attack, inversion of configuration, primary substrates preferred $\Rightarrow$ Option D

Answer: (D) Go Back to Q#15

Q16.

Solution

Concept — Friedel-Crafts Alkylation: Benzene is aromatic and reacts with electrophiles by electrophilic aromatic substitution (EAS). In Friedel-Crafts alkylation, an alkyl halide (e.g. CH_3Cl) and a Lewis acid ($AlCl_3$) generate an electrophilic alkyl cation, which attacks the benzene π-system.

Step 1 — Generation of the electrophile:

$$CH_3Cl + AlCl_3 \rightarrow [CH_3]^{\delta+} \cdots [AlCl_4]^{\delta-}$$

$AlCl_3$ (a strong Lewis acid) coordinates to the lone pair on Cl of CH_3Cl, generating a highly polarised complex (effectively a methyl carbocation, CH_3^+) that acts as the electrophile.

Step 2 — EAS mechanism:

(a) CH_3^+ (or the polarised complex) attacks the benzene ring, forming an arenium ion (Wheland intermediate or σ-complex).
(b) Loss of H^+ (proton) from the arenium ion restores aromaticity.
(c) Net reaction: $C_6H_6 + CH_3Cl \xrightarrow{AlCl_3} C_6H_5CH_3 + HCl$

Step 3 — Product: Toluene (methylbenzene, $C_6H_5CH_3$) and HCl.

Note on carbocation rearrangements: With longer-chain alkyl halides (e.g. n-propyl chloride), the initially formed primary carbocation can rearrange to a more stable secondary/tertiary one, giving a different product. With CH_3Cl this is not an issue.

Why other options are wrong:

- Option B: Benzyl chloride would be an EAS product if Cl were incorporated into the ring, which does not occur here; $AlCl_3$ is not a base.
- Option C: Benzene is indeed very stable but does undergo Friedel-Crafts alkylation (EAS) readily; the statement "too stable" is incorrect.
- Option D: Chlorobenzene is produced by halogenation ($Cl_2/AlCl_3$), not alkylation with CH_3Cl; a free-radical mechanism does not apply to aromatic EAS.

Final Answer: Toluene is the product; $AlCl_3$ generates electrophilic $CH_3^+ \Rightarrow$ Option A

Answer: (A) Go Back to Q#16

Q17.

Solution

Concept — Lucas Test for Alcohols: The Lucas test uses a mixture of anhydrous $ZnCl_2$ (Lewis acid) and concentrated HCl to convert alcohols to the corresponding alkyl chlorides. The alkyl chloride is insoluble in the aqueous reagent and appears as a cloudiness (turbidity) or a separate layer.

Step 1 — Mechanism: $ZnCl_2$ coordinates to the OH of the alcohol, facilitating the formation of the carbocation intermediate (S_N1 mechanism):

$$\text{R-OH} + ZnCl_2 \rightarrow R^+ + [ZnCl_2OH]^- \xrightarrow{Cl^-} \text{R-Cl} \downarrow$$

Step 2 — Reactivity order and observed times:

- **Tertiary (3°) alcohol**: forms a stable 3° carbocation immediately via S_N1 $\Rightarrow$ **immediate turbidity/cloudiness** upon mixing at room temperature.
- **Secondary (2°) alcohol**: forms a 2° carbocation more slowly $\Rightarrow$ **turbidity within ∼5 minutes** at room temperature.
- **Primary (1°) alcohol**: cannot easily form a 1° carbocation via S_N1; S_N2 is hindered by the reagent concentrations $\Rightarrow$ **no turbidity at room temperature** (requires heating for a positive result; in some protocols, primary alcohols are classified as "negative" Lucas test).

Why other options are wrong:

- Option A: The observation is reversed; tertiary (not primary) gives immediate turbidity.
- Option C: Secondary is not the fastest; the reactivity order is $3° > 2° > 1°$.
- Option D: $ZnCl_2$ activates alcohols by stabilising the leaving group (OH), but the rate is controlled by carbocation stability; 1°, 2°, and 3° alcohols react at very different rates.

Final Answer: 3°: immediate turbidity; 2°: slow turbidity (∼5 min); 1°: no turbidity at room temp $\Rightarrow$ Option B

Answer: (B) Go Back to Q#17

Q18.

Solution

Concept — Nitration of Benzene (Electrophilic Aromatic Substitution): Nitration is a classic EAS reaction in which a hydrogen atom on the benzene ring is replaced by the nitro group ($-NO_2$).

Step 1 — Generation of the electrophile (nitronium ion, NO_2^+): Concentrated H_2SO_4 (a strong Brønsted acid and Lewis acid) protonates HNO_3, which then loses water to generate the nitronium ion:

$$HNO_3 + 2\,H_2SO_4 \rightarrow NO_2^+ + H_3O^+ + 2\,HSO_4^-$$

or more simply:

$$HNO_3 + H_2SO_4 \rightarrow NO_2^+ + HSO_4^- + H_2O$$

NO_2^+ is a powerful electrophile (linear, isoelectronic with CO_2).

Step 2 — EAS mechanism:

(a) NO_2^+ attacks the benzene π-system $\Rightarrow$ arenium ion (σ-complex, Wheland intermediate).

(b) Loss of H^+ to HSO_4^- restores aromaticity $\Rightarrow$ **nitrobenzene** ($C_6H_5NO_2$) formed.

Net: $C_6H_6 + HNO_3 \xrightarrow{H_2SO_4,\,55\,^\circ C} C_6H_5NO_2 + H_2O$

Why other options are wrong:

- Option A: NO_3^- is a poor electrophile (nucleophile in some contexts); phenol requires different conditions (OH group, not nitration); HNO_3/H_2SO_4 gives nitrobenzene, not phenol.
- Option B: Benzenesulfonic acid ($C_6H_5SO_3H$) is the product of sulfonation (H_2SO_4 alone at higher temperature); H^+ is not the EAS electrophile for nitration.
- Option D: N_2O_4 is not the active electrophile in the standard HNO_3/H_2SO_4 nitration; azobenzene is a coupling product formed under entirely different conditions.

Final Answer: Electrophile is NO_2^+ (nitronium ion); product is nitrobenzene $\Rightarrow$ Option C

Answer: (C) Go Back to Q#18

Q19.

Solution

Concept — Ozonolysis of Alkenes (Oxidative Workup): Ozonolysis cleaves the C=C double bond. The workup conditions determine the final products:

- **Reductive workup** (Zn/H_2O or PPh_3/Me_2S): each fragment becomes an aldehyde (R-CHO) if R-CH= at that carbon.
- **Oxidative workup** (H_2O_2 or m-CPBA/H_2O): aldehydes are further oxidised to carboxylic acids (RCOOH); ketone fragments remain as ketones.

Step 1 — Structure of (Z)-but-2-ene:

$$CH_3 - CH = CH - CH_3 \quad (cis/Z)$$

Both carbons of the C=C double bond carry a methyl group (CH_3-) and one H.

Step 2 — Ozonolysis with oxidative workup: Each C=C carbon carries $-CH_3$ and $-H$. After oxidative cleavage:

- The carbon fragment CH_3-CH= $\rightarrow$ CH_3-CHO (acetaldehyde, reductive) $\rightarrow$ CH_3COOH (acetic acid, after oxidation).

Since both ends are identical (CH_3-CH=), the products are **two equivalents of acetic acid** (CH_3COOH).

Why other options are wrong:

- Option A (two CH_3CHO): Two equivalents of acetaldehyde would be the product of *reductive* ozonolysis; the question specifies oxidative workup (H_2O_2).
- Option B (succinic acid): Succinic acid ($HOOCCH_2CH_2COOH$) would require a different substrate with a C=C within a chain; but-2-ene gives two separate C_2 fragments, not one C_4 dicarboxylic acid.
- Option C (HCHO + CH_3CH_2CHO): This product pattern corresponds to ozonolysis of 1-butene (CH_2=$CHCH_2CH_3$), not 2-butene.

Final Answer: Two equivalents of CH_3COOH (acetic acid) from oxidative ozonolysis of (Z)-but-2-ene $\Rightarrow$ Option D

Answer: (D) Go Back to Q#19

Q20.

Solution

Concept — Anomers of D-Glucose (Haworth Projection): When the open-chain form of D-glucose cyclises to form a six-membered ring (pyranose form), the aldehyde carbon (C-1) becomes a new chiral centre called the **anomeric carbon**. Two anomers (α and β) can form:

Step 1 — Haworth projection convention for D-sugars: In the Haworth projection of a pyranose:

- Groups that are on the *right* in the Fischer projection are drawn *below* the ring plane.
- Groups on the *left* are drawn *above* the ring plane.

Step 2 — α vs β designation at C-1:

- **α-D-glucopyranose**: the OH at C-1 (anomeric OH) is on the *same side* as the ring oxygen reference group (i.e. on the side where C-6 substituent goes up). In Haworth notation for D-glucose, this means the anomeric OH is **below** the plane of the ring (axial position in the $^4C_1$ chair conformation).
- **β-D-glucopyranose**: the anomeric OH at C-1 is **above** the plane of the ring (equatorial in the $^4C_1$ chair, making β-D-glucose more stable).

The two forms are called **anomers** and interconvert in solution by mutarotation.

Why other options are wrong:

- Option B: Reverses the positions; in α-D-glucose the C-1 OH is *below* the ring (not above), and in β it is *above* (not below).
- Option C: α and β anomers differ at C-1; they do not have "identical configurations at all carbon atoms"; they differ in configuration precisely at the anomeric carbon.
- Option D: The anomeric carbon in glucose is C-1 (the former aldehyde carbon), not C-6; C-6 carries a $-CH_2OH$ group and is not the anomeric carbon.

Final Answer: α-D-glucose has C-1 OH *below* the ring plane in Haworth; β-D-glucose has it *above*; they are anomers $\Rightarrow$ Option A

Answer: (A) Go Back to Q#20

Q21.

Solution

Concept — Sigma Bonds in Benzene (C_6H_6): Benzene is a planar molecule with 6 carbon atoms arranged in a regular hexagon. Each carbon is sp^2 hybridised; the unhybridised p_z orbitals form the delocalised π system.

Step 1 — Count σ bonds:

- **C-C sigma bonds**: one σ bond between each adjacent pair of C atoms in the ring. There are 6 C-C pairs $\Rightarrow$ **6** C-C σ bonds.
- **C-H sigma bonds**: each of the 6 carbon atoms bears one H atom $\Rightarrow$ **6** C-H σ bonds.

Step 2 — Total:

$$\text{Total } \sigma \text{ bonds} = 6 \text{ (C-C)} + 6 \text{ (C-H)} = \mathbf{12}$$

(The 3 π bonds in the delocalised system are not σ bonds and are not counted.)

$$\boxed{12}$$

Answer: (12) Go Back to Q#21

Q22.

Solution

Concept — Oxidation State of N in N_2O_5: In a neutral compound, the sum of oxidation states of all atoms $= 0$. Standard assignments: O $= -2$.

Step 1 — Set up equation for N_2O_5: Let oxidation state of N $= x$.

$$2x + 5(-2) = 0$$

$$2x - 10 = 0 \implies 2x = 10 \implies x = +5$$

Step 2 — Context: Dinitrogen pentoxide (N_2O_5) is the anhydride of nitric acid (HNO_3): $N_2O_5 + H_2O \rightarrow 2\,HNO_3$. In HNO_3, N is also in the $+5$ state. The $+5$ state is the highest oxidation state of nitrogen.

$$\boxed{5}$$

Answer: (5) Go Back to Q#22

Q23.

Solution

Concept — Electronic Configuration of Sodium (Na):

$$\text{Na } (Z = 11) : 1s^2\, 2s^2\, 2p^6\, 3s^1$$

Step 1 — Identify the $3s$ subshell: The $3s$ subshell can hold a maximum of 2 electrons. In Na, only **1 electron** occupies the $3s$ subshell. This is the valence electron of sodium, which is readily lost to form Na^+.

Step 2 — Verification: Total electrons: $2 + 2 + 6 + 1 = 11 = Z$ ✓.

$$\boxed{1}$$

Answer: (1) Go Back to Q#23

Q24.

Solution

Concept — pH of a Dilute Strong Acid: HCl is a strong acid, completely dissociated in water:

$$\text{HCl} \rightarrow \text{H}^+ + \text{Cl}^-$$

Step 1 — Find $[\text{H}^+]$:

$$[\text{H}^+] = 0.001\,\text{M} = 1 \times 10^{-3}\,\text{M}$$

Step 2 — Calculate pH:

$$\text{pH} = -\log[\text{H}^+] = -\log(10^{-3}) = 3$$

Note: At $0.001\,\text{M}$, the contribution of H^+ from water autoionisation ($10^{-7}\,\text{M}$) is negligible compared to $10^{-3}\,\text{M}$.

$$\boxed{3}$$

Answer: (3) Go Back to Q#24

Q25.

Solution

Concept — Geometry and Bond Angle of BF_3: Boron trifluoride (BF_3) has 3 bonding pairs and *no* lone pairs on the central boron atom (B has only 3 valence electrons, all used in bonding; the octet is incomplete for B in BF_3). VSEPR predicts:

Step 1 — VSEPR analysis:

- Electron pair geometry: **trigonal planar** (3 bond pairs, 0 lone pairs).
- Hybridisation of B: sp^2.
- Bond angle: $\mathbf{120^\circ}$ (all three F-B-F angles are equal by symmetry).

Step 2 — Additional note: BF_3 is a Lewis acid because B has an empty p orbital perpendicular to the molecular plane, able to accept a lone pair from a Lewis base.

$$\boxed{120}$$

Answer: (120) Go Back to Q#25

Q26.

Solution

Concept — Atoms per Unit Cell in FCC: In a face-centred cubic (FCC) unit cell:

- 8 corner atoms, each shared by 8 adjacent unit cells $\Rightarrow$ contribution $= 8 \times \frac{1}{8} = 1$ atom.
- 6 face-centred atoms, each shared by 2 adjacent unit cells $\Rightarrow$ contribution $= 6 \times \frac{1}{2} = 3$ atoms.

Step 1 — Total atoms per unit cell:

$$Z = 1 + 3 = \mathbf{4}$$

Step 2 — Context: Many metals (Cu, Al, Ni, Ag, Au, Pt) crystallise in the FCC structure, also called cubic close-packed (CCP). The packing efficiency of FCC is $\approx 74\%$, the highest possible for single-sphere close packing.

$$\boxed{4}$$

Answer: (4) Go Back to Q#26

Q27.

Solution

Concept — Half-Life of a First-Order Reaction: For a first-order reaction, the half-life is independent of the initial concentration:

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

Step 1 — Substitute given value:

$$k = 0.693\,\text{min}^{-1}$$

$$t_{1/2} = \frac{0.693}{0.693\,\text{min}^{-1}} = 1\,\text{min}$$

Step 2 — Significance: The half-life for a first-order reaction is constant regardless of the reactant concentration. This is a hallmark feature of first-order kinetics (e.g. radioactive decay, many drug pharmacokinetics, and many chemical reactions in dilute solution).

$$\boxed{1}$$

Answer: (1) Go Back to Q#27

Q28.

Solution

Concept — Geometrical Isomerism of But-2-ene: Geometrical (cis/trans or E/Z) isomerism arises about a C=C double bond when each carbon of the double bond bears *two different* substituents.

Step 1 — Structure of but-2-ene:

$$\text{CH}_3 - CH = CH - \text{CH}_3$$

Carbon C-2 bears: CH_3 and H (two different groups). Carbon C-3 bears: CH_3 and H (two different groups). Therefore geometrical isomerism exists.

Step 2 — Count the isomers:

- **cis-but-2-ene (Z)**: Both CH_3 groups on the same side of the double bond. bp $= 3.7\,^\circ$C.
- **trans-but-2-ene (E)**: CH_3 groups on opposite sides. bp $= 0.9\,^\circ$C.

Total geometrical isomers $=$ **2**.

$$\boxed{2}$$

Answer: (2) Go Back to Q#28

Q29.

Solution

Concept — Lone Pairs on S in SF_6 (Expanded Octet): Sulfur has 6 valence electrons ($3s^2\,3p^4$, and access to $3d$ orbitals). In SF_6:

Step 1 — Bonding in SF_6:

- Sulfur forms 6 S-F bonds (expanded octet, 12 electrons around S using $3d$ orbitals in the valence shell expansion model).
- All 6 valence electrons of S are used in bonding: $6 \times 1 = 6$ electrons contributed by S to the 6 bonds.
- No electrons remain on S as lone pairs.

Step 2 — Geometry: With 6 bond pairs and **0 lone pairs** on S: geometry is **octahedral** (all F-S-F angles $= 90^\circ$ or 180°). SF_6 is highly symmetrical and chemically very stable (used as an insulating gas in high-voltage equipment).

Lone pairs on S $= 0$.

$$\boxed{0}$$

Answer: (0) Go Back to Q#29

Q30.

Solution

Concept — Resonance Structures of SO_3: Sulfur trioxide has a central S atom bonded to three O atoms. In each resonance structure, one S=O double bond and two S-O single bonds can be drawn (or, with expanded octet, three equivalent S=O bonds).

Step 1 — Count resonance structures: Using the simple model where the positive formal charge on S and negative on one O allow three structures, each differing in which O atom bears the double bond:

- Structure 1: O^-–S(=O)–O^- ... (double bond to O_1) — but conventionally, for SO_3, each structure has one S=O and two S-O bonds.
- The double bond can be placed on any of the three oxygen atoms: 3 equivalent resonance structures.

Step 2 — Geometry: SO_3 is trigonal planar (sp^2 hybridised S, all S-O-S angles $120°$). All three S-O bonds are equivalent (bond order ≈ 1.33). The three resonance structures contribute equally.

Number of equivalent resonance structures $= \mathbf{3}$.

$$\boxed{3}$$

Answer: (3) Go Back to Q#30

Answer Key

Section A (MCQ):

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

Section B (Numerical Value):

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
21	12	22	5						
23	1	24	3						
25	120	26	4						
27	1	28	2						
29	0	30	3						