ICS Boards 2023

Chemistry

SECTION – A

Question 1

(A) Fill in the blanks by choosing the appropriate word(s) from those given in the brackets: [stable, low, aldehyde, unstable, 6, 4, ethane, Clemmensen's, 2, 3, carboxylic acid, high, propane, Rosenmund's]

(i) The primary alcohols are easily oxidized first into ______ and then into ________.

Answer: The primary alcohols are easily oxidized first into **aldehyde** and then into **carboxylic acid.**

(ii) The intermediate activated complex in a chemical reaction is highly _______ due to _______ energy.

Answer: The intermediate activated complex in a chemical reaction is highly **unstable** due to **high** energy.

(iii) The coordination number and oxidation state of the complex $K_4[Fe(CN)_6]$ are ______ and ______ respectively.

Answer: The coordination number and oxidation state of the complex $K_4[Fe(CN)_6]$ are **6** and **2** respectively.

(iv) Propanone on reaction with zinc-amalgam in presence of conc. HCl gives _______ and the reaction is known as ________ reduction.

Answer: Propanone on reaction with zinc amalgam in presence of conc. HCl gives **propane** and the reaction is known as **Clemmensen's** reduction.

(B) Select and write the correct alternative from the choices given below:

(i) The reaction of a primary amine with chloroform and ethanolic KOH is called:

(a) Carbylamine reaction
(b) Kolbe's reaction
(c) Reimer-Tiemann reaction
(d) Wurtz-Fitting reaction

Answer (a)

Aliphatic or aromatic primary amines on heating with chloroform give foul smelling products called isocyanides or carbylamines and the reaction is known as carbylamine reaction.

$$\underset{\text{Ethyl amine}}{CH_3CH_2NH_3} + CHCl_3 + \underset{\text{Alcoholic}}{3KOH} \longrightarrow \underset{\text{Ethyl isocyanide}}{CH_3CH_2NC} + 3KCl + 3H_2$$

(ii) Which one of the following statements is TRUE for the galvanic cell?

(a) Electrons flow from copper electrode to zinc electrode.
(b) Current flows from zinc electrode to copper electrode
(c) Cations move towards copper electrode.
(d) Cations move towards zinc electrode.

Answer (c)

In Galvanic cell, following reaction occurs:

$Zn + Cu^{2+} \rightarrow Zn^{2+} + Cu$

At anode: $Zn \rightarrow Zn^{2+} + 2e^-$

At cathode: $Cu^{2+} + 2e^- \rightarrow Cu$

In this cell, electrons flow from anode to cathode i.e. zinc electrode to copper electrode whereas current flows from copper electrode to zinc electrode in an external circuit. And cations i.e., Cu^{2+} ions move towards the copper electrode.

(iii) Which one of the following compounds is diamagnetic and colourless?

(a) $K_2Cr_2O_7$
(b) $ZnSO_4$
(c) $KMnO_4$
(d) $Cr_2(SO_4)_3$

Answer (b)

$ZnsO_4$ is a diamagnetic and colourless compound, because here Zn is in $+2$ oxidation state i.e., its electronic configuration will be: $[Ar]3d^{10}$. Thus, Zn^{2+} has no unpaired electrons and it is colourless.

(iv) For a first order reaction, the half-life period $(t_{1/2})$ is:

(a) Proportional to the initial concentration.
(b) Inversely proportional to the initial concentration.
(c) Proportional to the square root of the initial concentration.

Independent of the initial concentration.

Answer (d)

For a first order reaction, half-life is independent of the initial concentration of the reactant.

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

Hence, option (D) is the correct answer.

(C) Match the following:

(i)	Phenol	(a)	Hexane + heptane
(ii)	EDTA	(b)	Globular protein
(iii)	Ideal solution	(c)	Azo dye
(iv)	Insulin	(d)	Hexadentate ligand

Answer

(i) Phenol → (c) Azo dye
(ii) EDTA → (d) Hexadentate ligand
(iii) Ideal solution → (a) hexane + heptane
(iv) Insulin → (b) Globular protein

(D)

(i) **Assertion:** If a solution contains both H^+ and Na^+ ions, the H^+ ions are reduced first at cathode.
Reason: Cations with higher E^0 value are reduced first at cathode.

(a) Both Assertion and Reason are true, and Reason is the correct explanation for Assertion.
(b) Both Assertion and Reason are true, but Reason is not the correct explanation for Assertion.
(c) Assertion is true but Reason is false.
(d) Assertion is false but Reason is true.

Answer (a)

Reactions at cathode:

$H^+ + e^- \rightarrow \frac{1}{2}H_2; E^0 = 0.0\ V$

$Na^+ + e^- \rightarrow Na;\ E^0 = -2.71\ V$

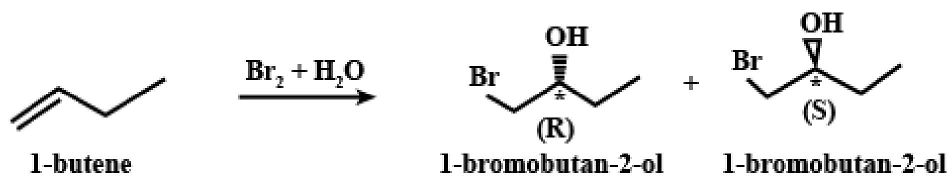
The cations having higher positive reduction potential will be reduced first at the cathode, that's why H^+ reduced first at the cathode.

(ii) **Assertion:** Addition of bromine water to 1-butene gives two optical isomers.
Reason: The product formed contains two asymmetric carbon atoms.

(a) Both Assertion and Reason are true, and Reason is the correct explanation for Assertion.
(b) Both Assertion and Reason are true, but Reason is not correct explanation for Assertion.
(c) Assertion is true but Reason is false.
(d) Assertion is false but Reason is true.

Answer (c)

Addition of bromine water to 1-butene gives two optical isomers as the product contains only one asymmetric carbon.



Hence, the assertion is true, but reason is false.

SECTION – B

Question 2

Calculate the mass of ascorbic acid (molecular mass = 176 g/mol) that should be dissolved in 155 g of acetic acid to cause a depression of freezing point by 1.15 K. Assume that ascorbic acid does not dissociate or associate in the solution.
(K_f for acetic acid =3.9 $K\ kg/mol$)

Answer: Depression in freezing point $= 1.15\ K$

As we know, $\Delta T_f = iK_f m$

$\Rightarrow \Delta T_f = 1 \times 3.9 \times \frac{x}{176 \times 0.155}$

$\Rightarrow \frac{1.15 \times 176 \times 0.155}{3.9} = x$

i.e. $x = 8.044\ g$

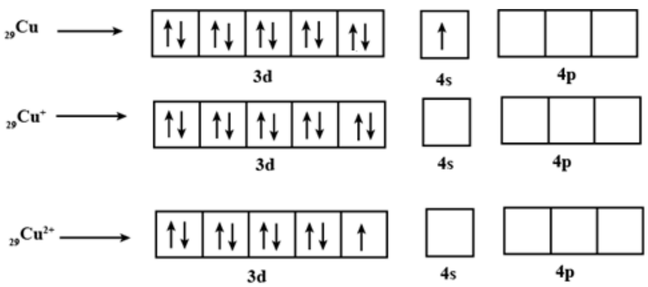
Thus, mass of ascorbic acid will be $8.044\ g$.

Question 3

Given a reason for the following:

(i) Cu^{2+} salts are paramagnetic while Cu^{+} salts are diamagnetic.

Answer:



Cu^{2+} has one unpaired electron. Therefore, it is paramagnetic. Cu^{+} has no unpaired electrons. Therefore, it is diamagnetic.

(ii) Mn^{2+} compounds are more stable than Fe^{2+} compounds.

Answer:

$Mn^{2+}: 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^5$

$Fe^{2+}: 1s^2, 2s^2, 2p^6, 3s^2, 3p^6, 3d^6$

Mn^{2+} compounds are more stable due to half-filled d-orbitals. Fe^{2+}compounds are comparatively less stable as they have six electrons in their 3d-orbitals. So, they tend to lose one electron (form Fe^{3+}) and get stable $3d^5$ configuration.

Question 4

Given chemical equations for each of the following:

(i) Ethyl chloride is treated with aqueous KOH solution.

Answer: Ethyl chloride undergoes a nucleophilic substitution reaction when treated with aqueous KOH solution & gives ethanol as a major product.

$$C_2H_5Cl + aq.KOH \rightarrow C_2H_5OH + KCl$$

(ii) Chlorobenzene is treated with ammonia at 573 K and high pressure.

Answer**:** Chlorobenzene on reaction with ammonia at 573 K and high pressure gives aniline as a major product.

$$C_6H_5Cl + NH_3 \rightarrow C_6H_5NH_2 + HCl$$

Question 5

State one reason for each of the following:

(i) Alkylamine is soluble in water whereas arylamine is insoluble in water.

Answer: Lower aliphatic alkylamine is soluble in water owing to their potential to form intermolecular hydrogen bonds with water. On the other hand, arylamine does not undergo hydrogen bonding because of the presence of the benzene which is highly hydrophobic. Therefore, arylamine is insoluble in water.

(ii) Methylamine is a stronger base than methyl alcohol.

Answer: Methylamine is a stronger base than methyl alcohol. This is because nitrogen in methylamine is less electronegative than oxygen in methanol. So, methylamine can easily donate a lone pair of electrons to a proton of an acid.

Question 6

Calculate the emf of the following cell at 298 K.

$Cu/Cu^{2+}_{(0.025\ M)}//Ag^{+}_{(0.005M)}/Ag$

Given $E^0_{Cu^{2+}/Cu} = 0.34V, E^0_{Ag^+/Ag} = 0.80\ V,$

1 Faraday- $96500\ C\ mol^{-1}$

Answer:

$$Cu/Cu^{2+}//Ag^+/Ag; Reaction: Cu + 2Ag^+ \rightarrow 2Ag + Cu^{2+}$$

$$E^0_{Cu^{2+}/Cu} = 0.34V$$

$$E^0_{Ag^+/Ag} = 0.80V$$

According to Nernst equation:

$$E_{cell} = E^0_{cell} - \frac{0.0591}{2} log\ \frac{[Cu^{2+}]}{[Ag^+]^2}$$

$$\Rightarrow E_{cell} = (0.80 - 0.34) - \frac{0.0591}{2} log\ \frac{0.025}{(0.005)^2}$$

$$\Rightarrow E_{cell} = 0.46 - \left(\frac{0.0591}{2} \times 3\right)$$

$$\Rightarrow E_{cell} = 0.371\ V$$

Question 7

Complete and balance the following chemical equations:

(i) $KMnO_4 + H_2SO_4 + KI \rightarrow$ _____ + _______ + _______ + _______

(ii) $K_2Cr_2O_7 + H_2SO_4 + H_2S \rightarrow$ _______ + _______ + _______ + ________

Answer:

(i) $2KMnO_4 + 8H_2SO_4 + 10KI \rightarrow 2MnSO_4 + 6K_2SO_4 + 5I_2 + 8H_2O$

(ii) $K_2Cr_2O_7 + 4H_2SO_4 + 3H_2S \rightarrow K_2SO_4 + Cr_2(SO_4)_3 + 3S + 7H_2O$

Question 8

(i) How will the following be obtained? (Give chemical equation)

a) Ethanol from Grignard's reagent.

b) Diethyl ether from sodium ethoxide.

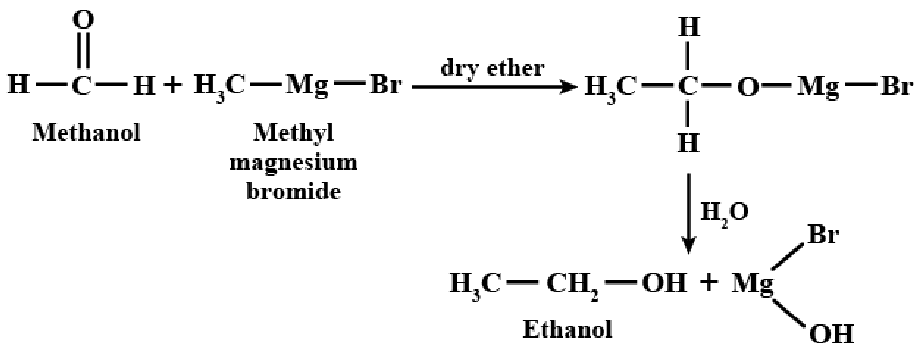
OR

(ii) An organic compound [A] C_2H_6O, on heating with conc. H_2SO_4 at 413 K gives a neutral compound [B] $C_4H_{10}O$. Compound [B] on treatment with PCl_5 gives a product, which on subsequent treatment with KCN yields compound [C] C_3H_5N. [A]. [B] [C] and [D] on hydrolysis gives an acid [D] $C_3H_6O_2$. Identify the compounds [A], [B], [C] and [D].

Answer:

i)

a)



b)

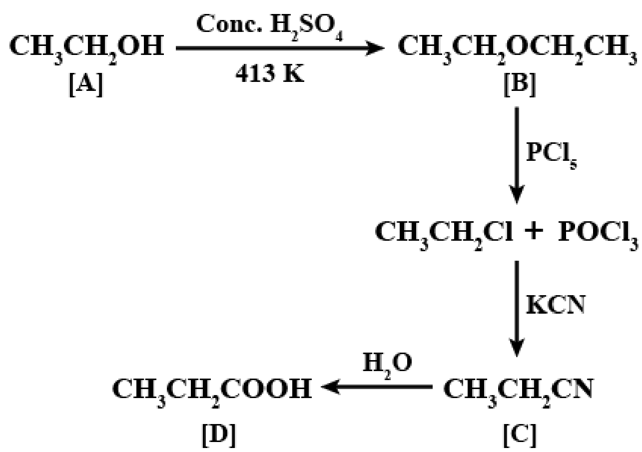
Preparation of Diethyl ether by Williamson's ether synthesis:

$$CH_3 - CH_2 - O^{-}Na^{+} + Br - CH_2 - CH_3 \xrightarrow{\Delta} CH_3 - CH_2 - O - CH_2 - CH_3 + NaBr$$

Sodium Ethoxide Ethyl Bromide Diethyl Ether

OR

(ii)



Question 9

The osmotic pressure of blood at $37°C$ is 8.21 atm. How much glucose in grams should be used per litre of aqueous solution for an intravenous injection so that it is isotonic with blood? (Molecular weight of glucose =180 g /mol)

Answer:

$\pi = 8.21\ atm, T = 273 + 37 = 310\ K$

Isotonic solutions are solution having equal osmotic pressure.

We know;

$\pi = iC\ R\ T$

$8.21 = \frac{m}{M \times 1} \times\ 0.082 \times\ 310$

$m = \frac{8.21 \times 180}{0.082 \times 310}$

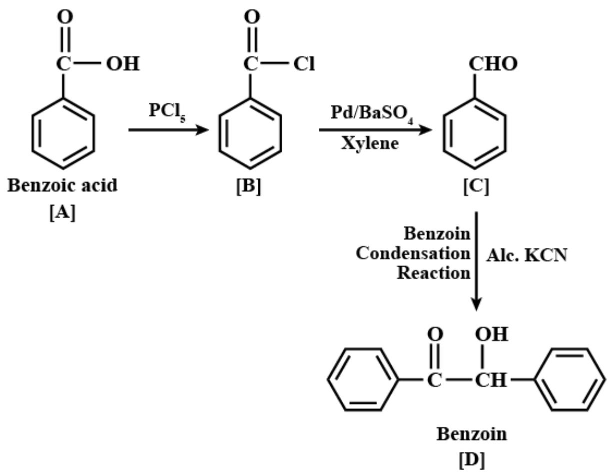
$m = 58.13\ g$

Question 10

An aromatic carboxylic acid [A] which readily sublimes on heating, produces compound [B] on treatment with PCl_5. Compound [B], when reduced in the presence of Pd catalyst over $BaSO_4$ poisoned by sulphur in xylene solution gives compound [C]. When compound [C] is condensed in the presence of alcoholic KCN, it gives compound [D]. (Molecular formula of compound [D] is $C_{14}H_{12}O_2$)

Identify the compounds [A], [B], [C] and [D].

Answer:



Question 11

State a reason for each of the following:

(i) $La(OH)_3$ is more basic than $Lu(OH)_3$.

(ii) Transition elements and their compounds act as catalyst.

Answer:

(i)
The basic strength of hydroxides is $La(OH)_3 > Lu(OH)_3$. Due to lanthanide contraction, size of M^{3+} ions decrease from La to Lu. Thus, there is an increase in the covalent character of $Lu - OH$ bond. (Small cation, more is covalent character - Fajan's rule).

(ii)
Transition metals and their compounds function as catalysts because of their ability to show variable oxidation state and to form complexes.

SECTION C - 21 MARKS

Question 12

20% of a first order reaction is completed in five minutes. How much time will the 60% reaction take to complete? Calculate the half-life period ($t_{1/2}$) for the above reaction.

Answer:

In 5 minutes, the reaction is 20% complete.
$[A]_0 = 100$ and $[A] = 100 - 20 = 80$
$k = \frac{2.303}{t} \log_{10} \frac{[A]_0}{[A]}$
$k = \frac{2.303}{5\ min} \log_{10} \frac{100}{80}$
$k = 0.0446\ min^{-1}$
Now, the reaction is 60% complete.
$[A]_0 = 100$ and $[A] = 100 - 60 = 40$

$$t = \frac{2.303}{k} \, log_{10} \frac{[A]_0}{[A]}$$
$$t = \frac{2.303}{0.0446 \, min^{-1}} \, log_{10} \frac{100}{40}$$
$$t = 20.5 \, min$$
$$And, t_{1/2} = \frac{0.693}{k} = \frac{0.693}{0.0446} = 15.538 \, min$$

Question 13

Write the balanced chemical equations for the following name reactions:

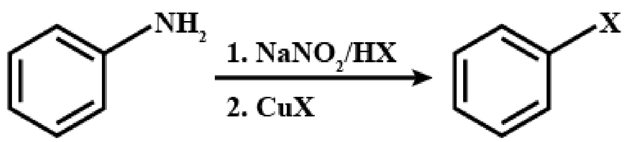
(i) Sandmeyer's reaction

(ii) Wurtz reaction

(iii) Finkelstein reaction

Answer:

(i) Sandmeyer reaction is a type of substitution reaction that is widely used in the production of aryl halides from aryl diazonium salts.



(ii) Wurtz's reaction is an organic chemical coupling reaction wherein sodium metal is reacted with two alkyl halides in the environment provided by a solution of dry ether in order to form a higher alkane.

$$2\, R - X + 2\, Na \xrightarrow{Dry\ Ether} R - R + 2\, NaX$$

(iii) In the Finkelstein reaction, alkyl iodides are prepared by the reaction of alkyl chlorides/bromides with NaI in dry acetone.

$$2\, R - X + 2\, NaI \xrightarrow{Acetone} R - I + 2\, NaX$$

(X = Cl, Br)

Question 14

(i) Give an example each of reducing sugar and non-reducing sugar.
(ii) What is denaturation of proteins?
(iii) Give an example each of water soluble vitamin and fat soluble vitamin.

Answer:

(i) Reducing sugars are sugars where the anomeric carbon has an -OH group attached that can reduce other compounds. Non-reducing sugars do not have an -OH group attached to the anomeric carbon so they cannot reduce other compounds.
Reducing sugar: Maltose
Non-reducing sugar: Sucrose

(ii) When a protein in its native form, is subjected to physical change like change in temperature or chemical change like change in pH, the hydrogen bonds are disturbed. Due to this, globules unfold and the helix gets uncoiled and protein loses its biological activity. This is called **denaturation of protein.**

(iii) Water soluble vitamin: Vitamin C
Fat soluble vitamin: Vitamin A, D, E and K

Question 15

When 2g of benzoic acid is dissolved in 25 g of benzene, it shows depression in freezing point equal to 1.62 K. Molal depression constant (K_f) of benzene is $4.9\ K\ kg\ mol^{-1}$ and molecular weight of benzoic acid = 122 g/mol. What will be the percentage association of the benzoic acid?

(Benzoic acid forms dimer when dissolved in benzene)

Answer:

Given,
$W_B = 2\ g, K_f = 4.9\ K\ kg\ mol^{-1}$
$W_A = 25\ g, \Delta T_f = 1.62\ K$
$Now,$
$\Delta T_f = i \times K_f \times \frac{W_B}{M_B} \times \frac{1000}{W_A}$
$i = \frac{1.62 \times 25 \times 122}{4.9 \times 2 \times 1000} = 0.504$

As, i = 1 + (1/n -1) α (Here, n is 2, since benzoic acid undergo dimerization in benzene)
0.504 = 1 – 0.5α
α = 0.992 = 99.2%
∴ Degree of association of benzene = 99.2 %

Question 16

Account for the following:

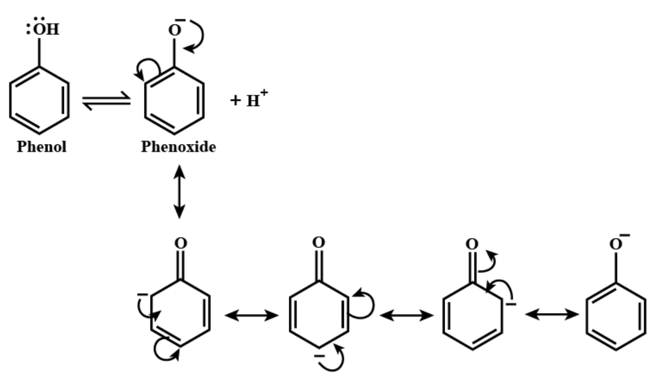
(i) Phenol is a stronger acid than aliphatic alcohols.

(ii) Ethanol gives iodoform reaction whereas methanol does not give iodoform reaction.

(iii) Ethers should not be distilled to dryness.

Answer:

(i) When a molecule of phenol loses a proton, it forms a phenoxide ion which is stabilized by resonance as the negative charge is delocalized over the aromatic nucleus. No such resonance is present when an alcohol loses a proton to form alkoxide ion. Hence, phenols are more acidic than alcohols.



(ii) Iodoform (in general haloform) reaction is given by ketones having methyl group attached to carbonyl carbon. Any compound that can be oxidized to a methyl ketone, also gives haloform reaction. Thus, ethyl alcohol $CH_3 - CH_2 - OH$ can be oxidized to acetaldehyde which contains methyl keto group. Hence, ethyl alcohol, can give haloform reaction. But methyl alcohol $CH_3 - OH$ does not form Iodoform as methyl alcohol cannot be oxidised to a compound containing methyl keto group as methyl alcohol has only one C-atom.

(iii) Heating ethers can also cause the formation of peroxides, especially towards the end of a distillation when a large amount of heat is being passed through a decreasing amount of liquid. For this reason, it is a standing rule in chemistry labs that ethers should never be distilled dryness.

Question 17

(i) Identify the compounds [A], [B] and [C] in the following reactions:

$$\text{(a). } CH_3COOH \xrightarrow[\Delta]{NH_3} [A] \xrightarrow{Br_2 + KOH} [B] \xrightarrow{CHCl_3 + NaOH\ (alc)} [C]$$

$$\text{(b). } CH_3Br \xrightarrow{KCN} [A] \xrightarrow{LiAlH_4} [B] \xrightarrow[273K]{HNO_2} [C]$$

OR

(ii) How will the following be converted? (Give chemical equation)

(a) Ethyl bromide to ethyl isocyanide.
(b) Aniline to benzene diazonium chloride.
(c) Benzene diazonium chloride to phenol.

Answer:

(i)

$$\text{(a). } CH_3COOH \xrightarrow[\Delta]{NH_3} \underset{[A]}{CH_3CONH_2} \xrightarrow{Br_2 + KOH} \underset{[B]}{CH_3\ddot{N}H_2} \xrightarrow[\text{Carbylamine Reaction}]{CHCl_3 + NaOH\ (alc)} \underset{[C]}{CH_3NC}$$

$$\text{(b). } CH_3Br \xrightarrow{KCN} \underset{[A]}{CH_3CN} \xrightarrow{LiAlH_4} \underset{[B]}{CH_3CH_2\ddot{N}H_2} \xrightarrow[273\ K]{HNO_2} \underset{\text{Unstable}}{[CH_3CH_2\overset{+}{N}_2]} \xrightarrow{H_2O} \underset{[C]}{CH_3CH_2OH} + N_2\uparrow$$

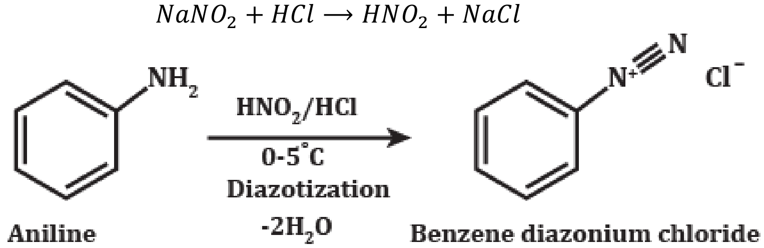
(ii)

(a) Ethyl bromide will react with alcoholic AgCN to form ethyl isocyanide.

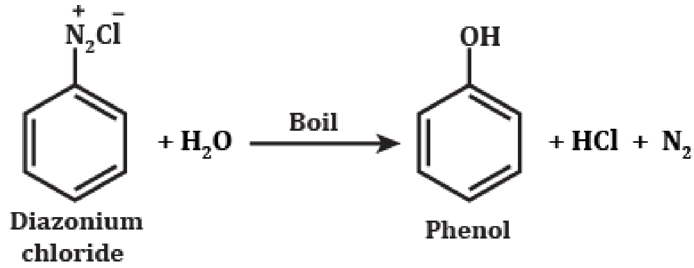
$$\underset{\text{Ethyl bromide}}{C_2H_5{-}Br} + \underset{\text{Alc.silver cyanide}}{AgCN} \longrightarrow \underset{\text{Ethyl isocyanide}}{C_2H_5{-}NC} + AgBr$$

(b) Diazotization of Aniline with $NaNO_2$/HCl gives Benzene diazonium chloride.

$$NaNO_2 + HCl \longrightarrow HNO_2 + NaCl$$



(c) The diazonium salt or diazonium chloride, on heating in the aqueous acidic medium, liberates nitrogen and forms phenol as a product.



Question 18

A first order reaction is 50% completed in 40 minutes at 300 K and in 20 minutes at 320 K. Calculate the activation energy of the reaction.

Answer:

When the first order reaction is 50% completed, the time is equal to half life period.
A first order reaction is 50% completed in 40 minutes at 300 K and in 20 minutes at 320 K.

$t_{1/2} = 40\ minutes$

$t'_{1/2} = 20\ minutes$

The Arrhenius equation and temperature variation is given by the expression:

$log\left(\frac{k'}{k}\right) = \frac{E_a}{2.303R}\left[\frac{T'-T}{TT'}\right]$

Also, $t_{1/2} = \frac{0.693}{k}\ \ or\ \ t_{1/2} \propto \frac{1}{k}$

Hence, $\log\left(\frac{t_{1/2}}{t'_{1/2}}\right) = \frac{E_a}{2.303R}\left[\frac{T'-T}{TT'}\right]$

$\log\left(\frac{t_{1/2}}{t'_{1/2}}\right) = \frac{E_a}{2.303\times8.314\ J/mol.K}\left[\frac{320K-300K}{300K\times320K}\right]$

$0.3010 = \frac{E_a}{19.147\ J/mol.K}[0.0002083/K]$

$E_a = 27668\ J/mol$

Question 19

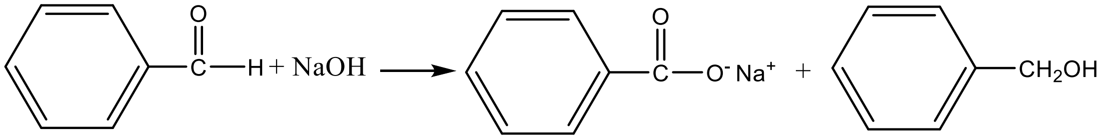
(i) Write the chemical equations to illustrate the following name reactions:
   (a) Cannizzaro's reaction
   (b) HVZ reaction
   (c) Aldol condensation

(ii) How will the following be converted? (Give chemical equation)
   (a) Acetaldehyde to acetone
   (b) Formaldehyde to urotropine

Answer:

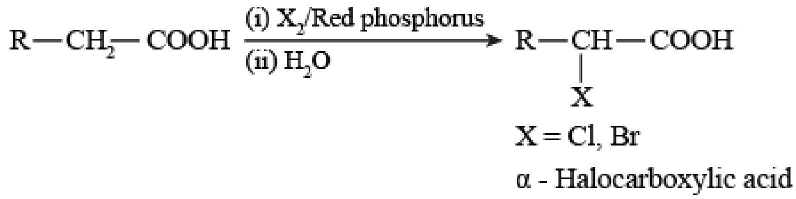
(a) Cannizzaro's reaction:

Aldehydes which do not contain alpha hydrogen when treated with a concentrated solution of an alkali undergoes self oxidation-reduction. As a result, one molecule of aldehyde is reduced to the corresponding alcohol while the other molecule is oxidized to the corresponding acid.



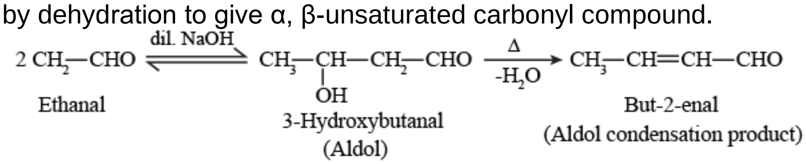
(b) HVZ reaction:

Carboxylic acids having an α-hydrogen are halogenated at the α-position on treatment with chlorine or bromine in the presence of small amount of red phosphorus to give α-halocarboxylic acids. The reaction is known as **Hell-Volhard-Zelinsky reaction.**



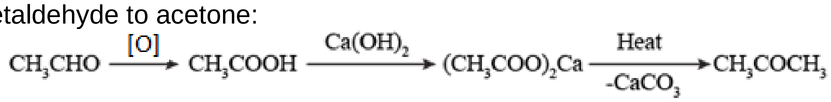
(c) Aldol condensation:

Aldehydes and ketones having at least one α-hydrogen undergo a reaction in the presence of dilute alkali as catalyst to form β-hydroxy aldehydes (aldol) or β-hydroxy ketones (ketol), respectively, and then followed by dehydration to give α, β-unsaturated carbonyl compound.



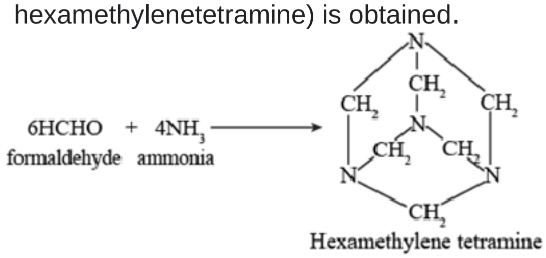
(ii)

(a) Acetaldehyde to acetone:



(b) Formaldehyde to urotropine:

When formaldehyde reacts with ammonia, a well known urinary antiseptic urotropine (also called hexamethylenetetramine) is obtained.



(Urotropine)

Question 20

(i) Name the type of isomerism exhibited by the following pairs of compounds.
- (a) $[Co(NH_3)_5(ONO)]Cl_2$ and $[Co(NH_3)_5(NO_2)]Cl_2$
- (b) $[Cr(H_2O)_5Cl]Cl_2$. H_2O and $[Cr(H_2O)_4Cl_2]Cl.2H_2O$
- (c) $[Pt(NH_3)_4Cl_2]Br_2$ and $[Pt(NH_3)_4Br_2]Cl_2$

(ii) Write the IUPAC names of the following complexes:
- (a) $[Co(NH_3)_4(H_2O)_2]Cl_3$
- (b) $K_2[Ni(CN)_4]$

Answer:

(i)
- (a) $[Co(NH_3)_5(ONO)]Cl_2$ and $[Co(NH_3)_5(NO_2)]Cl_2$: **Linkage Isomers**
- (b) $[Cr(H_2O)_5Cl]Cl_2.H_2O$ and $[Cr(H_2O)_4Cl_2]Cl.2H_2O$: **Hydrate Isomers**
- (c) $[Pt(NH_3)_4Cl_2]Br_2$ and $Pt(NH_3)_4Br_2]Cl_2$: **Ionization Isomers**

(ii) **IUPAC Name:**
- (a) $[Co(NH_3)_4(H_2O)_2]Cl_3$: Tetraamminediaquacobalt (III) chloride
- (b) $K_2[Ni(CN)_4]$: Potassium tetracyanonickelate (II)

Question 21

(i) The specific conductance of $2.5 \times 10^{-4} M$ formic acid is $5.25 \times 10^{-5} ohm^{-1} cm^{-1}$.
Calculate its molar conductivity and degree of dissociation.
Given $\lambda^0_{(H)^+} = 349.5\ ohm^{-1} cm^2 mol^{-1}$ and
$\lambda^0_{(Hcoo)^-} = 50.5\ ohm^{-1} cm^2 mol^{-1}$

(ii) Calculate the time taken to deposit 1.27 g of copper at cathode when a current of 2 amp. is passed through the solution of $CuSO_4$.
(Atomic weight of Cu = 63.5 g mol^{-1})

OR

(i) The resistance of a conductivity cell with 0.1M KCl solution is 200 ohm. When the same cell is filled with 0.02 M NaCl solution, the resistance is 1100 ohm. If the conductivity of 0.1 M KCl solution is 0.0129 $ohm^{1} cm^{-1}$. Calculate the cell constant and molar conductivity of 0.02 M NaCl solution.

(ii) The emf (E^0_{cell}) of the following reaction is 0.89 V.
$3Sn^{4+} + 2Cr \longrightarrow 3Sn^{2+} + 2Cr^{3+}$
Calculate the value of ΔG^0 for the reaction. Predict whether the above reaction will be spontaneous or not.

Answer:

i).
We know molar conductivity, $(\lambda_m) = \frac{1000 \times conductivity\ (k)}{concentration\ (c)}$
$\lambda_m = \frac{1000 \times 5.25 \times 10^{-5}}{2.5 \times 10^{-4}} = 210\ Scm^2 mol^{-1}$

$\lambda^0_{HCOOH} = \lambda^0_{H^+} + \lambda^0_{(HCOO^-)} = (349.5 + 50.5) = 400\ Scm^2 mol^{-1}$
$\therefore \alpha = \frac{\lambda_m}{\lambda_0} = \frac{210}{400} = 0.525$
$Or, \alpha = 52.5\%$

ii)
Given, mass of Cu deposited (z) = 1.27 g
Current, I = 2 A
Molar mass of Cu = 63.5 g mol^{-1}, 1F = 96500 C mol^{-1}
Reaction taking place: $Cu^{2+} + 2e^- \longrightarrow Cu$
By Faraday's first law,

$W = zQ (since\ Q = It)$
$W = zIt$ .....(1)

Where W, amount of substance deposited = 1.27g
I, current = 2 A and t = time
$Z = \frac{atomic\ weight}{no. of\ electrons\ required\ for\ reduction \times F} = \frac{63.5}{2 \times 96500}$

Substituting all values in equation (1)
$1.27 = \frac{63.5 \times 2 \times t}{2 \times 96500}$
$t = 1930\ s$

OR

i)
For 0.1 M KCl:
Resistance = 200 Ω

$k = 0.0129\ \Omega^{-1}cm^{-1}$

As, $k = Gx = \frac{x}{R} = \frac{x}{200}$
$\Rightarrow 0.0129 \times 200 = x = cell\ constant$
$\Rightarrow x = 2.58\ cm^{-1}$

For 0.02 M NaCl: R = 1100 Ω
And cell constant = x = 2.58 cm^{-1}
So, $k = \frac{x}{R} = \frac{2.58}{1100}\Omega^{-1}cm^{-1}$
And, $\lambda_m = \frac{k}{c} \times 1000 = \frac{2.58}{1100 \times 0.02} \times 1000 = 117.27\ \Omega^{-1}cm^2mol^{-1}$

ii)
$\Delta G^0 = -nFE^0$
Given, $E^0 = 0.89\ V$
$Sn^{4+} + 2e^- \longrightarrow Sn^{2+} (At\ cathode)$

$Cr \longrightarrow Cr^{3+} + 3e^-\ \ (At\ anode)$

$3Sn^{4+} + 2Cr \longrightarrow 3Sn^{2+} + 2Cr^{3+}$

Here n = 6
So,
$\Delta G^0 = -6 \times 96500 \times 0.89 = -515310\ J = -515.3\ kJ$

Hence, as the value of standard Gibbs free energy is negative i.e., reaction will be spontaneous in nature.