CBSE Class 12 Chemistry Board Paper 2026 (56/5/1) with Solutions

PREVIOUS YEAR PAPER · CLASS XII · CHEMISTRY (043) · BOARD EXAM 2026 · Q.P. CODE 56/5/1

TIME ALLOWED	MAXIMUM MARKS	QUESTIONS	NAME / ROLL NO.
3 hours	70	33 (A 16 · B 5 · C 7 · D 2 · E 3)	

GENERAL INSTRUCTIONS

Read the following instructions very carefully and strictly follow them:

1. This question paper contains 33 questions. All questions are compulsory.
2. This question paper is divided into five sections – Section A, B, C, D and E.
3. Section A – questions number 1 to 16 are multiple choice type questions. Each question carries 1 mark.
4. Section B – questions number 17 to 21 are very short answer type questions. Each question carries 2 marks.
5. Section C – questions number 22 to 28 are short answer type questions. Each question carries 3 marks.
6. Section D – questions number 29 and 30 are case-based questions. Each question carries 4 marks.
7. Section E – questions number 31 to 33 are long answer type questions. Each question carries 5 marks.
8. There is no overall choice given in the question paper. However, an internal choice has been provided in few questions in all the sections except Section – A.
9. Use of calculator is not allowed.
10. This is the official 2026 board paper (Q.P. Code 56/5/1). The step marks shown in the solutions are our marking scheme in the CBSE style; CBSE's own marking scheme may award steps differently.
11. The answer key and the marking scheme are at the end of this booklet. Attempt the paper in 3 hours before you look at them.

Questions: CBSE board examination 2026, Q.P. Code 56/5/1, as published by CBSE at cbse.gov.in; structures redrawn. Answers, step marks and worked solutions © Master Testing Agency. Free for personal practice; not for resale. Master Testing Agency is an independent test-prep publisher, not affiliated with, endorsed by or connected to the Central Board of Secondary Education (CBSE) or any other exam-conducting body.

Chapters: Full syllabus · **Topics:** Solutions · Electrochemistry · Chemical Kinetics · d- and f-Block Elements · Coordination Compounds · Haloalkanes and Haloarenes · Alcohols, Phenols and Ethers · Aldehydes, Ketones and Carboxylic Acids · Amines · Biomolecules

SECTION A

Multiple choice questions of 1 mark each (Q13–16 assertion-reason).

1. Which of the reactions is used in the conversion of a ketone into hydrocarbon ? 1

(A) Reimer-Tiemann reaction
(B) Wolff-Kishner reduction
(C) Aldol condensation
(D) Stephen reaction

2. Which of the following reagents are used to prepare primary amines by Hoffmann bromamide degradation reaction ? 1

(i) $R - CO - NH_2$ (ii) NaOH (iii) Br_2 (iv) $CHCl_3$

(A) (i), (ii) and (iv)
(B) (i) and (iii)
(C) (i), (ii) and (iii)
(D) (i), (iii) and (iv)

3. The major product of carbylamine reaction is : 1

(A) Carboxylic acid
(B) Aldehyde
(C) Cyanide
(D) Isocyanide

4. Actinoids show larger number of oxidation states : 1

(A) because they are radioactive in nature
(B) because they have large atomic numbers
(C) because they have large atomic masses
(D) due to comparable energies of 5f, 6d and 7s orbitals

5. Consider the following reaction and identify A and B : 1

$CH_3Cl + NaI \xrightarrow{\text{dry acetone}} A + B$

(A) A = CH_3I, B = NaCl
(B) A = CH_3OH, B = NaCl
(C) A = CH_3CHO, B = NaCl
(D) A = C_2H_6, B = CH_3I

6. The correct formula of Hinsberg's reagent is : 1

(A) C_6H_5COCl
(B) $C_6H_5SO_2Cl$
(C) $C_6H_5CONHCH_3$
(D) $C_6H_5CH_2NH_2$

7. Half-life ($t_{1/2}$) of a first order reaction is 1386 s. The value of rate constant is : 1

(A) $0{\cdot}5 \times 10^4\ s^{-1}$
(B) $5{\cdot}0 \times 10^{-4}\ s^{-1}$
(C) $0{\cdot}5 \times 10^{-5}\ s^{-1}$
(D) $0{\cdot}5 \times 10^{-2}\ s^{-1}$

8. Which of the following ligands forms a chelate complex ? 1

(A) Ammonia
(B) Water
(C) NO_2^-
(D) Oxalate ion

9. Primary, secondary and tertiary alcohols can be distinguished by : 1

(A) Lucas test
(B) Fehling's test
(C) Tollens' test
(D) Hinsberg's test

10. Consider the following compounds : 1

$C_2H_5NH_2$, $(C_2H_5)_2NH$, $C_6H_5CH_2NH_2$, NH_3, $C_6H_5NH_2$

The correct increasing order of the above compounds on the basis of their basic strength is :

(A) $C_6H_5NH_2 < NH_3 < C_6H_5CH_2NH_2 < C_2H_5NH_2 < (C_2H_5)_2NH$

(B) $NH_3 < C_6H_5NH_2 < C_6H_5CH_2NH_2 < C_2H_5NH_2 < (C_2H_5)_2NH$

(C) $C_6H_5CH_2NH_2 < (C_2H_5)_2NH < NH_3 < C_6H_5NH_2 < C_2H_5NH_2$

(D) $C_2H_5NH_2 < C_6H_5NH_2 < NH_3 < C_6H_5CH_2NH_2 < (C_2H_5)_2NH$

11. Identify the polysaccharide among the following : 1

(A) Fructose

(B) Maltose

(C) Glucose

(D) Cellulose

12. The polypeptide chain in a protein has amino acids linked with each other in a specific sequence. This specific sequence of amino acids is called : 1

(A) Primary structure of protein

(B) Secondary structure of protein

(C) Tertiary structure of protein

(D) Quaternary structure of protein

13. **Assertion (A) :** D (+) – Glucose is dextrorotatory in nature. 1

Reason (R) : (+) represents dextrorotatory nature and D represents the configuration.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

14. **Assertion (A) :** Highest oxidation state of Mn is +7 in first series of transition elements. 1

Reason (R) : Transition metals exhibit variable oxidation states.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

15. **Assertion (A) :** p-nitrophenol is more acidic than phenol. 1
Reason (R) : Nitro group is an electron-withdrawing group, it stabilises phenoxide ion by dispersal of negative charge.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

16. **Assertion (A) :** All aliphatic aldehydes give a positive Fehling's test. 1
Reason (R) : Aliphatic aldehydes are reduced by Fehling's reagent.

(A) Both Assertion (A) and Reason (R) are true and Reason (R) is the correct explanation of the Assertion (A).

(B) Both Assertion (A) and Reason (R) are true, but Reason (R) is not the correct explanation of the Assertion (A).

(C) Assertion (A) is true, but Reason (R) is false.

(D) Assertion (A) is false, but Reason (R) is true.

SECTION B

Very short answer questions of 2 marks each.

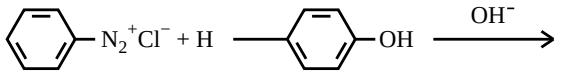
17. (a) 1·00 molal aqueous solution of trichloroacetic acid is heated to its boiling point. Boiling point of this solution was found to be 100·18°C. Calculate the van't Hoff factor for trichloroacetic acid. (Given : K_b for water = 0·512 K kg mol^{-1}) 2

OR

(b) State Henry's law. Calculate the mole fraction of CO_2 in water at 298 K under 760 mm Hg. (Given : K_H for CO_2 in H_2O at 298 K = $1{\cdot}25 \times 10^6$ mm Hg)

18. (a) Name the cell which was used in the Apollo space programme for providing electrical power. 2
(b) Define limiting molar conductivity.

19. (a) Complete the following equation : 2



(b) How will you convert nitromethane to methyl isocyanide ?

20. (a) What are the products obtained on hydrolysis of sucrose ? 2
(b) What are essential amino acids ?

21. (a) Write any two fat soluble vitamins. 2
(b) How will you confirm the presence of five – OH groups in a glucose molecule, which are attached to different carbon atoms ?

SECTION C

Short answer questions of 3 marks each.

22. Calculate emf of the following cell at 298 K : 3

Cr (s) | Cr^{3+}(aq) (0·1 M) || Fe^{2+}(aq) (0·01 M) | Fe (s)

(Given : $E°_{Cr^{3+}/Cr}$ = – 0·74 V, $E°_{Fe^{2+}/Fe}$ = – 0·44 V, [log 10 = 1])

23. (a) Define order of a reaction. 3

(b) The rate for the following reaction is given by : A + B → C, Rate = $k[A][B]^2$

(i) How is the rate of reaction affected if we double the concentration of B ?

(ii) Write the overall order of a reaction if 'A' is present in large excess.

24. The rate of the chemical reaction doubles when the temperature is raised from 298 K to 308 K. Calculate activation energy (E_a) for this reaction assuming that it does not change with temperature. 3

(Given : R = 8·314 J mol^{-1} K^{-1}, log 2 = 0·30)

25. (a) Write the IUPAC name of the following complex : $K_3[Cr(C_2O_4)_3]$ 3

(b) Differentiate between homoleptic complex and heteroleptic complex.

(c) Which type of isomerism is exhibited by the following complex : $[Pt(NH_3)_2Cl_2]$

26. (a) A coordination compound $CrCl_3 . 6H_2O$ is mixed with excess of $AgNO_3$ solution, two moles of AgCl are precipitated per mole of the compound. Write the structural formula of the coordination compound. 3

(b) Write the oxidation state and hybridisation of the central metal in the following complex : $[Fe(H_2O)_6]^{3+}$ [Atomic number of Fe = 26]

(c) Why is $[Ni(H_2O)_6]^{2+}$ coloured ? [Atomic number of Ni = 28]

27. How do you convert the following ? 3

(a) Acetophenone to Benzoic acid

(b) Acetonitrile to Acetone

(c) Benzoic acid to Benzene

28. (a) (i) Arrange the following compounds in increasing order of their acidic strengths : 3

$CH_3CH(Br)CH_2COOH$, $CH_3CH(CH_3)COOH$, $CH_3CH_2CH(Br)COOH$

(ii) Why is CH_3CHO more reactive than acetone towards reaction with HCN ?

(iii) Complete the equation : $(CH_3)(H)C = O + NH_2 – NH_2 \xrightarrow{H^+}$

OR

(b) An organic compound with the molecular formula C_8H_8O forms 2,4-DNP derivative, reduces Tollens' reagent and undergoes Cannizzaro reaction. On vigorous oxidation it gives Benzene-1,2-dicarboxylic acid. Identify the compound and write the reactions of compound 2,4-DNP and when it undergoes Cannizzaro reaction.

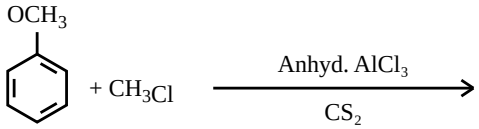
SECTION D

Case-based questions of 4 marks each.

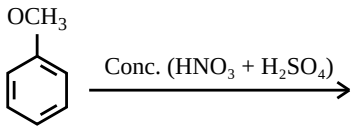
29. Ethers are prepared by the dehydration of alcohols in presence of protic acids at 413 K. Symmetrical and unsymmetrical ethers can also be prepared by Williamson synthesis. This reaction involves S_N2 attack of an alkoxide ion on primary alkyl halide. If a tertiary alkyl halide is used, elimination reaction occurs and an alkene is formed, no ether is formed. C – O bond in ethers are cleaved under drastic conditions with excess of HI. When unsymmetrical ethers react with HI, the alkyl halide is formed from smaller alkyl group. If one of the alkyl group is tertiary, the alkyl halide is formed from the tertiary alkyl group because tertiary alkyl carbocation is more stable than the primary carbocation. Cleavage of alkyl aryl ethers takes place at the alkyl-oxygen bond due to more stable aryl-oxygen bond. The order of reactivity of hydrogen halides is HI > HBr > HCl. Aromatic ethers undergo electrophilic substitution reactions. The alkoxy group attached to the aromatic ring activates the ring towards electrophilic substitution and directs the incoming group to ortho- and para-positions.
Answer the following questions :

(a) Complete the following equations :

(i)



(ii)



[2]

(b) Write the names of alkyl halide and sodium alkoxide used to prepare tert-butyl ethyl ether. [1]

OR

(b) Anisole on reaction with HI gives phenol and $CH_3 – I$ and not methanol and iodobenzene. Justify the statement. [1]

(c) Why is C – O – C bond angle in ethers slightly greater than tetrahedral angle ? [1]

30. Electrochemistry is the study of the relationship between chemical energy and electrical energy. Many spontaneously occurring chemical reactions liberate electrical energy. In electrolysis, electrical energy is converted directly into chemical energy. The product of an electrolytic reaction depends on the nature of the material being electrolysed and the type of electrode used. Oxidising and reducing species present in the electrolytic cell and their standard electrode potential too, affect the products of electrolysis. Electrolysis plays an important role in most people's daily lives, whether it is for the manufacturing of aluminium, electroplating of metals, or the synthesis of chemical compounds.
Michael Faraday was the first scientist who proposed two laws to explain the quantitative aspects of electrolysis, popularly known as Faraday's laws of electrolysis. Faraday's laws of electrolysis provide a basis for mathematical analysis of the mass deposited at electrodes and the amount of charge passed through them.
Faraday's laws are fundamental in various applications, including electroplating, metal extraction, battery technology and chemical synthesis. These laws also help in environmental monitoring and in various chemistry experiments.
Answer the following questions :

(a) Predict the products of electrolysis in each of the following :
(i) An aqueous solution of $CuCl_2$ with platinum electrodes.
(ii) A concentrated solution of H_2SO_4 with platinum electrodes. [2]

(b) How much charge in faraday is required for the reduction of 1 mol of Ag^+ to Ag ? [1]

OR

(b) State Faraday's second law of electrolysis. [1]

(c) The following reactions occur at the anode during the electrolysis of aqueous sodium chloride solution :
Cl^- (aq) $\longrightarrow$ ½ Cl_2 (g) + e^- $E°_{(cell)}$ = 1·36 V (I)
$2H_2O$ (*l*) $\longrightarrow$ O_2 (g) + $4H^+$ (aq) + $4e^-$ $E°_{(cell)}$ = 1·23 V (II)
Which reaction is feasible at the anode and why ? [1]

SECTION E

Long answer questions of 5 marks each.

31. (a) (i) Calculate the freezing point of a solution when 10·5 g of $MgBr_2$ was dissolved in 250 g of water, assuming $MgBr_2$ undergoes complete dissociation. (Given : Molar mass of $MgBr_2$ = 184 g mol^{-1}, K_f for water = 1·86 K kg mol^{-1}) 5
(ii) Write two differences between ideal and non-ideal solutions.

OR

(b) (i) A solution is prepared by dissolving 0·025 g of potassium sulphate in 2 L of water at 27°C. Assuming potassium sulphate is completely dissociated, determine its osmotic pressure. (Given : R = 0·082 L atm K^{-1} mol^{-1}, Molar mass of K_2SO_4 = 174 g mol^{-1})
(ii) What type of azeotrope will be formed by a solution of acetone and chloroform ? Give reason.

32. (a) (i) (I) Why do transition metals show variable oxidation states ? 5

(II) Out of Mn^{2+} and Ti^{2+} which will be more paramagnetic and why ? [Atomic No. : Ti = 22, Mn = 25]

(III) Which ion is the strongest oxidising agent in the options given below : Cr^{3+}, V^{3+}, Mn^{3+}. Give reason. [Atomic No. : Cr = 24, V = 23, Mn = 25]

(ii) Complete and balance the following equations :

(I) $2MnO_2 + 4KOH + O_2 \rightarrow$

(II) $5C_2O_4^{2-} + 2MnO_4^{-} + 16H^{+} \rightarrow$

OR

(b) (i) What is meant by lanthanoid contraction ?

(ii) Why do transition metals form coloured compounds ?

(iii) Why are $E°_{M^{2+}/M}$ values for Mn and Zn more negative than expected ?

(iv) Which is the most stable oxidation state of Cu and why ?

(v) Why is Ce^{4+} in aqueous solution a good oxidising agent ?

33. (a) (i) (I) Which of the following is more reactive towards S_N1 reaction : 2-Bromo-2-methylbutane or 1-Bromopentane 5

(II) What type of halide is present in the following compound : $CH_3 – CH(CH_3) – C(Cl) = CH_2$

(III) Why is chloroform stored in dark coloured bottles ?

(ii) Define the following terms :

(I) Ambident Nucleophiles

(II) Racemic mixture

OR

(b) (i) Answer the following :

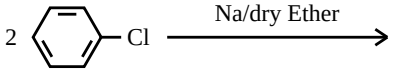
(I) Which isomer of C_4H_9Br is most reactive towards S_N1 reaction ?

(II) Predict the alkene that would be formed by dehydrohalogenation of 1-Bromo-1-methylcyclohexane.

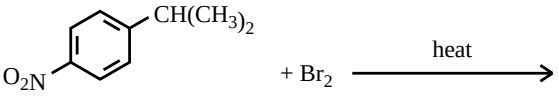
(III) Although chlorine shows strong – I effect, yet it is ortho/para-directing in electrophilic aromatic substitution reactions. Why ?

(ii) Write the major product in the following reactions :

(I)



(II)



END OF THE QUESTION PAPER

ANSWER KEY — SECTION A

Q1	Q2	Q3	Q4	Q5	Q6	Q7	Q8	Q9	Q10	Q11	Q12	Q13	Q14	Q15	Q16
(B)	(C)	(D)	(D)	(A)	(B)	(B)	(D)	(A)	(A)	(D)	(A)	(A)	(B)	(A)	(C)

MARKING SCHEME AND WORKED SOLUTIONS

Marks for each step are shown in brackets, as in the CBSE marking scheme. Any correct alternative method earns full marks.

Q1. Answer (B). Wolff-Kishner reduction (NH_2NH_2, then KOH/ethylene glycol, heat) converts >C=O into >CH_2.

Q2. Answer (C). $RCONH_2 + Br_2 + 4NaOH \rightarrow RNH_2 + Na_2CO_3 + 2NaBr + 2H_2O$: amide, NaOH and Br_2. Chloroform is not used.

Q3. Answer (D). $RNH_2 + CHCl_3 + 3KOH \rightarrow R–NC + 3KCl + 3H_2O$: an isocyanide (foul smell).

Q4. Answer (D). The 5f, 6d and 7s levels are close in energy, so a varying number of electrons can take part in bonding.

Q5. Answer (A). Finkelstein reaction: $CH_3Cl + NaI \rightarrow CH_3I + NaCl$; NaCl is insoluble in dry acetone and precipitates, driving the reaction forward.

Q6. Answer (B). Hinsberg's reagent is benzenesulphonyl chloride, $C_6H_5SO_2Cl$.

Q7. Answer (B). $k = 0.693/t½ = 0.693/1386 = 5.0 \times 10^{-4}\ s^{-1}$.

Q8. Answer (D). Oxalate, $C_2O_4^{2-}$, is didentate: it binds through two O atoms and forms a ring (chelate). NH_3 and H_2O are unidentate; NO_2^- is ambidentate, binding through one atom at a time.

Q9. Answer (A). With Lucas reagent (conc. HCl + $ZnCl_2$) tertiary alcohols turn turbid at once, secondary in about 5 minutes, primary not at room temperature.

Q10. Answer (A). pK_b values (NCERT): $C_6H_5NH_2$ 9.38 > NH_3 4.75 > $C_6H_5CH_2NH_2$ 4.70 > $C_2H_5NH_2$ 3.29 > $(C_2H_5)_2NH$ 3.00. Basic strength rises in that order. Aniline is weakest because its lone pair is delocalised into the ring.

Q11. Answer (D). Cellulose is a polymer of β-D-glucose. Fructose and glucose are monosaccharides; maltose is a disaccharide.

Q12. Answer (A). The sequence of amino acids in the chain is the primary structure.

Q13. Answer (A). Glucose rotates plane-polarised light to the right (A true). The (+) sign is what says it is dextrorotatory, while D gives only the configuration (R true), and that is why A follows from the name D(+)-glucose. Answer (A).

Q14. Answer (B). Mn shows +7 (as in $KMnO_4$), the highest in the 3d series, because it can use all its 3d and 4s electrons (A true). R is true but only general; it does not explain why Mn reaches +7. Answer (B).

Q15. Answer (A). $–NO_2$ (−I, −R) disperses the negative charge of the phenoxide ion and stabilises it, so p-nitrophenol (pKa 7.1) is more acidic than phenol (10.0). R explains A. Answer (A).

Q16. Answer (C). Aliphatic aldehydes reduce Fehling's solution to a red-brown Cu_2O precipitate (A true; aromatic aldehydes do not). The aldehyde is oxidised, not reduced, by Fehling's reagent (R false). Answer (C).

Q17. (2 marks) Answer: (a) i ≈ 0.35; (b) 6.08×10^{-4}.
(a) $\Delta T_b = 100.18 - 100 = 0.18$ K. $\Delta T_b = i K_b m$, so $i = 0.18/(0.512 \times 1.00) \approx 0.35$. [2]
Note: trichloroacetic acid is in fact a strong acid, so a value near 2 would be expected; with the data as printed the answer is 0.35, the value CBSE's data leads to.
OR (b) Henry's law: the partial pressure of a gas in the vapour phase is proportional to its mole fraction in the solution, $p = K_H x$. [1] $x(CO_2) = p/K_H = 760/(1.25 \times 10^6) = 6.08 \times 10^{-4}$. [1]

Q18. (2 marks) Answer: H_2–O_2 fuel cell; Λm at infinite dilution.
(a) The hydrogen–oxygen fuel cell. [1]
(b) The molar conductivity of an electrolyte when the concentration approaches zero (infinite dilution), Λ°m. [1]

Q19. (2 marks) Answer: p-hydroxyazobenzene; reduction then carbylamine.
(a) Coupling at the para position of phenol: C_6H_5–N=N–C_6H_4–OH (p-hydroxyazobenzene, orange dye) + Cl^- + H_2O. [1]
(b) Reduce, then carbylamine reaction: CH_3NO_2 —Sn/HCl (or H_2/Ni)→ CH_3NH_2 —$CHCl_3$ + alc. KOH, heat→ CH_3NC. [1]

Q20. (2 marks) Answer: glucose + fructose; not made by the body.
(a) D-(+)-glucose and D-(−)-fructose (invert sugar). [1]
(b) Amino acids that the body cannot make and that must be taken in the diet, e.g. valine, leucine, lysine. [1]

Q21. (2 marks) Answer: A, D, E, K; pentaacetate.
(a) Any two of vitamins A, D, E and K. [1]
(b) Acetylation with acetic anhydride gives glucose pentaacetate, a stable compound: five –OH groups, each on a different carbon. [1]

Q22. (3 marks) Answer: ≈ 0.26 V.
Cell reaction: $2Cr + 3Fe^{2+} \rightarrow 2Cr^{3+} + 3Fe$, n = 6. $E°_{cell} = -0.44 - (-0.74) = 0.30$ V. [1]
$E = E° - (0.059/6)\log([Cr^{3+}]^2/[Fe^{2+}]^3) = 0.30 - (0.059/6)\log((0.1)^2/(0.01)^3) = 0.30 - (0.059/6) \times 4$ [1]
$= 0.30 - 0.0393 = 0.2607$ V ≈ 0.26 V. [1]

Q23. (3 marks) Answer: 4 times; 2.
(a) The sum of the powers of the concentration terms in the experimentally found rate law. [1]
(b) (i) Rate ∝ $[B]^2$: doubling [B] makes the rate $2^2 = 4$ times. [1] (ii) [A] stays practically constant, so Rate = $k'[B]^2$: overall (pseudo) order 2. [1]

Q24. (3 marks) Answer: ≈ 52.7 kJ mol^{-1}.
$\log(k_2/k_1) = (E_a/2.303R)(T_2 - T_1)/(T_1T_2)$. [1]
$\log 2 = 0.30 = E_a \times 10 /(2.303 \times 8.314 \times 298 \times 308)$ [1]
$E_a = 0.30 \times 2.303 \times 8.314 \times 298 \times 308/10 \approx 52\,700$ J mol^{-1} = 52.7 kJ mol^{-1}. [1]

Q25. (3 marks) Answer: potassium trioxalatochromate(III); geometrical.
(a) Potassium trioxalatochromate(III). [1]
(b) Homoleptic: the metal is bound to only one kind of donor group, e.g. $[Co(NH_3)_6]^{3+}$. Heteroleptic: more than one kind, e.g. $[Co(NH_3)_4Cl_2]^+$. [1]
(c) Geometrical (cis–trans) isomerism of the square planar complex. [1]

Q26. (3 marks) Answer: $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O$; +3, sp^3d^2; d–d transition.
(a) Two Cl^- are ionisable, so one Cl is a ligand: $[Cr(H_2O)_5Cl]Cl_2 \cdot H_2O$. [1]
(b) Fe is +3 ($3d^5$); H_2O is a weak field ligand, so the outer 4d orbitals are used: sp^3d^2, octahedral, high spin. [1]
(c) Ni^{2+} is $3d^8$ with two unpaired electrons; it absorbs visible (red) light for d–d transitions and shows the complementary colour, green. [1]

Q27. (3 marks) Answer: haloform; Grignard then hydrolysis; decarboxylation with soda lime.
(a) Haloform reaction: $C_6H_5COCH_3$ —NaOI (I_2 + NaOH)→ C_6H_5COONa + CHI_3 —H_3O^+→ C_6H_5COOH. [1]
(b) $CH_3CN + CH_3MgBr \rightarrow CH_3C(=NMgBr)CH_3$ —H_3O^+→ CH_3COCH_3. [1]
(c) C_6H_5COOH —NaOH→ C_6H_5COONa —NaOH + CaO (soda lime), heat→ $C_6H_6 + Na_2CO_3$. [1]

Q28. (3 marks) Answer: (a) $(CH_3)_2CHCOOH$ < 3-bromo < 2-bromo acid; $CH_3CH{=}N{-}NH_2$; (b) 2-methylbenzaldehyde.
(a) (i) $(CH_3)_2CHCOOH < CH_3CH(Br)CH_2COOH < CH_3CH_2CH(Br)COOH$. $-CH_3$ (+I) weakens the acid; –Br (−I) strengthens it, more so the nearer it is to –COOH. [1]
(ii) In acetone two $-CH_3$ groups (+I) lower the positive charge on the carbonyl carbon and also crowd it; acetaldehyde has only one, so CN^- attacks it more easily. [1]
(iii) $CH_3CH{=}O + H_2N{-}NH_2 \xrightarrow{H^+} CH_3CH{=}N{-}NH_2$ (acetaldehyde hydrazone) + H_2O. [1]
OR (b) An aldehyde (Tollens', 2,4-DNP) with no α-H (Cannizzaro) whose two side chains are ortho (phthalic acid on oxidation): 2-methylbenzaldehyde (o-tolualdehyde), $CH_3{-}C_6H_4{-}CHO$. [1]
With 2,4-DNP: $CH_3C_6H_4CH{=}N{-}NH{-}C_6H_3(NO_2)_2$ (2,4-dinitrophenylhydrazone) + H_2O. [1]
Cannizzaro: 2 $CH_3C_6H_4CHO$ + conc. NaOH → $CH_3C_6H_4CH_2OH$ (2-methylbenzyl alcohol) + $CH_3C_6H_4COONa$ (sodium 2-methylbenzoate). [1]

Q29. (4 marks) Answer: o- and p-methylanisole; o- and p-nitroanisole; $C_2H_5Br + (CH_3)_3CONa$; repulsion of bulky groups.
(a) (i) Friedel–Crafts alkylation, ortho/para to $-OCH_3$: 2-methoxytoluene (minor) and 4-methoxytoluene (major) + HCl. [1]
(ii) Nitration: 2-nitroanisole (minor) and 4-nitroanisole (major) + H_2O. [1]
(b) Ethyl bromide (bromoethane) and sodium tert-butoxide: $(CH_3)_3CONa + C_2H_5Br \rightarrow (CH_3)_3C{-}O{-}C_2H_5 + NaBr$. (A tert-butyl halide would give an alkene by elimination.) [1]
OR (b) The O–CH_3 bond is broken: the aryl–O bond has partial double bond character (resonance) and is stronger, and I^- attacks the less hindered CH_3 by S_N2 (attack on the ring carbon is not possible). So $C_6H_5OCH_3 + HI \rightarrow C_6H_5OH + CH_3I$. [1]
(c) The two bulky alkyl groups repel each other, which opens the angle a little (about 111.7°) above 109°28′. [1]

Q30. (4 marks) Answer: Cu and Cl_2; H_2 and $S_2O_8^{2-}$; 1 F; reaction (I), overpotential of O_2.
(a) (i) Cathode: $Cu^{2+} + 2e^- \rightarrow Cu$ (copper deposits). Anode: $Cl^- \rightarrow \frac{1}{2}Cl_2 + e^-$ (chlorine gas). [1]
(ii) Cathode: hydrogen gas. Anode: in concentrated H_2SO_4 the sulphate is oxidised to peroxodisulphate, $2SO_4^{2-} \rightarrow S_2O_8^{2-} + 2e^-$ (in dilute acid, O_2 would be evolved). [1]
(b) $Ag^+ + e^- \rightarrow Ag$: 1 F. [1]
OR (b) When the same quantity of electricity is passed through solutions of different electrolytes in series, the masses of the substances liberated are proportional to their chemical equivalent weights (atomic mass/number of electrons). [1]
(c) Reaction (I): Cl_2 is liberated. Although (II) has the lower potential and should be preferred, oxidation of water is very slow and needs extra voltage (overpotential), so Cl^- is oxidised. [1]

Q31. (5 marks) Answer: (a) −1.27 °C; (b) 5.30×10^{-3} atm; maximum boiling azeotrope.
(a) (i) $MgBr_2 \rightarrow Mg^{2+} + 2Br^-$, i = 3. Moles = 10.5/184 = 0.0571; m = 0.0571/0.250 = 0.228 mol kg^{-1}. [1]
$\Delta T_f = i K_f m = 3 \times 1.86 \times 0.228 = 1.27$ K. [1]
Freezing point = 0 − 1.27 = −1.27 °C (271.88 K). [1]
(ii) Ideal: obeys Raoult's law at all concentrations; $\Delta H_{mix} = 0$ and $\Delta V_{mix} = 0$ (A–B interactions equal to A–A and B–B). Non-ideal: does not obey Raoult's law; $\Delta H_{mix} \neq 0$ and $\Delta V_{mix} \neq 0$ (shows positive or negative deviation). [2]
OR (b) (i) $K_2SO_4 \rightarrow 2K^+ + SO_4^{2-}$, i = 3. Moles = 0.025/174 = 1.437×10^{-4}; C = 7.18×10^{-5} mol L^{-1}. [1] $\pi = iCRT = 3 \times 7.18 \times 10^{-5} \times 0.082 \times 300$ [1] = 5.30×10^{-3} atm. [1]
(ii) A maximum boiling azeotrope. Chloroform's H forms a hydrogen bond with the O of acetone, so A–B attractions are stronger than A–A and B–B: negative deviation from Raoult's law, lower vapour pressure and a higher boiling point. [2]

Q32. (5 marks) Answer: (a) Mn^{2+}; Mn^{3+}; K_2MnO_4; $Mn^{2+} + CO_2$; (b) see the model answer.

(a) (i) (I) The (n−1)d and ns electrons are close in energy, so different numbers of them can be used in bonding. [1] (II) Mn^{2+} ($3d^5$, five unpaired electrons) is more paramagnetic than Ti^{2+} ($3d^2$, two unpaired). [1] (III) Mn^{3+}: it is $3d^4$ and readily gains an electron to become the stable half-filled Mn^{2+} ($3d^5$), so $E°(Mn^{3+}/Mn^{2+})$ is high (+1.57 V); Cr^{3+} (stable t_2g^3) and V^{3+} are not easily reduced. [1]

(ii) (I) $2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4 + 2H_2O$. [1] (II) $5C_2O_4^{2-} + 2MnO_4^- + 16H^+ \rightarrow 2Mn^{2+} + 10CO_2 + 8H_2O$. [1]

OR (b) (i) The steady decrease in the atomic and ionic (M^{3+}) radii from La to Lu, because the 4f electrons shield the increasing nuclear charge poorly. [1]

(ii) They have partly filled d orbitals; in a complex or ion the d orbitals split, and an electron absorbs visible light to move between them (d–d transition). The complementary colour is seen. [1]

(iii) Mn^{2+} is $3d^5$ (half-filled) and Zn^{2+} is $3d^{10}$ (completely filled): these extra-stable configurations make the ions easy to form. [1]

(iv) +2 in aqueous solution: although Cu^+ is $3d^{10}$, the much larger (more negative) hydration enthalpy of Cu^{2+} more than makes up for the second ionisation enthalpy (Cu^+ disproportionates in water). [1]

(v) Cerium's most stable state is +3, so Ce^{4+} readily takes an electron to become Ce^{3+} ($E°(Ce^{4+}/Ce^{3+}) = +1.74$ V). [1]

Q33. (5 marks) Answer: (a) 2-bromo-2-methylbutane; vinylic; phosgene; (b) $(CH_3)_3CBr$; 1-methylcyclohexene; biphenyl; benzylic bromide.

(a) (i) (I) 2-Bromo-2-methylbutane: it is tertiary and gives a stable tertiary carbocation. [1] (II) A vinylic halide: Cl is on an sp^2 carbon of the C=C. [1] (III) In light and air chloroform is slowly oxidised to the poisonous gas phosgene ($2CHCl_3 + O_2 \rightarrow 2COCl_2 + 2HCl$); dark bottles, filled to the brim, keep light and air out. [1]

(ii) (I) Nucleophiles with two nucleophilic sites through which they can attack, e.g. CN^- (C or N) and NO_2^- (N or O). [1] (II) An equimolar mixture of the two enantiomers; it is optically inactive (the rotations cancel). [1]

OR (b) (i) (I) 2-Bromo-2-methylpropane, $(CH_3)_3CBr$: most stable tertiary carbocation. [1] (II) Saytzeff rule: 1-methylcyclohexene (the double bond inside the ring). [1] (III) The −I effect deactivates the ring, but Cl donates its lone pairs by resonance (+R), which raises the electron density at the ortho and para positions more than at meta. [1]

(ii) (I) Fittig reaction: $2C_6H_5Cl + 2Na \rightarrow C_6H_5–C_6H_5$ (biphenyl) + 2NaCl. [1] (II) Free radical bromination at the benzylic C–H (heat): $O_2N–C_6H_4–C(Br)(CH_3)_2$, 2-bromo-2-(4-nitrophenyl)propane, + HBr. [1]

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