CBSE Class 12 Chemistry 2026 — Set 3 — Answer Key

English Medium

Time Allowed: 3 Hours

General Instructions:

1. This is an answer key — each question is shown with its correct answer and a step-by-step explanation.
2. Questions appear in the original paper order.

Q.1

Which of the following will be the least reactive towards nucleophilic substitution reaction ?

(a) $C_6H_5CH_2Cl$ (benzyl chloride)

(b) $p\text{-}CH_3C_6H_4Cl$ (p-chlorotoluene) <<

(c) $CH_3–Cl$

(d) Chlorocyclohexane

Explanation:

The aryl halide p-chlorotoluene has Cl on an sp^2 carbon;

the C–Cl bond has partial double-bond character (resonance with the ring), so it is least reactive towards nucleophilic substitution.

Benzyl chloride, CH_3Cl and chlorocyclohexane are all alkyl halides on sp^3 carbon and are reactive.

Q.2

The intermediate formed during the slowest step involved in the dehydration of alcohol is :

(a) protonated alcohol

(b) carbanion

(c) free radical

(d) carbocation <<

Explanation:

The dehydration of alcohol proceeds by the E1 mechanism.

The rate-determining (slowest) step is the ionisation of the protonated alcohol to form a carbocation.

The carbocation is the intermediate formed in this step.

Q.3

The oxidation number of Co in [Co(en)3]2(SO4)3 is :

(a) +3 <<

(b) +2

(c) +4

(d) +6

Explanation:

SO4^2- carries a charge of -2 each; three SO4^2- give -6 total.

The complex cation is [Co(en)3]2^3+ each (total charge on cations = +6, balancing -6 from sulfates).

So each [Co(en)3]^3+ has charge +3.

en is a neutral ligand, so Co = +3.

Q.4

According to Werner's theory, the primary valencies of the central metal atom :

(a) are satisfied by neutral molecules or negative ions.

(b) are equal to its coordination number.

(c) are satisfied by negative ions. <<

(d) are non-ionisable.

Explanation:

According to Werner's theory, primary valencies (ionisable valencies) are satisfied only by negative ions (counter ions outside the coordination sphere).

Secondary valencies are satisfied by neutral molecules or negative ions within the coordination sphere.

Q.5

Which of the following reagent is used to distinguish between (C2H5)2NH and (C2H5)3N ?

(a) CHCl3 + KOH

(b) C6H5SO2Cl <<

(c) Conc. HCl + ZnCl2

(d) NaOH + I2

Explanation:

Hinsberg's reagent (C6H5SO2Cl) is used to distinguish between primary, secondary, and tertiary amines.

(C2H5)2NH is a secondary amine — it reacts with Hinsberg's reagent to form a sulfonamide that is insoluble in NaOH.

(C2H5)3N is a tertiary amine — it does not react with Hinsberg's reagent (or the product is soluble).

This distinguishes the two.

Q.6

Among the following, which is the strongest base ?

(a) $O_2N–C_6H_4–NH_2$ (4-nitroaniline)

(b) $C_6H_5–CH_2NH_2$ (benzylamine) <<

(c) $H_3C–C_6H_4–NH_2$ (4-methylaniline)

(d) $C_6H_5–NH_2$ (aniline)

Explanation:

In benzylamine the $–NH_2$ sits on an sp^3 CH_2, so the lone pair is not delocalised into the ring and it is the strongest base.

In the anilines the lone pair is delocalised;

the $–NO_2$ group makes 4-nitroaniline the weakest and the $–CH_3$ group makes 4-methylaniline stronger than aniline.

Order: B > C > D > A.

Q.7

In aqueous solution, Cr2O7^2- ion converts to which of the following in alkaline medium ?

(a) Cr3+

(b) CrO4^2- <<

(c) CrO

(d) CrO3

Explanation:

In alkaline medium, dichromate (Cr2O7^2-) converts to chromate (CrO4^2-): Cr2O7^2- + 2OH^- →

2CrO4^2- + H2O.

The solution changes from orange to yellow.

Q.8

The boiling point of an azeotropic mixture of water and ethanol is less than that of pure water and ethanol. The mixture shows :

(a) positive deviation from Raoult's Law. <<

(b) negative deviation from Raoult's Law.

(c) no deviation from Raoult's Law.

(d) that the solution is an ideal solution.

Explanation:

When the boiling point of an azeotropic mixture is lower than that of either pure component, it is a minimum boiling azeotrope.

This forms when A–B interactions are weaker than A–A and B–B interactions, leading to higher vapour pressure (positive deviation from Raoult's Law).

Water–ethanol mixture shows positive deviation.

Q.9

The mole fraction of a solute in 2·0 molal aqueous solution is :

(a) 1·87

(b) 0·347

(c) 0·0347 <<

(d) 0·00347

Explanation:

2·0 molal = 2·0 mol solute per 1000 g water.

Moles of water = 1000/18 = 55·56 mol.

Mole fraction of solute = 2·0 / (2·0 + 55·56) = 2·0 / 57·56 = 0·0347.

Q.10

On electrolysis of very dilute aqueous solution of NaCl using platinum electrodes :

(a) H2 gas is evolved at anode.

(b) Na is produced at cathode.

(c) O2 gas is evolved at anode. <<

(d) H2 gas is evolved at cathode.

Explanation:

In a very dilute NaCl solution, water is oxidised at the anode in preference to Cl^-, giving O_2 gas.

Water is also reduced at the cathode in preference to Na^+, giving H_2 gas.

The very dilute solution is what changes the anode product, so option (C).

Note: this key is unconfirmed, because (D) H_2 at the cathode is also true.

Q.11

For a reaction 3A → 2B, the rate of reaction +d[B]/dt is equal to :

(a) -3/2 × d[A]/dt

(b) -2/3 × d[A]/dt <<

(c) -1/3 × d[A]/dt

(d) +2 × d[A]/dt

Explanation:

For 3A → 2B, the rate in terms of stoichiometry: rate = -1/3 × d[A]/dt = +1/2 × d[B]/dt.

Therefore d[B]/dt = 2/3 × (-d[A]/dt) = -2/3 × d[A]/dt.

So +d[B]/dt = -2/3 × d[A]/dt.

Q.12

On hydrolysis, which of the following carbohydrates gives only glucose ?

(a) Sucrose

(b) Galactose

(c) Lactose

(d) Maltose <<

Explanation:

Maltose on hydrolysis gives two molecules of glucose only.

Sucrose gives glucose + fructose.

Lactose gives glucose + galactose.

Galactose is itself a monosaccharide (does not hydrolyse further).

So the answer is Maltose.

Q.13

Assertion (A) : Separation of Zr and Hf is difficult.

Reason (R) : Because Zr and Hf lie in the same group of the periodic table.

(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.

Explanation:

Assertion is true: separation of Zr and Hf is indeed difficult.

Reason is also true: they are in the same group (Group 4).

However, the real reason for the difficulty of separation is lanthanoid contraction — due to the lanthanoid contraction, Zr and Hf have almost identical ionic radii and similar chemical properties.

Merely being in the same group is not the complete or correct explanation;

many group members can be separated.

So Reason does not correctly explain the Assertion.

Q.14

Assertion (A) : Phenol is less acidic than 4-methylphenol.

Reason (R) : The presence of an electron releasing group in phenol makes it less acidic.

(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. <<

Explanation:

Assertion is false: 4-methylphenol has an electron-releasing methyl group that further destabilises the phenoxide ion, making 4-methylphenol LESS acidic than phenol — not more.

So phenol is MORE acidic than 4-methylphenol, not less.

Reason is true: electron-releasing groups do make phenol less acidic (they destabilise the phenoxide ion).

Since the Assertion is false and Reason is true, the answer is (D).

Q.15

Assertion (A) : Aromatic primary amines cannot be prepared by Gabriel phthalimide synthesis.

Reason (R) : Gabriel phthalimide synthesis is used for the preparation of primary aliphatic amines.

(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.

Explanation:

Both are true and R correctly explains A.

Gabriel phthalimide synthesis requires alkylation of potassium phthalimide with an alkyl halide.

Aryl halides do not undergo such nucleophilic substitution under normal conditions, so aromatic primary amines cannot be prepared by this route.

The synthesis is therefore limited to primary aliphatic amines.

Q.16

Assertion (A) : Order of reaction is applicable to elementary as well as complex reactions.

Reason (R) : Order of a reaction is an experimental quantity.

(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.

Explanation:

Both are true and R correctly explains A.

Order of reaction is applicable to both elementary and complex reactions.

It is determined experimentally from the rate law (not from stoichiometry), so Reason correctly explains why it applies broadly — it is an experimentally determined quantity.

Note: this key is unconfirmed.

Q.17

For the compound having molecular formula C4H9Br, write :

(a) the isomer which is most reactive towards SN1 displacement.

(b) the isomer which, on reacting with Na metal in the presence of dry ether, gives 2,5-Dimethylhexane.

Answer: (a) (CH3)3CBr (tert-butyl bromide / 2-bromo-2-methylpropane) — the tertiary substrate forms the most stable (tertiary) carbocation and is most reactive towards SN1. (b) 2-methylpropyl bromide (isobutyl bromide, (CH3)2CHCH2Br) — two moles of (CH3)2CHCH2Br react with Na (Wurtz reaction) to give (CH3)2CHCH2CH2CH(CH3)2 = 2,5-dimethylhexane.

Explanation:

(a) SN1 reactivity follows carbocation stability: tertiary > secondary > primary.

Among C4H9Br isomers, (CH3)3CBr (tert-butyl bromide) gives the most stable tertiary

carbocation and is most reactive towards SN1.

(b) Wurtz reaction: 2 R–Br + 2Na → R–R + 2NaBr.

Product 2,5-dimethylhexane = (CH3)2CHCH2CH2CH(CH3)2 has the symmetrical C6-chain with methyl at C2 and C5.

Each half = (CH3)2CHCH2– = isobutyl group;

so the bromide is (CH3)2CHCH2Br (isobutyl bromide / 1-bromo-2-methylpropane).

Q.18

For a reaction A + B → Products, the rate law is :

Rate = k[A][B]^(3/2)

Write the overall order of the reaction. Can this reaction be an elementary reaction ? Give reason in support of your answer.

Answer: Overall order = 1 + 3/2 = 5/2 (= 2.5). No, this cannot be an elementary reaction because for an elementary reaction the order must be a whole number equal to its molecularity. A fractional order (5/2) is not possible for an elementary step.

Explanation:

Overall order = sum of powers of concentration terms in the rate law = 1 (for A) + 3/2 (for B) = 5/2.

For an elementary reaction, the rate law is derived directly from stoichiometry and the order must be a positive integer (1, 2, or rarely 3).

A fractional order like 5/2 indicates a complex (multi-step) mechanism, so this cannot be an elementary reaction.

Q.19

Explain why, on addition of 1 mol of KCl to 1 litre of water, the boiling point of water increases, while the addition of 1 mol of methyl alcohol to 1 litre of water decreases the boiling point.

Answer: KCl is a non-volatile solute that does not contribute to vapour pressure. Adding KCl lowers the vapour pressure of water (Raoult's law), so a higher temperature is needed to reach atmospheric pressure — boiling point increases (elevation of boiling point). Methyl alcohol (methanol) is a volatile solute with its

own vapour pressure. Adding methanol to water increases the total vapour pressure of the solution above that of pure water (positive deviation from Raoult's law), so the solution reaches atmospheric pressure at a lower temperature — boiling point decreases.

Explanation:

The key distinction is volatile vs.

non-volatile solute.

Non-volatile solutes (like KCl) always raise the boiling point by lowering vapour pressure (colligative property).

Volatile solutes (like methanol, bp 64.7°C) contribute their own vapour pressure to the solution, raising the total vapour pressure above that of pure water at the same temperature, thus lowering the boiling point of the water-methanol mixture.

Q.20

(a) Write IUPAC names of the following compounds :

(i) [PtCl2(en)2]SO4

(ii) (NH4)2[CoF4]

Answer: (i) Dichloridobis(ethane-1,2-diamine)platinum(IV) sulfate

(ii) Ammonium tetrafluoridocobaltate(II)

Explanation:

(i) [PtCl2(en)2]SO4: The cation is [PtCl2(en)2]^2+.

Ligands: Cl- = chlorido (×2), en = ethane-1,2-diamine (×2).

Metal = Pt; charge: +2(from SO4^2-) so Pt oxidation state = +2 + 2 = +4.

Name: dichloridobis(ethane-1,2-diamine)platinum(IV) sulfate.

(ii) (NH4)2[CoF4]: The anion is [CoF4]^2-.

Ligands: F- = fluorido (×4).

Co oxidation state: -2 = 4(-1) + x → x = +2.

Cation = ammonium.

Name: ammonium tetrafluoridocobaltate(II).

OR

Q.20

(b) Define the following terms with a suitable example in each case :

(i) Ambidentate ligand

(ii) Double salt

Answer: (i) Ambidentate ligand: A ligand that can coordinate to the central metal atom through two different donor atoms. Example: NO2^- can coordinate through N (nitro, -NO2) or through O (nitrito, -ONO); SCN^- can coordinate through S or N. (ii) Double salt: A salt that contains two different salts crystallised together and dissociates completely into its constituent ions in solution, losing its identity. Example: Mohr's salt, FeSO4.(NH4)2SO4.6H2O, which gives Fe^2+, NH4^+, and SO4^2- ions in solution.

Explanation:

(i) Ambidentate ligands have two donor atoms but coordinate through only one at a time, giving rise to linkage isomerism.

(ii) Double salts differ from complex salts: in solution they dissociate completely into simple ions (no complex ion persists).

Alum, KAl(SO4)2.12H2O, and Mohr's salt are classic examples.

Q.21

How do you explain the following ?

(a) Presence of a straight chain in glucose

(b) Presence of five –OH groups in glucose which are attached to different carbon atoms

Answer: (a) Prolonged heating of glucose with HI gives n-hexane, so all six carbons are in a straight, unbranched chain. (b) Glucose forms a pentaacetate with acetic anhydride, showing five –OH groups. Since no carbon carries two –OH groups (a gem-diol is unstable), the five –OH groups are on five different carbons (C-2 to C-6); C-1 is the –CHO carbon.

Explanation:

(a) HI/red P reduces glucose to n-hexane, proving an unbranched six-carbon chain.

(b) Acetylation gives pentaacetate → five –OH.

Two –OH on one carbon would be unstable, so they lie on different carbon atoms (C-2 to C-6).

Q.22

The half-life period of a radioactive element is 1·5 × 10^10 years. Calculate the time in which the activity of the element is reduced to 75% of its original value.

[Given : log 2 = 0·30, log 3 = 0·48, log 4 = 0·60]

Answer: t = 6·0 × 10^9 years

Explanation:

Radioactive decay is first order: k = 0·693/t½ and t = (2·303/k) log(A_0/A).

Equivalently t = t½ × log(A_0/A) / log 2.

A = 75% of A_0 → A_0/A = 4/3; log(4/3) = log 4 − log 3 = 0·60 − 0·48 = 0·12.

t = 1·5 × 10^{10} × 0·12/0·30 = 1·5 × 10^{10} × 0·4 = 6·0 × 10^9 years.

Q.23

State Kohlrausch's law of independent migration of ions. With the help of a curve, explain why it is not easy to determine Lambda_m^o for weak electrolytes by extrapolating the concentration − molar conductivity curve, as it is for strong electrolytes.

Answer: Kohlrausch's law: The molar conductivity of an electrolyte at infinite dilution (Lambda_m^o) is the sum of the contributions of the molar conductivities of the individual ions: Lambda_m^o = nu+ × lambda+^o + nu- × lambda-^o, where nu+ and nu- are the number of cations and anions per formula unit.

For strong electrolytes, the plot of Lambda_m vs. sqrt(c) is nearly linear at low concentrations and can be extrapolated to c = 0 to get Lambda_m^o. For weak electrolytes (e.g., acetic acid), the curve is not linear — at low concentrations Lambda_m rises sharply (because weak electrolytes dissociate more as dilution increases) and the curve does not approach Lambda_m^o asymptotically in a predictable way. Extrapolation to c = 0 is therefore not reliable. Lambda_m^o for

weak electrolytes is instead calculated using Kohlrausch's law from the Lambda_m^o values of constituent ions obtained from strong electrolytes.

Explanation:

Kohlrausch's law allows Lambda_m^o of a weak electrolyte (e.g., CH3COOH) to be calculated as: Lambda_m^o(CH3COOH) = Lambda_m^o(CH3COONa) + Lambda_m^o(HCl) - Lambda_m^o(NaCl).

The sharp non-linear rise of Lambda_m at low c for weak electrolytes makes graphical extrapolation impossible.

Q.24

An antifreeze solution is prepared by dissolving 31 g of ethylene glycol (Molar mass = 62 g mol^-1) in 600 g of water. Calculate the freezing point of the solution.

(Kf for water = 1·86 K kg mol^-1)

Answer: Freezing point = -1·55°C (i.e., depression = 1·55 K, so freezing point = 0 - 1·55 = -1·55°C)

Explanation:

Moles of ethylene glycol = 31/62 = 0·5 mol.

Mass of solvent = 600 g = 0·600 kg.

Molality (m) = 0·5 / 0·600 = 0·833 mol kg^-1.

Delta Tf = Kf × m = 1·86 × 0·833 = 1·55 K.

Freezing point = 0 - 1·55 = -1·55°C.

Q.25

(a) Answer the following questions about the complexes [NiCl4]^2- and [Ni(CN)4]^2- :

(i) Write the hybridization involved in each case.

(ii) Which of them is the inner orbital complex and which one is the outer orbital complex ?

(iii) Compare their magnetic behaviour.

[Atomic number : Ni = 28]

Answer: (i) [NiCl4]^2-: sp3 hybridization (tetrahedral). [Ni(CN)4]^2-: dsp2 hybridization (square planar). (ii) [Ni(CN)4]^2- is the inner orbital complex (uses 3d orbital in hybridization — dsp2). [NiCl4]^2- is the outer orbital complex (uses 4s and 4p only — sp3). (iii) [NiCl4]^2-: Ni^2+ has configuration [Ar]3d^8. In sp3 (weak field Cl-), electrons are not forced to pair; 3d^8 has 2 unpaired electrons → paramagnetic (magnetic moment ≈ 2·83 BM). [Ni(CN)4]^2-: CN- is a strong field ligand; in dsp2 hybridization, 3d electrons pair up completely in the lower d orbitals; all electrons are paired → diamagnetic (magnetic moment = 0).

Explanation:

Ni^2+ = [Ar]3d^8 (2 unpaired e in free ion).

Cl- is a weak field ligand: no pairing, sp3, tetrahedral, paramagnetic.

CN- is a strong field ligand: forces pairing, one 3d orbital vacated, dsp2, square planar, diamagnetic.

OR

Q.25

(b)

(i) Name two coordination compounds which are important in biological systems.

(ii) What is meant by chelate effect ? Give an example.

(iii) Why are low spin tetrahedral complexes rarely formed ?

Answer: (i) Haemoglobin (iron-porphyrin complex) and Chlorophyll (magnesium-porphyrin complex). (ii) Chelate effect: The tendency of polydentate (chelating) ligands to form more stable complexes compared to analogous complexes with monodentate ligands, due to an increase in entropy (more particles released during complexation). Example: [Ni(en)3]^2+ is more stable than [Ni(NH3)6]^2+ even though en and NH3 have similar donor strength; en is bidentate and its coordination increases the number of free molecules in solution. (iii) In tetrahedral geometry the crystal field splitting (Delta_t) is small (= 4/9 × Delta_o). Since Delta_t is smaller than the pairing energy for most ligands, electrons remain unpaired (high spin). A low spin state would require a ligand with

an exceptionally large field strength which is rare in tetrahedral geometry.

Explanation:

The chelate effect arises from the favourable entropy change when a polydentate ligand replaces multiple monodentate ligands.

Tetrahedral complexes almost always form high-spin because Delta_t < P (pairing energy) for nearly all ligand combinations.

Q.26

Give reasons for the following :

(a) Although chlorine is an electron-withdrawing group, yet it is ortho-, para-directing in electrophilic aromatic substitution reactions.

(b) Aryl halides cannot be prepared by reacting phenol with concentrated halogen acids or phosphorus halides.

(c) Chloroform is stored in closed dark coloured bottles.

Answer: (a) Chlorine has two opposing effects: it withdraws electrons by induction (-I effect) making the ring less reactive, but it donates electrons by resonance (+M effect) through lone pairs on Cl into the ring, specifically at ortho and para positions. The +M effect dominates in directing the incoming electrophile to ortho/para positions, so Cl is an ortho–para director despite being deactivating overall. (b) The C–O bond in phenol has partial double bond character due to resonance between the ring and the oxygen lone pairs (C–O bond is stronger/shorter than in aliphatic alcohols). This makes the C–O bond harder to cleave, so phenol does not react with HX or PX3/PX5 to give aryl halides. (c) Chloroform (CHCl3) oxidises slowly in air and light to form phosgene (COCl2), a toxic gas: 2CHCl3 + O2 → 2COCl2 + 2HCl. Storage in closed dark bottles prevents exposure to air and light, preventing this oxidation.

Explanation:

These are standard Class 12 reasoning questions on haloalkanes/haloarenes.

Chlorine's dual behaviour (induction vs.

resonance) explains both deactivation and ortho-para direction.

Q.27

How will you obtain the following from benzenediazonium chloride ? Give chemical equations involved :

(a) Chlorobenzene

(b) Benzene

(c) Benzonitrile

Answer: (a) Chlorobenzene — Sandmeyer reaction: C6H5N2+Cl- + CuCl → C6H5Cl + N2 + CuCl (warm with CuCl/HCl). Equation: C6H5N2+Cl- --Cu2Cl2/HCl--> C6H5Cl + N2

(b) Benzene — Reduction with hypophosphorous acid (H3PO2): C6H5N2+Cl- + H3PO2 + H2O → C6H6 + N2 + H3PO3 + HCl

(c) Benzonitrile — Sandmeyer reaction with CuCN: C6H5N2+Cl- + CuCN → C6H5CN + N2 + CuCl

Explanation:

(a) Sandmeyer reaction: diazonium salt + CuCl (or Cu2Cl2/HCl) → chlorobenzene.

(b) Replacement of diazonium group by H using H3PO2.

(c) Sandmeyer reaction with CuCN gives benzonitrile.

Q.28

An organic compound (A) with molecular formula C3H5N on reaction with C6H5MgBr followed by hydrolysis, gives a compound (B). Compound (B) forms an orange-red precipitate with 2,4-DNP reagent and does not give iodoform test. It neither reduces Tollens' or Fehling's reagent nor does it decolourise bromine water. On drastic oxidation with chromic acid it gives a carboxylic acid (C) having molecular formula C7H6O2. Identify the compounds (A), (B) and (C). Write the reactions of compound (A) with C6H5MgBr followed by hydrolysis to give compound (B).

Answer: (A) = propanenitrile, CH_3CH_2CN (C_3H_5N); (B) = propiophenone (1-phenylpropan-1-one), $C_6H_5COCH_2CH_3$; (C) = benzoic acid, C_6H_5COOH ($C_7H_6O_2$).

Reactions: $CH_3CH_2CN + C_6H_5MgBr \rightarrow CH_3CH_2C(=NMgBr)C_6H_5$; $CH_3CH_2C(=NMgBr)C_6H_5 + H_2O\ (H_3O^+) \rightarrow C_6H_5COCH_2CH_3 + NH_3 + Mg(OH)Br$

Explanation:

C_3H_5N with a Grignard reagent followed by hydrolysis suggests a nitrile: CH_3CH_2CN gives the ketone $C_6H_5COCH_2CH_3$ (B).

B gives 2,4-DNP (C=O), no iodoform (no $CH_3CO–$), does not reduce Tollens'/Fehling's (not an aldehyde) and does not decolourise bromine water (no C=C).

Drastic oxidation with chromic acid cleaves the ethyl side chain to give benzoic acid ($C_7H_6O_2$).

Q.29(a)

(Case study — Biomolecules) Living systems are made up of various complex biomolecules like carbohydrates, proteins, nucleic acids, lipids, etc. Proteins and carbohydrates are essential constituents of our food. All proteins are polymers of alpha-amino acids. Proteins can be classified into two types on the basis of their molecular shape — Fibrous and Globular proteins. Vitamins are accessory food factors required in the diet. Nucleic acids are the polymers of nucleotides which in turn consist of a base, a pentose sugar and phosphate moiety.

(a) Write the name of basic building units of proteins and nucleic acids. How can you differentiate between Fibrous and Globular proteins on the basis of their structures ?

Answer: Basic building units: Proteins — alpha-amino acids. Nucleic acids — nucleotides.

Fibrous proteins: polypeptide chains run parallel and are held together by hydrogen bonds and disulfide bridges, forming long fibre-like structures. They are generally insoluble in water. Examples: keratin (hair, nails), myosin (muscles).

Globular proteins: polypeptide chains are folded around themselves to give a spherical (globular) shape. They are generally soluble in water and mobile in

nature. Examples: insulin, albumin, haemoglobin.

Explanation:

Fibrous proteins have structural roles (hair, nails, silk).

Globular proteins have dynamic roles (enzymes, hormones, transport).

The key structural distinction is the elongated fibrous arrangement vs. the compact spherical arrangement.

Q.29(b)

(Case study — Biomolecules)

(b)(i) What products would be formed when a nucleotide from DNA containing thymine is hydrolyzed ?

Answer: Hydrolysis of a thymine-containing nucleotide from DNA gives: (1) Thymine (the nitrogenous base), (2) Deoxyribose (2-deoxyribose, a pentose sugar), and (3) Phosphoric acid (H_3PO_4).

Explanation:

A nucleotide = base + pentose sugar + phosphate group.

In DNA, the sugar is deoxyribose.

Hydrolysis breaks the N-glycosidic bond (releasing base) and the phosphoester bond (releasing phosphate), giving three products: thymine, 2-deoxyribose, and phosphoric acid.

OR

Q.29(b)

(Case study — Biomolecules)

(b)(ii) Write one structural difference between DNA and RNA.

Answer: DNA contains deoxyribose sugar (2-deoxyribose) while RNA contains ribose sugar. (Alternatively: DNA contains thymine as one of its bases while RNA contains uracil instead of thymine. Or: DNA is usually double-stranded while RNA is usually single-stranded.)

Explanation:

The most fundamental structural difference at the nucleotide level: DNA has 2'-deoxyribose (no –OH at C-2'), RNA has ribose (–OH at C-2').

At the base level, thymine (DNA) vs.

uracil (RNA).

Q.29(c)

(Case study — Biomolecules)

(c) Give one example each of a fat-soluble vitamin and a water-soluble vitamin.

Answer: Fat-soluble vitamin: Vitamin A (or Vitamin D, E, K). Water-soluble vitamin: Vitamin C (ascorbic acid) (or Vitamin B complex).

Explanation:

Fat-soluble vitamins (A, D, E, K) are stored in body fat and liver.

Water-soluble vitamins (B group, C) are not stored and must be replenished through diet regularly.

Q.30(a)

(Case study — Alcohols, Ethers, Phenols) Alcohols have higher boiling points than other compounds, namely hydrocarbons, ethers and haloalkanes of comparable molecular masses. On oxidation, primary alcohols yield aldehydes with mild oxidizing agents and carboxylic acids with strong oxidizing agents. Secondary alcohols yield ketones on oxidation while tertiary alcohols are resistant to oxidation. In presence of NaOH, phenol generates phenoxide ion and undergoes Kolbe's reaction.

(a) Name the reagents used in the following reactions :

(i) Oxidation of a primary alcohol to aldehyde

(ii) Oxidation of a primary alcohol to carboxylic acid

Answer: (i) Pyridinium chlorochromate (PCC) / or acidified $K_2Cr_2O_7$ at low temperature / or MnO_2 (for allylic/benzylic alcohols). For controlled oxidation to

aldehyde: PCC (pyridinium chlorochromate) in CH_2Cl_2, or acidified $K_2Cr_2O_7$ with careful conditions.

(ii) Acidified $KMnO_4$ / or acidified $K_2Cr_2O_7$ / or Jones reagent (CrO_3 in H_2SO_4/H_2O). Strong oxidising agents such as acidified $KMnO_4$ oxidise primary alcohol all the way to carboxylic acid.

Explanation:

(i) Mild/controlled oxidation to stop at aldehyde stage: PCC is most selective.
Acidified $K_2Cr_2O_7$ can also be used carefully.
(ii) Strong oxidation to carboxylic acid: acidified $KMnO_4$ is the standard reagent.

Q.30(b)

(Case study — Alcohols, Ethers, Phenols)

(b) Write the reaction involved in Kolbe's reaction.

Answer: $C_6H_5OH + NaOH \rightarrow C_6H_5ONa + H_2O$; then $C_6H_5ONa + CO_2$ (high pressure, 400 K) $\rightarrow C_6H_4(OH)(COONa)$ [sodium salicylate]; acidification gives salicylic acid (2-hydroxybenzoic acid). Reaction: $C_6H_5ONa + CO_2 \rightarrow HOC_6H_4COONa$ (sodium salicylate).

Explanation:

Kolbe's reaction (Kolbe–Schmitt reaction): Sodium phenoxide (C_6H_5ONa) reacts with CO_2 under pressure (~5 atm) at about 400 K to give sodium salicylate, which on acidification yields salicylic acid (2-hydroxybenzoic acid).
The carboxylation occurs at the ortho position.

Q.30(c)

(Case study — Alcohols, Ethers, Phenols)

(c)(i) Why are tertiary alcohols resistant to oxidation ?

Answer: Tertiary alcohols have no hydrogen atom attached to the carbon bearing the –OH group (the alpha-carbon). Oxidation requires the removal of at least one hydrogen from the alpha-carbon (the carbon bonded to –OH). Since no such hydrogen is present in a tertiary alcohol, oxidation cannot proceed under normal

conditions, making tertiary alcohols resistant to oxidation.

Explanation:

The mechanism of oxidation of alcohols involves the abstraction of the alpha-H.

Primary (R–CH2OH) and secondary (R–CHOH–R') alcohols have alpha-H atoms available;

tertiary alcohols (R3COH) do not.

OR

Q.30(c)

(Case study — Alcohols, Ethers, Phenols)

(c)(ii) Write the products of the following reaction :

(CH3)3C − O − C2H5 + HI →

Answer: (CH3)3C–O–C2H5 + HI → (CH3)3CI + C2H5OH

Products: tert-butyl iodide [(CH3)3CI] and ethanol (C2H5OH).

Explanation:

Ethers react with HI via SN1 or SN2 mechanism.

When one group is tertiary, the reaction goes by SN1: the ether is protonated, then the tertiary carbocation [(CH3)3C+] forms and is attacked by I- to give tert-butyl iodide.

The other fragment is C2H5OH (ethanol).

So products are (CH3)3CI and C2H5OH.

Q.31(a)

(a)(i) Describe giving reason which one of the following pairs has the property indicated :

(I) Fe or Cu — higher melting point

(II) Ti3+ or Sc3+ — coloured in aqueous solution

(III) Cr or Zn — higher third ionisation enthalpy

(a)(ii) Write the ionic equations for the oxidizing action of MnO4- in acidic medium with :

(I) Fe2+ ion

(II) I- ion

Answer: (a)(i)(I) Fe has the higher melting point: it has more unpaired 3d electrons ($3d^6 4s^2$) available for metallic bonding than Cu ($3d^{10} 4s^1$).

(II) Ti^{3+} is coloured: it is $3d^1$, so d–d transitions are possible; Sc^{3+} is $3d^0$ and colourless.

(III) Zn has the higher third ionisation enthalpy: the third electron must be removed from the stable, completely filled $3d^{10}$ of Zn^{2+}, whereas Cr^{2+} ($3d^4$) goes to the stable $3d^3$ of Cr^{3+}.

(a)(ii)(I) $MnO_4^- + 8H^+ + 5Fe^{2+} \rightarrow Mn^{2+} + 5Fe^{3+} + 4H_2O$

(II) $2MnO_4^- + 16H^+ + 10I^- \rightarrow 2Mn^{2+} + 5I_2 + 8H_2O$

Explanation:

(i)(III) Zn^{2+} = $[Ar]3d^{10}$ is very stable, so removing a third electron needs a great deal of energy;

Cr^{2+} = $3d^4$ loses an electron to reach $3d^3$ more easily.

(ii) MnO_4^- is reduced to Mn^{2+} (gains $5e^-$) in acidic medium; $Fe^{2+} \rightarrow$ Fe^{3+} and $I^- \rightarrow$ I_2 supply the electrons (5 Fe^{2+} per MnO_4^-; 10 I^- per 2 MnO_4^-).

Q.31(b)

(b)(i) A black-brown coloured solid (A) when fused with KOH in the presence of air, produces a dark green coloured compound (B) which on electrolytic oxidation in alkaline medium gives a dark purple coloured compound (C). Identify (A), (B) and (C). Write the reactions involved.

(b)(ii) What happens when an acidic solution of the green compound (B) is allowed to stand for some time ? Also write the equation involved. What is this type of reaction called ?

Answer: (b)(i) (A) = MnO_2 (black-brown); (B) = K_2MnO_4 (dark green); (C) = $KMnO_4$ (dark purple).

$2MnO_2 + 4KOH + O_2 \rightarrow 2K_2MnO_4 + 2H_2O$ (fusion in air)

$MnO_4^{2-} \rightarrow MnO_4^- + e^-$ (electrolytic oxidation in alkaline medium)

(b)(ii) In acidic solution the green manganate ion disproportionates: $3MnO_4^{2-} + 4H^+ \rightarrow 2MnO_4^- + MnO_2 + 2H_2O$ (green → purple + brown solid). This type of reaction is called disproportionation.

Explanation:

MnO_2 (Mn +4) fused with KOH/air gives K_2MnO_4 (Mn +6), which is oxidised electrolytically to $KMnO_4$ (Mn +7).

In acid, MnO_4^{2-} (Mn +6) simultaneously goes to MnO_4^- (+7) and MnO_2 (+4): disproportionation.

Q.32(a)

(a)(i) Write the product(s) when :

(I) One mol of ethanal is treated with 1 mol of CH3OH in the presence of dry HCl gas.

(II) Benzaldehyde is treated with conc. NaOH.

(III) Ethanoic acid is heated in the presence of P2O5.

(a)(ii) Write a simple chemical test to distinguish between Ethanal and Propanal.

(a)(iii) Write the name of the reagent to transform Allyl alcohol to Propenal.

Answer: (i) (I) $CH_3CH(OH)OCH_3$ (hemiacetal); (II) $C_6H_5CH_2OH + C_6H_5COONa$ (Cannizzaro); (III) $(CH_3CO)_2O$ (ethanoic anhydride). (ii) Iodoform test: ethanal gives yellow CHI_3 ppt with $NaOH/I_2$, propanal does not. (iii) PCC (pyridinium chlorochromate)

Explanation:

(i)(I) One equivalent of alcohol adds to the aldehyde in dry HCl to give the hemiacetal: $CH_3CHO + CH_3OH \rightarrow$

$CH_3CH(OH)OCH_3$ (with excess CH_3OH it goes on to the acetal $CH_3CH(OCH_3)_2$).

(II) Benzaldehyde has no α-H, so conc.

NaOH brings about the Cannizzaro reaction: $2C_6H_5CHO + NaOH \rightarrow C_6H_5CH_2OH +$

C_6H_5COONa.

(III) P_2O_5 dehydrates the acid: $2CH_3COOH \rightarrow (CH_3CO)_2O + H_2O$.

(ii) Ethanal contains $CH_3CO–$ and gives a yellow precipitate of iodoform (CHI_3) on warming with NaOH and I_2;

propanal does not.

(iii) PCC (pyridinium chlorochromate) oxidises the primary allylic alcohol $CH_2=CH–CH_2OH$ to $CH_2=CH–CHO$ without attacking the C=C (activated MnO_2 also works).

Q.32(b)

(b)(i) Draw the structure of the semicarbazone of acetone.

(b)(ii) Why are α-hydrogen atoms of aldehydes and ketones acidic in nature ?

(b)(iii) Arrange the following compounds in increasing order of their reactivity towards HCN :

CH_3COCH_3, CH_3CHO, $(CH_3)_3C–CO–CH_3$

(b)(iv) Write the reaction involved in Etard reaction.

(b)(v) Write the product when cyclohexanecarbaldehyde (a cyclohexane ring bearing –CHO) reacts with Zn(Hg)/conc. HCl.

Answer: (i) Semicarbazone of acetone: CH3–C(=N–NH–CO–NH2)–CH3. Structure: acetone reacts with semicarbazide (H2N–NH–CO–NH2) to form CH3–C(=N–NH–CONH2)–CH3.

(ii) Alpha-hydrogen atoms are acidic because the adjacent carbonyl group (C=O) is strongly electron-withdrawing. Removal of the alpha-H gives a carbanion that is stabilised by resonance with the C=O group, forming a stable enolate ion. This resonance stabilisation of the conjugate base makes the alpha-H acidic (pKa ~ 20).

(iii) Increasing order of reactivity towards HCN (nucleophilic addition): (CH3)3C–CO–CH3 < CH3COCH3 < CH3CHO. Reactivity increases as steric

hindrance decreases and electrophilicity of the carbonyl carbon increases. Aldehyde (CH3CHO) is most reactive; the bulky tert-butyl ketone [(CH3)3C–CO–CH3] is least reactive.

(iv) Etard reaction: Chromyl chloride (CrO2Cl2) oxidises the methyl group of toluene selectively to the aldehyde stage via a chromyl complex. C6H5CH3 + 2CrO2Cl2 → [C6H5CH(CrO2Cl)2·OCrOCl2] complex –H2O→ C6H5CHO + Cr2O3 + 2HCl.

(v) The substrate shown in the image is cyclohexanecarbaldehyde (a cyclohexane ring with a –CHO substituent). Clemmensen reduction (Zn(Hg)/conc. HCl) reduces the aldehyde (–CHO) to –CH3: cyclohexane–CHO → methylcyclohexane (cyclohexylmethane, C6H11–CH3). Product = methylcyclohexane.

Explanation:

(i) Acetone + semicarbazide → $(CH_3)_2C=N–NH–CO–NH_2$.

(ii) The carbonyl group is strongly electron-withdrawing, and the enolate formed on losing α-H is resonance-stabilised.

(iii) Less steric hindrance and fewer electron-donating alkyl groups increase reactivity: $(CH_3)_3C–CO–CH_3 < CH_3COCH_3 < CH_3CHO$.

(iv) Etard: toluene + CrO_2Cl_2 (in CS_2) gives a chromium complex, which on hydrolysis (H_3O^+) gives benzaldehyde.

(v) Clemmensen reduction converts –CHO to $–CH_3$: cyclohexanecarbaldehyde → methylcyclohexane.

Q.33(a)

(a)(i) Calculate the electrode potential of a half-cell for zinc electrode dipping in 0·01 M ZnSO4 solution at 25°C.

Given : E°(Zn2+/Zn) = −0·76 V

[log 10 = 1]

(a)(ii) Write anode, cathode and overall reaction involved in dry cell.

(a)(iii) Equilibrium constant (Kc) is related to E°cell, but not to Ecell. Why ?

Answer: (i) Nernst equation for Zn2+/Zn half-cell:

E = E° - (0·0591/n) × log(1/[Zn2+]) = E° - (0·0591/2) × log(1/0·01)

[Zn2+] = 0·01 M; n = 2; log(1/0·01) = log(100) = 2.

E = -0·76 - (0·0591/2) × 2 = -0·76 - 0·0591 = -0·8191 V ≈ -0·82 V.

(ii) Dry cell reactions:

Anode (negative): Zn → Zn2+ + 2e- (Zn oxidised)

Cathode (positive): MnO2 + NH4+ + e- → MnO(OH) + NH3

Overall: Zn + 2MnO2 + 2NH4Cl → ZnCl2·2NH3 + 2MnO(OH)

(iii) Kc is related to E°cell (standard EMF) because E°cell is measured at standard conditions (all concentrations = 1 M, all pressures = 1 atm, 25°C) — conditions at which a unique equilibrium constant is defined. The relationship is: Delta_G° = -nFE°cell = -RT ln Kc. Ecell (non-standard) varies with concentration (as given by the Nernst equation) and is not a fixed value; it depends on the instantaneous concentrations which change as the reaction proceeds, so no unique Kc can be derived from it.

Explanation:

(i) $Zn^{2+} + 2e^- \rightarrow$ Zn; $E = E^\circ - (0.059/2)\log(1/[Zn^{2+}]) = -0.76 - 0.0295 \times \log 100 = -0.76 - 0.059 = -0.819\ V \approx -0.82\ V$.

(ii) Dry cell: anode $Zn \rightarrow Zn^{2+} + 2e^-$; cathode $MnO_2 + NH_4^+ + e^- \rightarrow MnO(OH) + NH_3$; overall $Zn + 2MnO_2 + 2NH_4^+ \rightarrow Zn^{2+} + 2MnO(OH) + 2NH_3$.

(iii) $\Delta G^\circ = -nFE^\circ_{cell} = -RT \ln K_c$, so Kc is tied to E°cell (standard state); Ecell changes with concentration as the reaction proceeds and is zero at equilibrium, so it gives no fixed Kc.

Q.33(b)

(b)(i) The conductivity of 0·001 M solution of acetic acid is 3·905 × 10^-5 S cm^-1. Calculate its molar conductivity and degree of dissociation (alpha).
Given : lambda°(CH3COO-) = 40·9 S cm2 mol^-1
lambda°(H+) = 349·6 S cm2 mol^-1

(b)(ii) Give reasons for the following :
(I) Why does a mercury cell deliver a constant voltage for its entire life ?
(II) Why is it necessary to use salt bridge in a galvanic cell ?

Answer: (i) Molar conductivity Lambda_m = (kappa × 1000) / c [if c in mol/L and kappa in S/cm]
Lambda_m = (3·905 × 10^-5 × 1000) / 0·001 = (3·905 × 10^-2) / 0·001 = 39·05 S cm2 mol^-1.
Lambda_m^o(CH3COOH) = lambda°(H+) + lambda°(CH3COO-) = 349·6 + 40·9 = 390·5 S cm2 mol^-1.
alpha = Lambda_m / Lambda_m^o = 39·05 / 390·5 = 0·10 (i.e., 10%).

(ii):
(I) In a mercury cell, the overall reaction is: Zn(Hg) + HgO → ZnO + Hg. The electrolyte used is KOH/ZnO paste — an alkaline medium in which the concentrations of reactants and products remain essentially constant throughout the cell's life (ZnO is insoluble and does not change the electrolyte concentration). Since Ecell depends on concentration (Nernst equation), a constant concentration gives a constant voltage throughout the cell's life.
(II) A salt bridge is necessary in a galvanic cell to: (a) complete the electrical circuit by allowing ions to migrate between the two half-cells, maintaining electrical neutrality; and (b) prevent mixing of the two electrolyte solutions (which could cause a chemical reaction between them and reduce the EMF). Without a salt bridge, charge would build up in each half-cell, stopping the cell reaction.

Explanation:

(i) Lambda_m = kappa × 1000/c = 3·905×10^-5 × 1000/0·001 = 39·05 S cm2 mol^-1.

Lambda_m^o = 390·5 S cm2 mol^-1.

alpha = 39·05/390·5 = 0·10.

(ii)(I) Constant concentration of reactants/products in mercury cell →

constant Nernst equation →

constant EMF.

(ii)(II) Salt bridge maintains electrical neutrality in both half-cells and prevents direct mixing.