Maharashtra Board Class 12 Chemistry Question Paper 2026 with Solution

General Instructions

This question paper is divided into **four** sections.

1. **Section A** : Q.No. 1 contains **Ten** multiple choice type of questions carrying **One** mark each.
   Q.No. 2 contains **Eight** very short answer type of questions carrying **One** mark each.
2. **Section B** : Q.No. 3 to Q.No. 14 are **Twelve** short answer type of questions carrying **Two** marks each.(Attempt **any Eight**)
3. **Section C** : Q.No. 15 to Q.No. 26 are **Twelve** short answer type of questions carrying **Three** marks each.(Attempt **any Eight**)
4. **Section D** : Q.No. 27 to Q.No. 31 are **Fice** long answer type of questions carrying **Four** marks each.(Attempt **any Three**)
5. Use of log table is allowed. Use of calculator is not allowed.

Section A

1(i). The electrolyte used in $H_2 - O_2$ fuel cell is ______.

(A) aqueous KCl
(B) aqueous KOH
(C) aqueous HCl
(D) aqueous KNO_3

Correct Answer: (B) aqueous KOH

Solution:

Step 1: Understanding the Concept:
A fuel cell is an electrochemical cell that converts the chemical energy of a fuel (hydrogen) and an oxidizing agent (oxygen) into electricity through a pair of redox reactions.

Step 3: Detailed Explanation:
In a standard alkaline $H_2 - O_2$ fuel cell, the electrolyte used is a concentrated aqueous solution of potassium hydroxide (KOH) or sodium hydroxide ($NaOH$).
Aqueous KOH is preferred because of its high ionic conductivity.
The electrodes are made of porous carbon impregnated with catalysts like platinum.
The hydroxide ions (OH^-) migrate through the electrolyte to complete the circuit.

Step 4: Final Answer:
The correct electrolyte is aqueous KOH.

Quick Tip

Remember that $H_2 - O_2$ fuel cells are used in space programs (like Apollo) because they are highly efficient and produce pure water as a byproduct.

1(ii). The oxidation state of bromine in $HOBrO_2$ oxoacid is ______.

(A) +7
(B) +5
(C) +3
(D) +1

Correct Answer: (B) +5

Solution:

Step 1: Understanding the Concept:
The oxidation state is the hypothetical charge of an atom if all of its bonds to different atoms were fully ionic.
For a neutral molecule, the sum of oxidation states of all atoms must be zero.

Step 2: Key Formula or Approach:
The chemical formula $HOBrO_2$ is equivalent to $HBrO_3$ (bromic acid).
Let the oxidation state of Br be x.
Oxidation state of $H = +1$
Oxidation state of $O = -2$

Step 3: Detailed Explanation:
Sum of oxidation states = 0

$$(+1) + x + 3 \times (-2) = 0$$

$$1 + x - 6 = 0$$

$$x - 5 = 0$$

$$x = +5$$

Step 4: Final Answer:
The oxidation state of bromine in $HOBrO_2$ is +5.

Quick Tip

Always simplify the formula of oxoacids (e.g., $HOBrO_2$ to $HBrO_3$) to make oxidation state calculations faster.

1(iii). Acetonitrile may be prepared by heating the following reactants:

(A) Ethyl chloride with alcoholic KCN
(B) Ethyl chloride with alcoholic $AgCN$
(C) Methyl chloride with alcoholic KCN
(D) Methyl chloride with alcoholic $AgCN$

Correct Answer: (C) Methyl chloride with alcoholic KCN

Solution:

Step 1: Understanding the Concept:
Acetonitrile is CH_3CN (ethanenitrile).
Alkyl halides react with cyanide salts to form nitriles via nucleophilic substitution (S_N2).

Step 3: Detailed Explanation:
When Methyl chloride (CH_3Cl) reacts with alcoholic Potassium Cyanide (KCN), the CN^- ion (an ambident nucleophile) attacks the methyl group.
Since KCN is ionic, the nucleophilic attack occurs through the Carbon atom, leading to the formation of a nitrile.
Reaction:

$$CH_3Cl + KCN(alc.) \xrightarrow{\Delta} CH_3CN + KCl$$

If $AgCN$ were used, the attack would occur through Nitrogen, forming an isocyanide (CH_3NC).

Step 4: Final Answer:
Acetonitrile is prepared by heating Methyl chloride with alcoholic KCN.

> 💡 Quick Tip
>
> KCN gives Cyanide $(R-CN)$ while $AgCN$ gives Isocyanide $(R-NC)$ because KCN is ionic and $AgCN$ is predominantly covalent.

1(iv). The carbonated water is an example of ______.

(A) solid in liquid solution
(B) liquid in liquid solution
(C) gas in liquid solution
(D) liquid in gas solution

Correct Answer: (C) gas in liquid solution

Solution:

Step 1: Understanding the Concept:
A solution consists of a solute and a solvent. Carbonated water (soda water) is water in which carbon dioxide gas has been dissolved under pressure.

Step 3: Detailed Explanation:
In carbonated water, Carbon Dioxide (CO_2) is the solute and Water (H_2O) is the solvent. Since CO_2 is a gas and water is a liquid, it is classified as a "gas in liquid" type of solution.

Step 4: Final Answer:
Carbonated water is an example of a gas in liquid solution.

> 💡 Quick Tip
>
> Henry's Law explains the solubility of gases in liquids, stating that solubility is directly proportional to the partial pressure of the gas above the liquid.

1(v). The unit of rate constant is per second, the order of reaction is –

(A) Zero
(B) First
(C) Second
(D) Third

Correct Answer: (B) First

Solution:

Step 1: Understanding the Concept:
The unit of the rate constant (k) depends on the overall order of the reaction (n).

Step 2: Key Formula or Approach:
The general formula for units of rate constant is:

$$\text{Units of } k = (mol \cdot L^{-1})^{1-n} \cdot s^{-1}$$

where n is the order of reaction.

Step 3: Detailed Explanation:
Given unit of $k = s^{-1}$ (per second).
Matching this with the formula:

$$(mol \cdot L^{-1})^{1-n} \cdot s^{-1} = s^{-1}$$

This implies the concentration term must be raised to the power of zero.

$$1 - n = 0 \implies n = 1$$

Therefore, the reaction is of the first order.

Step 4: Final Answer:
The order of the reaction is First.

Quick Tip

For any n^{th} order reaction, just remember the term (Concentration)$^{1-n}$time^{-1}. For $n = 1$, concentration terms cancel out.

1(vi). A system releases 10 **kJ of heat and performs** 15 **kJ of work on the surrounding. Hence the change in internal energy is :**

(A) +5 kJ
(B) −5 kJ
(C) +25 kJ
(D) −25 kJ

Correct Answer: (D) −25 kJ

Solution:

Step 1: Understanding the Concept:
According to the first law of thermodynamics, energy can neither be created nor destroyed, only transformed. The change in internal energy (ΔU) of a system is the sum of heat exchanged (q) and work done (w).

Step 2: Key Formula or Approach:

$$\Delta U = q + w$$

Sign convention (IUPAC):
Heat released by system: q is negative.
Work done by system on surroundings: w is negative.

Step 3: Detailed Explanation:
Given:
Heat released, $q = -10$ kJ
Work done by system, $w = -15$ kJ
Substituting the values in the formula:

$$\Delta U = (-10 \text{ kJ}) + (-15 \text{ kJ})$$

$$\Delta U = -25 \text{ kJ}$$

Step 4: Final Answer:
The change in internal energy is -25 kJ.

> Quick Tip
>
> Always be careful with sign conventions. Heat 'released' and work 'performed by' the system always decrease the system's energy (negative sign).

1(vii). The co-ordination complex ions $[Co(NH_3)_5(NO_2)]^{2+}$ and $[Co(NH_3)_5(ONO)]^{2+}$ are ______ of each other.

(A) ionization isomers
(B) solvate isomers
(C) linkage isomers
(D) co-ordination isomers

Correct Answer: (C) linkage isomers

Solution:

Step 1: Understanding the Concept:
Linkage isomerism occurs in coordination compounds containing ambidentate ligands, which can bind to the central metal atom through more than one donor atom.

Step 3: Detailed Explanation:
In the given complexes, the ligand is the nitrite ion (NO_2^-).
In $[Co(NH_3)_5(NO_2)]^{2+}$, the nitrite ligand is linked to the Cobalt metal atom through the Nitrogen atom ($M - NO_2$).
In $[Co(NH_3)_5(ONO)]^{2+}$, the nitrite ligand is linked to the Cobalt metal atom through an Oxygen atom ($M - ONO$).
Because the same ligand is attached through different donor atoms, these are linkage isomers.

Step 4: Final Answer:
The complexes are linkage isomers.

> Quick Tip
>
> Look for ambidentate ligands like SCN^-/NCS^-, NO_2^-/ONO^-, or CN^-/NC^- to quickly identify linkage isomerism.

1(viii). The correct order for basic strength of amines and ammonia is ______.

(A) $NH_3 > R - NH_2 > R_2NH > R_3N$
(B) $NH_3 > R_3N > R_2NH > R - NH_2$
(C) $NH_3 < R - NH_2 > R_3N > R_2NH$
(D) $NH_3 < R - NH_2 < R_2NH > R_3N$

Correct Answer: (D) $NH_3 < R - NH_2 < R_2NH > R_3N$

Solution:

Step 1: Understanding the Concept:
Basicity of amines depends on the availability of the lone pair of electrons on the Nitrogen atom. It is influenced by inductive effects ($+I$), steric hindrance, and solvation effects in aqueous solution.

Step 3: Detailed Explanation:
In aqueous solution, the basic strength is determined by a combination of the electron-donating $+I$ effect of alkyl groups and the stabilization of the conjugate acid by hydration.
Alkyl groups (R) increase electron density on Nitrogen through the $+I$ effect, making alkyl

amines more basic than NH_3.
However, as the number of alkyl groups increases to three (R_3N), steric hindrance to hydration and crowding around Nitrogen reduces its basicity compared to secondary amines (R_2NH).
Thus, the general order in aqueous phase follows: $Secondary > Primary > Tertiary > Ammonia$, which matches option (D): $NH_3 < R - NH_2 < R_2NH > R_3N$.

Step 4: Final Answer:
The correct order is $NH_3 < R - NH_2 < R_2NH > R_3N$.

> Quick Tip
>
> In the gas phase, the order is strictly $3° > 2° > 1° > NH_3$ due to the $+I$ effect. In water, always remember that the $2°$ amine is the most basic.

1(ix). Amongst the following $3d$-series elements, having highest value of first ionization enthalpy is ______.

(A) Zn
(B) Cu
(C) Co
(D) Sc

Correct Answer: (A) Zn

Solution:

Step 1: Understanding the Concept:
First Ionization Enthalpy is the energy required to remove the first electron from an isolated gaseous atom. It generally increases across a period due to increasing nuclear charge and decreasing atomic size.

Step 3: Detailed Explanation:
Across the $3d$ series (Sc to Zn), the effective nuclear charge increases.
Zinc (Zn) is the last element of the $3d$ transition series.
The electronic configuration of Zn is $[Ar]3d^{10}4s^2$.
Both the $3d$ and $4s$ subshells are completely filled, providing extra stability.
Removing an electron from the stable, fully-filled $4s^2$ configuration of Zn requires significantly more energy compared to other elements in the series.

Step 4: Final Answer:
Zinc (Zn) has the highest first ionization enthalpy among the given elements.

Quick Tip

Ionization enthalpy generally peaks at elements with fully filled ($d^{10}s^2$) or half-filled (d^5s^2) subshells within a series.

1(x). The pOH of 0.01 M HCl solution is ______.

(A) 1
(B) 2
(C) 11
(D) 12

Correct Answer: (D) 12

Solution:

Step 1: Understanding the Concept:
HCl is a strong acid that dissociates completely in water. The concentration of H^+ ions is equal to the molarity of the acid.

Step 2: Key Formula or Approach:

$$pH = -\log[H^+]$$

$$pH + pOH = 14 \text{ (at 298 K)}$$

Step 3: Detailed Explanation:
Given: $[HCl] = 0.01 \text{ M} = 10^{-2} \text{ M}$
Since it's a strong acid, $[H^+] = 10^{-2}$ M
Calculate pH:

$$pH = -\log(10^{-2}) = 2$$

Calculate pOH:

$$pOH = 14 - pH$$

$$pOH = 14 - 2 = 12$$

Step 4: Final Answer:
The pOH of the solution is 12.

> 💡 Quick Tip
>
> Always check if the question asks for pH or pOH. For acidic solutions, $pH < 7$ and $pOH > 7$.

2(i). Write the name of product obtained, when selenium is treated with magnesium metal.

Correct Answer: Magnesium selenide

Solution:

Step 1: Understanding the Concept:
Magnesium (Group 2) is a highly reactive metal, and Selenium (Group 16) is a non-metal. Metals react with chalcogens to form binary compounds called selenides, oxides, sulfides, etc.

Step 3: Detailed Explanation:
When Magnesium (Mg) is heated with Selenium (Se), a direct combination reaction occurs to form a binary ionic compound.
Magnesium forms Mg^{2+} ions and Selenium forms Se^{2-} ions.
The chemical equation is:

$$Mg + Se \xrightarrow{\Delta} MgSe$$

The resulting compound is named Magnesium selenide.

Step 4: Final Answer:
The product obtained is Magnesium selenide.

> 💡 Quick Tip
>
> Binary compounds of metals with Group 16 elements always end in the suffix "-ide" (e.g., Oxide, Sulfide, Selenide).

2(ii). Write the SI unit of cell constant.

Correct Answer: m^{-1}

Solution:

Step 1: Understanding the Concept:
Cell constant (b) is a characteristic property of a conductivity cell, defined as the ratio of the distance between electrodes to the cross-sectional area of the electrodes.

Step 2: Key Formula or Approach:

$$\text{Cell constant } (b) = \frac{l}{a}$$

where l is length and a is area.

Step 3: Detailed Explanation:
The SI unit of length (l) is meters (m).
The SI unit of area (a) is square meters (m^2).
Units of cell constant $= \frac{m}{m^2} = m^{-1}$ (per meter).
While cm^{-1} is frequently used in laboratories, the SI unit is m^{-1}.

Step 4: Final Answer:
The SI unit of cell constant is m^{-1}.

> Quick Tip
>
> Be careful to distinguish between common units used in practice (cm^{-1}) and the official SI unit (m^{-1}).

2(iii). Write the name of radioactive element in lanthanide series.

Correct Answer: Promethium

Solution:

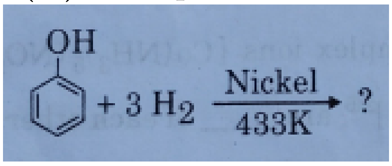
Step 1: Understanding the Concept:
Lanthanides are the elements from atomic number 58 to 71. Most lanthanides are stable or have very long half-lives, except for one element.

Step 3: Detailed Explanation:
Promethium (Pm) with atomic number 61 is the only radioactive element in the Lanthanide series.
It does not occur naturally in the Earth's crust in significant amounts and is typically produced artificially.

Step 4: Final Answer:
The radioactive lanthanide is Promethium.

> 💡 Quick Tip
>
> While all actinoids are radioactive, in the lanthanide series, only Promethium is radioactive. This is a common objective question.

2(iv). Complete the following reaction :



Correct Answer: Cyclohexanol

Solution:

Step 1: Understanding the Concept:
The catalytic hydrogenation of aromatic compounds involves the addition of hydrogen to the unsaturated carbon-carbon double bonds in the presence of a catalyst like Nickel.

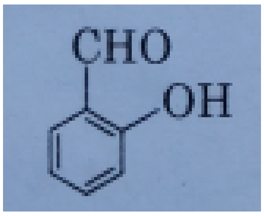
Step 3: Detailed Explanation:
When Phenol (C_6H_5OH) is treated with hydrogen gas (H_2) in the presence of a Nickel catalyst at 433 K, the aromatic ring undergoes complete reduction.
The three double bonds in the benzene ring are saturated by adding three molecules of H_2.
The product formed is a saturated cyclic alcohol.
Reaction:

$$C_6H_5OH + 3H_2 \xrightarrow[433K]{Ni} C_6H_{11}OH \text{ (Cyclohexanol)}$$

Step 4: Final Answer:
The product is Cyclohexanol.

> 💡 Quick Tip
>
> Hydrogenation of benzene rings requires vigorous conditions (high temperature/pressure) compared to simple alkenes.

2(v). Write the IUPAC name of :



Correct Answer: 2-Hydroxybenzaldehyde

Solution:

Step 1: Understanding the Concept:
The compound shown is Salicylaldehyde. In IUPAC nomenclature, we must identify the principal functional group to determine the parent name and numbering.

Step 3: Detailed Explanation:
The molecule contains two functional groups: an aldehyde group ($-CHO$) and a hydroxyl group ($-OH$).
According to priority rules, the aldehyde group has higher priority than the hydroxyl group.
Thus, the parent name is "benzaldehyde".
We number the carbon atoms starting from the Carbon attached to the aldehyde group ($C1$).
The hydroxyl group is at the second position ($C2$).
Therefore, the name is 2-Hydroxybenzaldehyde.

Step 4: Final Answer:
The IUPAC name is 2-Hydroxybenzaldehyde.

> Quick Tip
>
> Priority order for IUPAC: Carboxylic acid > Aldehyde > Ketone > Alcohol. Since aldehyde wins, the $-OH$ becomes a substituent named 'hydroxy'.

2(vi). Copper has fcc structure with edge length 495 pm. What is the radius of copper atom in pm?

Correct Answer: 175 pm

Solution:

Step 1: Understanding the Concept:
In a Face-Centered Cubic (fcc) unit cell, atoms touch each other along the face diagonal.

Step 2: Key Formula or Approach:
The relationship between atomic radius (r) and edge length (a) for an fcc structure is:

$$4r = \sqrt{2}a \implies r = \frac{\sqrt{2}a}{4} = \frac{a}{2\sqrt{2}}$$

Step 3: Detailed Explanation:
Given: $a = 495$ pm
Using the formula:

$$r = \frac{1.414 \times 495}{4}$$

$$r = \frac{699.93}{4}$$

$$r \approx 174.98 \text{ pm} \approx 175 \text{ pm}$$

Step 4: Final Answer:
The radius of the copper atom is 175 pm.

Quick Tip
Remember: Simple Cubic: $r = a/2$ BCC: $r = \sqrt{3}a/4$ FCC: $r = \sqrt{2}a/4$

2(vii). Write the chemical name of Teflon.

Correct Answer: Polytetrafluoroethene

Solution:

Step 1: Understanding the Concept:
Teflon is a synthetic polymer used widely for non-stick coatings. It is an addition polymer formed from a fluorinated monomer.

Step 3: Detailed Explanation:
The monomer for Teflon is Tetrafluoroethene ($CF_2 = CF_2$).

When these monomers undergo polymerization, they form a long-chain polymer.
The chemical name is derived from the monomer by adding the prefix "poly-".
Therefore, the name is Polytetrafluoroethene (often abbreviated as PTFE).

Step 4: Final Answer:
The chemical name of Teflon is Polytetrafluoroethene.

> Quick Tip
>
> PTFE is extremely inert and has a very low coefficient of friction, making it ideal for non-stick pans.

2(viii). Write the name of nanoparticle which acts as highly effective bacterial disinfectant.

Correct Answer: Silver nanoparticles

Solution:

Step 1: Understanding the Concept:
Certain metal nanoparticles exhibit antimicrobial properties due to their high surface-to-volume ratio, allowing them to interact effectively with microbial cell membranes.

Step 3: Detailed Explanation:
Silver (Ag) nanoparticles are well-known for their potent antibacterial, antifungal, and antiviral activities.
They release silver ions which damage the cell wall and metabolic pathways of bacteria, leading to their death.
They are used in wound dressings, water purifiers, and consumer products for disinfection.

Step 4: Final Answer:
The nanoparticle is Silver (Ag) nanoparticle.

> Quick Tip
>
> Silver has been used for centuries for its antimicrobial properties; nanotechnology simply enhances this effect by increasing the surface area.

Section B

3(a). Define Isomorphism.

Correct Answer: Two or more substances having the same crystal structure are said to be isomorphous.

Solution:

Step 1: Understanding the Concept:
Isomorphism is a phenomenon observed in solid-state chemistry where different chemical substances crystallize in the same geometric form.

Step 3: Detailed Explanation:
In isomorphous substances, the atoms are arranged in the same way, and the ratio of atoms in their chemical formulas is identical.
For example, NaF and MgO are isomorphous because they both have a 1:1 atomic ratio and crystallize in the same cubic structure.
Similarly, K_2SO_4 and K_2SeO_4 are isomorphous as they share the same crystal lattice arrangement.

Step 4: Final Answer: Isomorphism is defined as the property of two or more different substances to have the same crystal structure and similar chemical formulas.

> Quick Tip
>
> Isomorphous substances usually have similar chemical properties and can form mixed crystals (solid solutions) because their constituent particles can replace each other in the lattice.

3(b). Define Unit Cell.

Correct Answer: The smallest repeating structural unit of a crystalline solid is called a unit cell.

Solution:

Step 1: Understanding the Concept:
A crystal lattice is a highly ordered three-dimensional arrangement of particles. To describe this massive structure, we look at its fundamental building block.

Step 3: Detailed Explanation: When a unit cell is repeated in three dimensions in different directions, it generates the entire crystal lattice.
A unit cell is characterized by its edge lengths (a, b, c) and the angles between these edges (α, β, γ).
Depending on the symmetry and dimensions, there are 14 types of Bravais lattices grouped into 7 crystal systems.

Step 4: Final Answer: A unit cell is the basic repeating unit that defines the symmetry and structure of the entire crystal.

Quick Tip
Think of a unit cell like a single brick in a large wall; the arrangement of that one brick determines the pattern of the whole wall.

4(i). Explain the trends in atomic radii of group 17 elements.

Correct Answer: Atomic radii increase down the group from Fluorine to Astatine.

Solution:

Step 1: Understanding the Concept:
The atomic radius is the distance from the center of the nucleus to the outermost shell of an atom. In a group, this is primarily influenced by the number of energy levels.

Step 3: Detailed Explanation:
As we move down Group 17 (Halogens: F, Cl, Br, I, At), a new principal energy level (shell) is added at each successive element.
Although the nuclear charge increases, the effect of the additional shells outweighs the increased nuclear pull.
The inner shells also provide a "shielding effect," reducing the attraction between the nucleus and the valence electrons.
Consequently, the outermost electrons are further from the nucleus, leading to an increase in atomic size.

Step 4: Final Answer: The atomic radii of group 17 elements increase down the group due to the addition of new shells.

Quick Tip

Fluorine is the smallest element in the halogen group and has the highest effective nuclear charge relative to its shells.

4(ii). Explain the trends in electronegativity of group 17 elements.

Correct Answer: Electronegativity decreases down the group.

Solution:

Step 1: Understanding the Concept:
Electronegativity is the tendency of an atom to attract a shared pair of electrons in a chemical bond.

Step 3: Detailed Explanation:
Electronegativity is inversely proportional to atomic size.
As we move down Group 17, the atomic radius increases.
As the size increases, the distance between the nucleus and the shared pair of electrons increases.
This leads to a weaker electrostatic attraction for the shared electrons.
Fluorine is the most electronegative element in the periodic table (value of 4.0), and the value decreases significantly as we reach Iodine.

Step 4: Final Answer: Electronegativity decreases down the group as atomic size increases.

Quick Tip

Fluorine is the "king" of electronegativity. It always takes electrons and has an oxidation state of -1 in all its compounds.

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5. Explain Homoleptic and Heteroleptic complexes with example.

Correct Answer: Homoleptic complexes contain one type of ligand, while Heteroleptic complexes contain more than one type.

Solution:

Step 1: Understanding the Concept:
Coordination complexes consist of a central metal ion bonded to surrounding molecules or ions

called ligands. The classification depends on the variety of ligands present.

Step 3: Detailed Explanation:
1. Homoleptic Complexes:
These are complexes in which the central metal atom or ion is coordinated to only one kind of donor group (ligand).
Example: $[Co(NH_3)_6]^{3+}$ (Hexaamminecobalt(III) ion). Here, all six ligands are ammonia molecules.
2. Heteroleptic Complexes:
These are complexes in which the central metal atom or ion is coordinated to more than one kind of donor group (ligand).
Example: $[Co(NH_3)_4Cl_2]^+$ (Tetraamminedichloridocobalt(III) ion). Here, two types of ligands are present: four ammonia molecules and two chloride ions.

Step 4: Final Answer: Homoleptic complexes have uniform ligands (e.g., $[Ni(CO)_4]$), whereas heteroleptic complexes have varied ligands (e.g., $[Pt(NH_3)_2Cl_2]$).

> Quick Tip
>
> "Homo-" means same and "Hetero-" means different. This prefix logic applies across chemistry for mixtures, bonds, and complexes.

6(a). Write the reaction of bromine water on glucose.

Correct Answer: Glucose is oxidized to Gluconic acid.

Solution:

Step 1: Understanding the Concept:
Bromine water (Br_2/H_2O) is a mild oxidizing agent. It is specific for the oxidation of the aldehyde group ($-CHO$) in carbohydrates.

Step 3: Detailed Explanation:
Glucose is an aldohexose, containing an aldehyde group at $C1$.
When glucose is treated with bromine water, the aldehyde group is oxidized to a carboxylic acid group ($-COOH$).
The polyhydroxy nature of the rest of the molecule remains unchanged.
The product formed is Gluconic acid.
Chemical Equation:

$$CHO-(CHOH)_4-CH_2OH+[O] \xrightarrow{Br_2/H_2O} COOH-(CHOH)_4-CH_2OH$$

Step 4: Final Answer: The reaction of glucose with bromine water yields Gluconic acid.

> Quick Tip
>
> This reaction proves that glucose contains an aldehyde group. Strong oxidizing agents like conc. HNO_3 would further oxidize the primary alcohol to form Saccharic acid.

6(b). Define – Enantiomers

Correct Answer: Optical isomers that are non-superimposable mirror images of each other.

Solution:

Step 1: Understanding the Concept:
Enantiomers occur in molecules that possess "chirality," meaning they lack an internal plane of symmetry.

Step 3: Detailed Explanation:
Enantiomers have identical physical properties like melting point, boiling point, and solubility. They differ only in the direction in which they rotate plane-polarized light (one is dextrorotatory, the other is levorotatory).
They also react differently with other chiral reagents.
Example: d-Lactic acid and l-Lactic acid are enantiomers.

Step 4: Final Answer: Enantiomers are a pair of stereoisomers that are related to each other as an object and its non-superimposable mirror image.

> Quick Tip
>
> A 50:50 mixture of two enantiomers is called a Racemic mixture, which is optically inactive due to external compensation.

7(i). Write example of one dimensional nanostructure of size less than 100 nm.

Correct Answer: Nanowires or Nanorods.

Solution:

Step 1: Understanding the Concept:
Nanostructures are classified by the number of dimensions that are NOT in the nanoscale ($1 - 100$ nm).

Step 3: Detailed Explanation:
In a one-dimensional (1D) nanostructure, two dimensions are in the nanoscale (width and thickness < 100 nm), while the third dimension (length) can be significantly larger.
Common examples include Nanowires and Nanorods.
These structures have unique electronic and optical properties because electron movement is restricted in two directions but free in one.

Step 4: Final Answer: A typical example of a 1D nanostructure is a Nanowire.

> 💡 Quick Tip
>
> Remember: 0D = Nanoparticles (all 3 dimensions small), 1D = Nanowires (2 dimensions small), 2D = Nanofilms (1 dimension small).

7(ii). Write the hydrolysis reaction of ethyl methyl ether.

Correct Answer: $CH_3 - O - C_2H_5 + H_2O \xrightarrow{H^+} CH_3OH + C_2H_5OH$

Solution:

Step 1: Understanding the Concept:
Ethers are relatively unreactive but can be cleaved (hydrolyzed) by heating with dilute mineral acids under pressure or with concentrated halogen acids.

Step 3: Detailed Explanation:
Ethyl methyl ether ($CH_3 - O - CH_2CH_3$) is an unsymmetrical ether.
Upon hydrolysis with dilute sulfuric acid (H_2SO_4) under pressure, the $C - O$ bond breaks.
The reaction produces two different alcohols: Methanol and Ethanol.
Chemical Equation:

$$CH_3 - O - C_2H_5 + H - OH \xrightarrow{H^+/\Delta} CH_3OH + C_2H_5OH$$

Step 4: Final Answer: Hydrolysis of ethyl methyl ether yields methanol and ethanol.

Quick Tip

In the lab, cleavage is usually done with HI or HBr. With HI, the smaller alkyl group usually forms the alkyl iodide (CH_3I) while the larger forms the alcohol.

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8. Calculate the osmotic pressure of solution containing 0.822 **gm of sucrose in** 300 **mL of water at** 298 **K. [Given : Molar mass of sucrose** 342 **g/mol,** $R = 0.08205$ **dm**^{3} **atm. K**$^-$

Correct Answer: 0.196 atm

Solution:

Step 1: Understanding the Concept:
Osmotic pressure (π) is a colligative property that depends on the molar concentration of the solute.

Step 2: Key Formula or Approach:

$$\pi = CRT = \frac{n}{V}RT = \frac{w_2}{M_2V}RT$$

Where:
$w_2 = 0.822$ g (Mass of solute)
$M_2 = 342$ g/mol (Molar mass of solute)
$V = 300$ mL $= 0.3$ L $= 0.3$ dm^3
$R = 0.08205$ dm^3 atm K^{-1} mol^{-1}
$T = 298$ K

Step 3: Detailed Explanation:
First, calculate the number of moles of sucrose:

$$n_2 = \frac{0.822}{342} \approx 0.002403 \text{ mol}$$

Now, substitute into the osmotic pressure formula:

$$\pi = \frac{0.002403}{0.3} \times 0.08205 \times 298$$

$$\pi = 0.00801 \times 0.08205 \times 298$$

$$\pi \approx 0.196 \text{ atm}$$

Step 4: Final Answer: The osmotic pressure of the solution is 0.196 atm.

> Quick Tip
>
> Ensure the volume is in Liters (dm^3) when using $R = 0.08205$. Forgetting to convert 300 mL to 0.3 L is a common error.

9(a). Write the mathematical equation of first law of thermodynamics for following processes : Isochoric process

Correct Answer: $\Delta U = q_v$

Solution:

Step 1: Understanding the Concept:
The First Law of Thermodynamics is $\Delta U = q + w$. For a pressure-volume work, $w = -P\Delta V$.

Step 3: Detailed Explanation:
In an isochoric process, the volume of the system remains constant (V = constant), which means $\Delta V = 0$.
Substituting this into the work equation: $w = -P \times 0 = 0$.
Applying this to the First Law:

$$\Delta U = q + 0$$

$$\Delta U = q_v$$

This indicates that the entire heat supplied to the system is used to increase its internal energy.

Step 4: Final Answer: The equation for an isochoric process is $\Delta U = q_v$.

> Quick Tip
>
> Isochoric = constant volume. If volume doesn't change, the piston doesn't move, and no PV-work is done.

9(b). Write the mathematical equation of first law of thermodynamics for following processes : Adiabatic process

Correct Answer: $\Delta U = w$

Solution:

Step 1: Understanding the Concept:
An adiabatic process is one in which there is no heat exchange between the system and its surroundings.

Step 3: Detailed Explanation:
For an adiabatic process, $q = 0$.
Applying this to the First Law of Thermodynamics ($\Delta U = q + w$):

$$\Delta U = 0 + w$$

$$\Delta U = w$$

This means that in an adiabatic process, the work done on the system results in an equivalent increase in its internal energy.

Step 4: Final Answer: The equation for an adiabatic process is $\Delta U = w$.

> Quick Tip
>
> In adiabatic expansion, the system does work at the expense of its own internal energy, causing a drop in temperature.

---

10. Write two similarities and two differences between lanthanoids and actinoids.

Correct Answer: Similarities: Both show +3 OS and contraction. Differences: Lanthanoids are mostly non-radioactive; Actinoids are all radioactive.

Solution:

Step 1: Understanding the Concept:
Lanthanoids ($4f$ series) and Actinoids ($5f$ series) are the f-block elements located in the inner transition series.

Step 3: Detailed Explanation:
Similarities:
1. Both series show a predominant oxidation state of +3.

2. Both series exhibit a steady decrease in ionic radii across the series, known as Lanthanoid contraction and Actinoid contraction respectively.
Differences:
1. Except for Promethium (Pm), lanthanoids are non-radioactive, whereas all actinoids are radioactive.
2. Lanthanoids have a lesser tendency to form complexes compared to actinoids because $5f$ orbitals are more extended in space and participate more in bonding.

Step 4: Final Answer: The primary similarities are OS and contraction; primary differences are radioactivity and complex formation.

> Quick Tip
>
> Actinoid contraction is greater than lanthanoid contraction because the shielding effect of $5f$ electrons is poorer than that of $4f$ electrons.

11(i). What is the action of conc. HNO_3 on chlorobenzene?

Correct Answer: Formation of 1-chloro-2-nitrobenzene and 1-chloro-4-nitrobenzene.

Solution:

Step 1: Understanding the Concept:
Electrophilic substitution in haloarenes. Chlorine is ortho-para directing due to resonance effects, even though it is deactivating due to its inductive effect.

Step 3: Detailed Explanation:
When chlorobenzene is treated with a nitrating mixture (conc. HNO_3 + conc. H_2SO_4), nitration occurs.
The nitro group ($-NO_2$) attaches to the ortho and para positions relative to the chlorine atom.
1-chloro-4-nitrobenzene (para isomer) is the major product due to less steric hindrance, and 1-chloro-2-nitrobenzene (ortho isomer) is the minor product.

Step 4: Final Answer: Chlorobenzene reacts with conc. HNO_3 to give a mixture of o-nitrochlorobenzene and p-nitrochlorobenzene.

> Quick Tip
>
> In almost all electrophilic aromatic substitutions on chlorobenzene, the para product is major because of symmetry and reduced steric repulsion.

11(ii). What is the action of fuming H_2SO_4 on chlorobenzene?

Correct Answer: Formation of 2-chlorobenzenesulfonic acid and 4-chlorobenzenesulfonic acid.

Solution:

Step 1: Understanding the Concept:
Sulfonation is the introduction of the sulfonic acid group ($-SO_3H$) into the aromatic ring.

Step 3: Detailed Explanation:
Heating chlorobenzene with fuming sulfuric acid (oleum) leads to the substitution of a hydrogen atom by the $-SO_3H$ group.
Like nitration, the reaction produces ortho and para isomers.
Products: 2-chlorobenzenesulfonic acid and 4-chlorobenzenesulfonic acid (major).

Step 4: Final Answer: Chlorobenzene yields chlorobenzenesulfonic acids upon treatment with fuming H_2SO_4.

> Quick Tip
>
> Fuming H_2SO_4 contains SO_3 dissolved in H_2SO_4. Here, SO_3 acts as the actual electrophile.

---

12. Explain Cannizzaro reaction with suitable example.

Correct Answer: Self-oxidation and reduction of aldehydes having no α-H atoms in the presence of conc. alkali.

Solution:

Step 1: Understanding the Concept:
The Cannizzaro reaction is a redox (disproportionation) reaction where two molecules of an aldehyde react to produce one molecule of an alcohol and one molecule of a carboxylic acid salt.

Step 3: Detailed Explanation:
This reaction is characteristic of aldehydes that do not have any α-hydrogen atoms (e.g., Formaldehyde, Benzaldehyde).
When such aldehydes are treated with concentrated alkali (50% $NaOH$ or KOH), one molecule is reduced to an alcohol, and the other is simultaneously oxidized to a salt of carboxylic acid.

Example: Reaction of Formaldehyde ($HCHO$):

$$2HCHO + \text{conc. } NaOH \rightarrow CH_3OH \text{ (Methanol)} + HCOONa \text{ (Sodium formate)}$$

Step 4: Final Answer: The Cannizzaro reaction involves the disproportionation of non-enolizable aldehydes into alcohols and carboxylates.

> Quick Tip
>
> If the aldehyde has an α-hydrogen, it will undergo Aldol condensation instead. If no α-H, it goes for Cannizzaro.

---

13. A chemical reaction occurs in two steps :
(i) $NO_2Cl(g) \xrightarrow{\text{slow}} NO_2(g) + Cl(g)$
(ii) $NO_2Cl(g) + Cl(g) \xrightarrow{\text{fast}} NO_2(g) + Cl_2(g)$
(a) Write down the rate law.
(b) Identify the reaction intermediate.

Correct Answer: (a) $Rate = k[NO_2Cl]$, (b) $Cl(g)$

Solution:

Step 1: Understanding the Concept:
In a multi-step reaction mechanism, the overall rate of the reaction is determined by the slowest step, known as the Rate Determining Step (RDS).

Step 3: Detailed Explanation:
(a) Rate Law:
Step (i) is the slow step. Therefore, it determines the rate.
The rate depends on the concentration of the reactants in the slow step.
Rate law: $Rate = k[NO_2Cl]$.
(b) Reaction Intermediate:
An intermediate is a species that is produced in one step and consumed in a subsequent step, and thus does not appear in the overall balanced equation.
In this mechanism, $Cl(g)$ is formed in step (i) and used up in step (ii).
Intermediate: $Cl(g)$ (atomic chlorine).

Step 4: Final Answer: The rate law is $Rate = k[NO_2Cl]$ and the intermediate is $Cl(g)$.

Quick Tip

Always look for the "slow" tag to write the rate law. Intermediates are the "cross-out" species when you sum up the steps.

---

14. The standard potential of electrode $Cu^{2+}(0.02\ \mathbf{M})|Cu(s)$ is 0.337 volt. Calculate its potential in volt.

Correct Answer: 0.287 volt

Solution:

Step 1: Understanding the Concept:
The Nernst equation allows the calculation of electrode potential under non-standard conditions.

Step 2: Key Formula or Approach:
The Nernst equation for the reduction $Cu^{2+} + 2e^- \to Cu(s)$ is:

$$E = E^\circ - \frac{0.0592}{n} \log \frac{1}{[Cu^{2+}]}$$

Given: $E^\circ = 0.337$ V, $[Cu^{2+}] = 0.02$ M, $n = 2$.

Step 3: Detailed Explanation:

$$E = 0.337 - \frac{0.0592}{2} \log \frac{1}{0.02}$$

$$E = 0.337 - 0.0296 \log(50)$$

Since $\log(50) = \log(100/2) = \log 100 - \log 2 = 2 - 0.301 = 1.699$:

$$E = 0.337 - (0.0296 \times 1.699)$$

$$E = 0.337 - 0.0503$$

$$E = 0.2867 \approx 0.287 \text{ V}$$

Step 4: Final Answer: The potential of the copper electrode is 0.287 volt.

> Quick Tip
>
> If the concentration is less than 1 M, the electrode potential (E) will be less than the standard potential (E°) for a reduction process.

Section C

15(i). Derive relationship between relative lowering of vapour pressure and molar mass of non volatile solute.

Correct Answer: $M_2 = \frac{w_2 M_1 P_1^\circ}{w_1 \Delta P}$

Solution:

Step 1: Understanding the Concept:
Relative Lowering of Vapour Pressure (RLVP) is a colligative property. According to Raoult's law, it is equal to the mole fraction of the solute.

Step 2: Key Formula or Approach:

$$\frac{P_1^\circ - P_1}{P_1^\circ} = x_2$$

Step 3: Detailed Explanation:
Let w_1 and w_2 be the masses of solvent and solute, and M_1 and M_2 be their molar masses.
Number of moles of solute, $n_2 = w_2/M_2$
Number of moles of solvent, $n_1 = w_1/M_1$
For dilute solutions, $n_2 \ll n_1$, so $n_1 + n_2 \approx n_1$.
Mole fraction of solute, $x_2 = \frac{n_2}{n_1+n_2} \approx \frac{n_2}{n_1} = \frac{w_2/M_2}{w_1/M_1} = \frac{w_2 M_1}{M_2 w_1}$.
Substituting into Raoult's Law:

$$\frac{\Delta P}{P_1^\circ} = \frac{w_2 M_1}{M_2 w_1}$$

Rearranging for M_2:

$$M_2 = \frac{w_2 M_1 P_1^\circ}{w_1 \Delta P}$$

Step 4: Final Answer: The molar mass M_2 is given by $\frac{w_2 M_1 P_1^\circ}{w_1 \Delta P}$.

> Quick Tip
>
> Note that $\Delta P = P_1^\circ - P_1$. This formula is used to determine the molar mass of unknown non-volatile solutes.

15(ii). Write statement of second law of thermodynamics.

Correct Answer: The total entropy of an isolated system always increases over time.

Solution:

Step 1: Understanding the Concept:
The Second Law of Thermodynamics deals with the direction of spontaneous processes and the quality of energy.

Step 3: Detailed Explanation:
There are various ways to state this law:
1. **Entropy Statement:** Any spontaneous process in an isolated system leads to an increase in total entropy ($\Delta S_{total} > 0$).
2. **Clausius Statement:** Heat cannot flow spontaneously from a colder body to a hotter body without external work.
3. **Kelvin-Planck Statement:** It is impossible to construct a heat engine that converts heat from a reservoir completely into work with 100% efficiency.

Step 4: Final Answer: The second law states that spontaneous processes are accompanied by an increase in the entropy of the universe.

> Quick Tip
>
> While the 1st law is about energy conservation, the 2nd law explains why certain reactions occur while others don't (spontaneity).

16(i). Convert acetamide into ethyl amine.

Correct Answer: Acetamide is reduced to ethyl amine using Lithium Aluminium Hydride ($LiAlH_4$).

Solution:

Step 1: Understanding the Concept:
Reduction of amides can be carried out using strong reducing agents like $LiAlH_4$. This process converts the carbonyl group ($> C = O$) of the amide into a methylene group ($-CH_2-$) without changing the number of carbon atoms.

Step 3: Detailed Explanation:
Acetamide (CH_3CONH_2) contains two carbon atoms.
When it is treated with $LiAlH_4$ in ether, followed by hydrolysis, the amide group is reduced to an amine group.
The product is ethyl amine ($CH_3CH_2NH_2$).
Chemical Equation:

$$CH_3 - CO - NH_2 \xrightarrow[ii) H_2O]{i) LiAlH_4/\text{ether}} CH_3 - CH_2 - NH_2$$

Step 4: Final Answer:
Acetamide is converted to ethyl amine by reduction with $LiAlH_4$.

> Quick Tip
>
> Do not confuse this with the Hoffmann Bromamide degradation, which uses Br_2/KOH and removes one carbon atom to give methyl amine. For ethyl amine, you must use reduction.

16(ii). Explain amphoteric nature of water.

Correct Answer: Water acts as an acid as well as a base.

Solution:

Step 1: Understanding the Concept:
An amphoteric (or amphiprotic) substance is one that can act as both a Bronsted-Lowry acid (proton donor) and a Bronsted-Lowry base (proton acceptor).

Step 3: Detailed Explanation:
Water exhibits amphoteric behavior depending on the chemical environment:
1. **As a Base:** When reacting with an acid stronger than itself (like HCl), water accepts a proton to form the hydronium ion (H_3O^+).

$$HCl(aq) + H_2O(l) \rightarrow H_3O^+(aq) + Cl^-(aq)$$

2. **As an Acid:** When reacting with a base (like NH_3), water donates a proton to form the hydroxide ion (OH^-).

$$NH_3(aq) + H_2O(l) \rightarrow NH_4^+(aq) + OH^-(aq)$$

Step 4: Final Answer:
Water is amphoteric because it can donate protons to bases and accept protons from acids.

> **Quick Tip**
>
> Self-ionization of water ($H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$) is a perfect demonstration of one water molecule acting as an acid and another as a base.

17(i). Convert Ethanol into sodium ethoxide.

Correct Answer: Reaction of ethanol with sodium metal.

Solution:

Step 1: Understanding the Concept:
Alcohols are weakly acidic. They react with active metals like Sodium (Na), Potassium (K), or Magnesium (Mg) to release hydrogen gas and form metal alkoxides.

Step 3: Detailed Explanation:
When ethanol (C_2H_5OH) is treated with metallic sodium, the sodium atom replaces the acidic hydrogen of the hydroxyl group.
The product formed is sodium ethoxide (C_2H_5ONa) and hydrogen gas is evolved.
Chemical Equation:

$$2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2(g) \uparrow$$

Step 4: Final Answer:
Ethanol is converted to sodium ethoxide by reacting it with sodium metal.

> **Quick Tip**
>
> Alkoxides are very strong bases and good nucleophiles. Sodium ethoxide is frequently used in Williamson Ether synthesis.

17(ii). Convert Phenol into o-phenol sulfonic acid.

Correct Answer: Sulfonation of phenol at low temperature ($288 - 293$ K).

Solution:

Step 1: Understanding the Concept:
Sulfonation of phenol is temperature-dependent. The $-OH$ group is ortho-para directing.

Step 3: Detailed Explanation:
When phenol is treated with concentrated sulfuric acid (H_2SO_4) at a lower temperature ($288 - 293$ K), the major product is o-phenol sulfonic acid (2-hydroxybenzenesulfonic acid). At high temperature (373 K), the para-isomer becomes the major product.
Chemical Equation:

$$C_6H_5OH + \text{conc. } H_2SO_4 \xrightarrow{288 \text{ K}} \text{o-}HOC_6H_4SO_3H$$

Step 4: Final Answer:
Phenol yields o-phenol sulfonic acid when reacted with conc. H_2SO_4 at room temperature.

> Quick Tip
>
> Sulfonation is reversible. At low temperatures, the reaction is kinetically controlled (ortho product); at high temperatures, it is thermodynamically controlled (para product).

17(iii). Convert Bromomethane into methoxyethane.

Correct Answer: Williamson Ether Synthesis using sodium ethoxide.

Solution:

Step 1: Understanding the Concept:
Williamson synthesis is an S_N2 reaction between a primary alkyl halide and a sodium alkoxide to form an ether.

Step 3: Detailed Explanation:
To prepare methoxyethane ($CH_3 - O - C_2H_5$) from bromomethane (CH_3Br), we react the methyl halide with sodium ethoxide ($NaOC_2H_5$).
Chemical Equation:

$$CH_3Br + NaOC_2H_5 \rightarrow CH_3 - O - C_2H_5 + NaBr$$

Step 4: Final Answer:
Reaction of bromomethane with sodium ethoxide produces methoxyethane.

> 💡 Quick Tip
>
> For Williamson synthesis, always use the less hindered alkyl halide (preferably methyl or primary) to avoid elimination (alkene formation).

18(i). What is peptide linkage?

Correct Answer: An amide bond ($-CO-NH-$) formed between two amino acids.

Solution:

Step 1: Understanding the Concept:
Proteins are polymers of amino acids. These amino acids are joined together by a specific covalent bond known as a peptide linkage.

Step 3: Detailed Explanation:
A peptide linkage is formed when the carboxyl group ($-COOH$) of one amino acid reacts with the amino group ($-NH_2$) of another amino acid.
This reaction involves the elimination of a water molecule (condensation).
The resulting bond is $-CO-NH-$.
Structure: $...-CO-NH-CH(R)-CO-NH-....$

Step 4: Final Answer:
A peptide linkage is the covalent amide bond that connects amino acids in a polypeptide chain.

> 💡 Quick Tip
>
> Dipeptides have 2 amino acids and 1 peptide bond. Tripeptides have 3 amino acids and 2 peptide bonds. Generally, n amino acids have $n-1$ peptide bonds.

18(ii). Write general characteristics of interhalogen compounds.

Correct Answer: Covalent, diamagnetic, and more reactive than halogens (except fluorine).

Solution:

Step 1: Understanding the Concept:
Interhalogen compounds are molecules formed by the reaction of two different halogens with each other (e.g., ClF_3, IBr).

Step 3: Detailed Explanation:
1. **Bonding:** They are essentially covalent molecules.
2. **Physical state:** They can be gases, liquids, or solids at room temperature.
3. **Magnetic Property:** They are diamagnetic as they contain only paired electrons.
4. **Reactivity:** Interhalogen compounds are generally more reactive than the individual constituent halogens (except F_2) because the $X - X'$ bond is weaker than the $X - X$ bond (due to unequal size and electronegativity).
5. **Hydrolysis:** On hydrolysis, they give a halide ion from the smaller halogen and an oxyhalide ion from the larger halogen.

Step 4: Final Answer:
Interhalogens are covalent, diamagnetic, and highly reactive compounds.

Quick Tip

The general formula is XX'_n where $n = 1, 3, 5, 7$. The larger halogen X is always the central atom.

19(i). Write observed electronic configuration of chromium ($Z = 24$).

Correct Answer: $[Ar]3d^5 4s^1$

Solution:

Step 1: Understanding the Concept:
The electronic configuration of elements usually follows the Aufbau principle. However, half-filled and completely filled subshells provide extra stability.

Step 3: Detailed Explanation:
Expected configuration of Cr ($Z = 24$): $[Ar]3d^4 4s^2$.
Observed configuration of Cr: $[Ar]3d^5 4s^1$.
The shift of one electron from the $4s$ to the $3d$ orbital occurs because a half-filled d-subshell (d^5) and a half-filled s-subshell (s^1) together are more stable than the $d^4 s^2$ arrangement due to symmetry and higher exchange energy.

Step 4: Final Answer:
The observed electronic configuration of Chromium is $[Ar]3d^5 4s^1$.

Quick Tip

Chromium ($Z = 24$) and Copper ($Z = 29$) are the two classic exceptions in the $3d$ series that students must memorize.

19(ii). Calculate magnetic moment of Ti^{3+} by using spin only formula. (Z **of** $Ti = 22$)

Correct Answer: 1.73 BM

Solution:

Step 1: Understanding the Concept:
Magnetic moment (μ) of transition metal ions depends on the number of unpaired electrons (n).

Step 2: Key Formula or Approach:
Spin-only formula: $\mu = \sqrt{n(n+2)}$ BM

Step 3: Detailed Explanation:
1. Write configuration of Ti ($Z = 22$): $[Ar]3d^2 4s^2$.
2. Write configuration of Ti^{3+}: Remove 2 electrons from $4s$ and 1 from $3d$.
Configuration: $[Ar]3d^1$.
3. Number of unpaired electrons, $n = 1$.
4. Calculate μ:

$$\mu = \sqrt{1(1+2)} = \sqrt{3}$$

$$\mu \approx 1.732 \text{ BM}$$

Step 4: Final Answer:
The magnetic moment of Ti^{3+} is 1.73 BM.

Quick Tip

If $n = 1, \mu \approx 1.73$. If $n = 2, \mu \approx 2.83$. If $n = 3, \mu \approx 3.87$. The digit before the decimal is always equal to the number of unpaired electrons.

19(iii). Define Green chemistry.

Correct Answer: Sustainable chemistry designed to reduce or eliminate hazardous substances.

Solution:

Step 1: Understanding the Concept:
Green chemistry is an approach to chemical research and engineering that seeks to minimize the environmental impact of chemical processes.

Step 3: Detailed Explanation:
Green chemistry is the design of chemical products and processes that reduce or eliminate the use or generation of hazardous substances.
It focuses on 12 principles, including atom economy, use of safer solvents, energy efficiency, and use of renewable feedstocks.
Its goal is to prevent pollution at the molecular level.

Step 4: Final Answer:
Green chemistry is the use of chemistry for pollution prevention and environmental sustainability.

> Quick Tip
>
> It is often called sustainable chemistry. The ultimate goal is to make chemical production "clean" from start to finish.

20(i). Write examples of coordination metal complexes in biology.

Correct Answer: Chlorophyll, Hemoglobin, and Vitamin B_{12}.

Solution:

Step 1: Understanding the Concept:
Coordination compounds play vital roles in living systems, where metal ions are coordinated to large organic ligands.

Step 3: Detailed Explanation:
1. **Chlorophyll:** A coordination complex of Magnesium (Mg^{2+}) essential for photosynthesis in plants.
2. **Hemoglobin:** A coordination complex of Iron (Fe^{2+}) responsible for oxygen transport in the blood of animals.
3. **Vitamin B_{12} (Cyanocobalamin):** A coordination complex of Cobalt (Co) involved in metabolism and red blood cell formation.
4. **Cisplatin:** A platinum complex used in cancer chemotherapy.

Step 4: Final Answer:
Common examples are Hemoglobin (Iron complex) and Chlorophyll (Magnesium complex).

Quick Tip

Hemoglobin contains the "heme" group, which is a porphyrin ring with an Iron center. Chlorophyll has a similar ring but with Magnesium.

20(ii). Calculate the work done in oxidation of 2 moles of SO_2 at 298 K, if $SO_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow SO_{3(g)}$. [Given : $R = 8.314$ J/K mol]

Correct Answer: 2477.57 J

Solution:

Step 1: Understanding the Concept:
The work done in a chemical reaction involving gases is given by the change in the number of gaseous moles.

Step 2: Key Formula or Approach:

$$W = -\Delta n_g RT$$

Where Δn_g = (moles of gaseous products) − (moles of gaseous reactants).

Step 3: Detailed Explanation:
The equation for 1 mole of SO_2 is: $SO_{2(g)} + 0.5O_{2(g)} \rightarrow SO_{3(g)}$.
For 2 moles of SO_2, the balanced equation is:

$$2SO_{2(g)} + 1O_{2(g)} \rightarrow 2SO_{3(g)}$$

$\Delta n_g = 2 - (2 + 1) = 2 - 3 = -1$ mole.
Now, substitute into the work formula:

$$W = -(-1) \times 8.314 \times 298$$

$$W = 1 \times 8.314 \times 298$$

$$W = 2477.57 \text{ J}$$

Since W is positive, work is done ON the system (compression).

Step 4: Final Answer:
The work done is 2477.57 J.

> Quick Tip
>
> A positive value of work indicates the surroundings did work on the system because the volume decreased (Δn_g is negative).

21(i). Write the formula to measure % atom economy according to green chemistry.

Correct Answer: $\%$ Atom Economy $= \frac{\text{Formula weight of desired product}}{\text{Sum of formula weight of all reactants}} \times 100$

Solution:

Step 1: Understanding the Concept:
Atom economy is a measure of the efficiency of a chemical reaction in terms of how many atoms from the reactants end up in the desired final product.

Step 3: Detailed Explanation:
High atom economy means that most of the reactant atoms are incorporated into the useful product, minimizing waste.
The formula is:

$$\% \text{ Atom Economy} = \frac{\text{Molecular mass of the desired product}}{\text{Total molecular mass of all reactants used in the balanced equation}} \times 100$$

Step 4: Final Answer:
The % atom economy is the ratio of product mass to total reactant mass, expressed as a percentage.

> Quick Tip
>
> An ideal green reaction would have 100% atom economy, meaning no by-products are formed (e.g., addition reactions).

21(ii)(a). Convert Benzene into benzaldehyde.

Correct Answer: Gatterman-Koch Reaction.

Solution:

Step 1: Understanding the Concept:
Direct formylation of benzene is achieved by reacting benzene with carbon monoxide and HCl in the presence of a catalyst.

Step 3: Detailed Explanation:
When benzene is treated with carbon monoxide (CO) and hydrogen chloride (HCl) in the presence of anhydrous aluminium chloride ($AlCl_3$) or cuprous chloride ($CuCl$), benzaldehyde is formed.
Chemical Equation:

$$C_6H_6 + CO + HCl \xrightarrow{\text{anh. } AlCl_3} C_6H_5CHO$$

Step 4: Final Answer:
Benzaldehyde is prepared from benzene using the Gatterman-Koch reaction.

> Quick Tip
>
> The CO/HCl mixture behaves like formyl chloride ($HCOCl$), which is otherwise unstable.

21(ii) (b). Convert Cyclohexene into adipic acid.

Correct Answer: Oxidative cleavage using acidic $KMnO_4$.

Solution:

Step 1: Understanding the Concept:
Strong oxidizing agents can cleave the carbon-carbon double bond in alkenes to form carboxylic acids.

Step 3: Detailed Explanation:
Cyclohexene is a cyclic alkene. Upon treatment with hot acidic potassium permanganate ($KMnO_4$), the ring opens at the double bond site.
Both carbons of the original double bond are oxidized to carboxyl ($-COOH$) groups.
The resulting straight-chain dicarboxylic acid is Adipic acid (Hexanedioic acid).
Reaction:

$$\text{Cyclohexene} + [O] \xrightarrow{KMnO_4/H^+} HOOC - (CH_2)_4 - COOH$$

Step 4: Final Answer:
Adipic acid is formed by the oxidative cleavage of cyclohexene.

> 💡 Quick Tip
>
> Adipic acid is a key monomer used in the industrial production of Nylon-6,6.

22(i). Write a reaction for preparation of Nylon-6.

Correct Answer: Ring-opening polymerization of ε-caprolactam.

Solution:

Step 1: Understanding the Concept:
Nylon-6 is a homopolymer made from a single monomer that contains both an amino and a carboxyl group (in the form of a cyclic amide).

Step 3: Detailed Explanation:
The monomer for Nylon-6 is ε-caprolactam.
When ε-caprolactam is heated with water at high temperature ($533 - 543$ K), the ring opens to form ε-aminocaproic acid, which then polymerizes.
Reaction:

$$n(\text{Caprolactam}) \xrightarrow[H_2O]{\text{533−543 K}} [-NH-(CH_2)_5-CO-]_n$$

Step 4: Final Answer:
Nylon-6 is prepared by heating ε-caprolactam with water.

> 💡 Quick Tip
>
> Nylon-6 is named "6" because its repeating unit contains 6 carbon atoms. Unlike Nylon-6,6, it is formed by only one type of monomer.

22(ii). The salt of Sc^{3+} ion is colourless and the salt of Mn^{3+} ion is coloured. Explain. $[Z$ **of** $Sc = 21$ **and** Z **of** $Mn = 25]$

Correct Answer: Presence of unpaired electrons in Mn^{3+} allows d-d transitions, while Sc^{3+} has no d-electrons.

Solution:

Step 1: Understanding the Concept:
The color of transition metal ions is generally due to $d-d$ electronic transitions. For such transitions, the metal ion must have a partially filled d-orbital (d^1 to d^9).

Step 3: Detailed Explanation:
1. Sc^{3+} **ion:**
Configuration of Sc ($Z = 21$): $[Ar]3d^1 4s^2$.
Configuration of Sc^{3+}: $[Ar]3d^0$.
Since there are no electrons in the d-orbital, $d-d$ transitions are impossible. Hence, its salts are colourless.
2. Mn^{3+} **ion:**
Configuration of Mn ($Z = 25$): $[Ar]3d^5 4s^2$.
Configuration of Mn^{3+}: $[Ar]3d^4$.
It has 4 unpaired electrons in the $3d$ subshell. When light falls on the salt, electrons can jump between split d-orbitals ($d-d$ transition), absorbing specific wavelengths and reflecting the rest. Thus, it is coloured (typically violet/purple).

Step 4: Final Answer:
Sc^{3+} is $3d^0$ (colourless) and Mn^{3+} is $3d^4$ (coloured).

Quick Tip

Common colourless transition ions: Sc^{3+} (d^0), Ti^{4+} (d^0), Zn^{2+} (d^{10}), and Cu^+ (d^{10}).

23(i). Write the postulates of Werner's theory of co-ordination complexes.

Correct Answer: Metals possess primary and secondary valencies. Secondary valencies are non-ionizable and directional.

Solution:

Step 1: Understanding the Concept:
Werner's theory was the first successful explanation of the bonding and structure of coordination compounds.

Step 3: Detailed Explanation:
1. Metals in coordination compounds show two types of valency: Primary and Secondary.
2. **Primary Valency:** It is ionizable and corresponds to the oxidation state of the metal. It is satisfied by negative ions.

3. **Secondary Valency:** It is non-ionizable and corresponds to the coordination number. It is satisfied by negative ions or neutral molecules (ligands).
4. Secondary valencies are fixed for a metal and are directed in space toward specific positions, which determines the geometry of the complex.

Step 4: Final Answer:
Werner's postulates differentiate between ionizable oxidation states and non-ionizable coordination numbers.

> Quick Tip
>
> Primary valency is usually shown by dotted lines in structures, and secondary valency by thick lines.

23(ii). What is the action of ethane-1,2-diol on acetone?

Correct Answer: Formation of a cyclic ketal (acetonide).

Solution:

Step 1: Understanding the Concept:
Ketones react with 1,2-diols in the presence of an acid catalyst to form cyclic structures known as ketals.

Step 3: Detailed Explanation:
Acetone (CH_3COCH_3) reacts with ethane-1,2-diol (ethylene glycol) in the presence of dry HCl gas or p-toluenesulfonic acid.
One molecule of water is eliminated, and the two hydroxyl oxygens of the glycol bond to the carbonyl carbon of acetone.
The product is 2,2-dimethyl-1,3-dioxolane (ethylene glycol ketal).
Reaction:

$$(CH_3)_2C = O + HO - CH_2 - CH_2 - OH \xrightarrow{H^+} \text{Cyclic Ketal} + H_2O$$

Step 4: Final Answer:
The action of ethane-1,2-diol on acetone produces a cyclic ketal.

> Quick Tip
>
> Cyclic acetals and ketals are used in organic synthesis to "protect" carbonyl groups from reacting with bases or nucleophiles.

24(i). Write Tollen's reagent test for acetaldehyde.

Correct Answer: Formation of a silver mirror.

Solution:

Step 1: Understanding the Concept:
Tollen's reagent (ammoniacal silver nitrate) is a mild oxidizing agent that oxidizes aldehydes but not ketones.

Step 3: Detailed Explanation:
When acetaldehyde (CH_3CHO) is heated with Tollen's reagent $[Ag(NH_3)_2]^+$, the aldehyde is oxidized to an acetate ion.
Simultaneously, the silver ions (Ag^+) are reduced to metallic silver (Ag).
This silver deposits on the inner wall of the test tube, forming a shiny "silver mirror".
Reaction:

$$CH_3CHO + 2[Ag(NH_3)_2]^+ + 3OH^- \rightarrow CH_3COO^- + 2Ag \downarrow + 4NH_3 + 2H_2O$$

Step 4: Final Answer:
Acetaldehyde reduces Tollen's reagent to produce a silver mirror.

> Quick Tip
>
> This test is used to distinguish between aldehydes (positive) and ketones (negative).

24(ii). Write the structure of zwitter ion of sulfanilic acid.

Correct Answer: $^+NH_3 - C_6H_4 - SO_3^-$

Solution:

Step 1: Understanding the Concept:
A zwitterion is a dipolar ion formed by the internal transfer of a proton from an acidic group to a basic group within the same molecule.

Step 3: Detailed Explanation:
Sulfanilic acid ($NH_2 - C_6H_4 - SO_3H$) contains a basic amino group ($-NH_2$) and an acidic sulfonic acid group ($-SO_3H$).
The proton (H^+) from the $-SO_3H$ group is transferred to the $-NH_2$ group.

This results in a structure where the nitrogen carries a positive charge and the sulfonate group carries a negative charge.
Structure:

$$\text{A benzene ring with } {}^{+}NH_3 \text{ at one end and } SO_3^{-} \text{ at the para position.}$$

Step 4: Final Answer:
The zwitterion form of sulfanilic acid is ${}^{+}NH_3 - C_6H_4 - SO_3^{-}$.

> Quick Tip
>
> Zwitterions have high melting points and are generally soluble in water but insoluble in organic solvents.

24(iii). Write the reaction between benzene diazonium chloride and phenol in alkaline medium.

Correct Answer: Formation of p-hydroxyazobenzene (orange dye).

Solution:

Step 1: Understanding the Concept:
Azo coupling is an electrophilic aromatic substitution reaction where a diazonium cation reacts with an activated aromatic ring (like phenol).

Step 3: Detailed Explanation:
Benzene diazonium chloride ($C_6H_5N_2^{+}Cl^{-}$) reacts with phenol in a cold, weakly alkaline medium ($pH \approx 9 - 10$).
The diazonium cation attacks the para position of the phenol ring.
The product is p-hydroxyazobenzene, which is an orange-coloured dye.
Reaction:

$$C_6H_5 - N \equiv N^{+}Cl^{-} + C_6H_5OH \xrightarrow{OH^{-}} C_6H_5 - N = N - C_6H_4 - OH + HCl$$

Step 4: Final Answer:
The reaction produces p-hydroxyazobenzene, an orange azo dye.

Quick Tip

Coupling with phenol gives an orange dye, while coupling with aniline gives a yellow dye (p-aminoazobenzene).

25(i). Define Common ion effect.

Correct Answer: Suppression of dissociation of a weak electrolyte by the addition of a strong electrolyte having a common ion.

Solution:

Step 1: Understanding the Concept:
The common ion effect is an application of Le Chatelier's principle to ionic equilibria.

Step 3: Detailed Explanation:
When a strong electrolyte and a weak electrolyte containing a common ion are dissolved in the same solution, the strong electrolyte dissociates completely, increasing the concentration of the common ion.
According to Le Chatelier's principle, the equilibrium of the weak electrolyte shifts in the direction that consumes the common ion (the reverse direction).
As a result, the degree of dissociation of the weak electrolyte decreases.
Example: Adding CH_3COONa (strong) to CH_3COOH (weak) suppresses the ionization of acetic acid.

Step 4: Final Answer:
The common ion effect is the reduction in solubility or ionization of an electrolyte when another compound containing the same ion is added.

Quick Tip

This effect is the basis for the preparation of buffer solutions and the qualitative analysis of salt cations.

25(ii). Write preparation of glucose from starch.

Correct Answer: Hydrolysis of starch with dilute H_2SO_4.

Solution:

Step 1: Understanding the Concept:
Starch is a polysaccharide made up of many glucose units linked by glycosidic bonds. Hydrolysis breaks these bonds.

Step 3: Detailed Explanation:
In industrial production, starch is boiled with dilute sulfuric acid (H_2SO_4) at 393 K under $2-3$ atm pressure.
The glycosidic linkages are cleaved by water, yielding a large number of glucose molecules.
Reaction:

$$(C_6H_{10}O_5)_n + nH_2O \xrightarrow[\text{393 K, 2−3 atm}]{H^+} nC_6H_{12}O_6(\text{Glucose})$$

Excess acid is neutralized with chalk (calcium carbonate), and the solution is concentrated to get glucose crystals.

Step 4: Final Answer:
Glucose is prepared commercially by the acid hydrolysis of starch.

> Quick Tip
>
> Starch consists of two components: Amylose (linear) and Amylopectin (branched). Both yield glucose on complete hydrolysis.

26(i). Draw the structure of 2, 4 − dinitrophenylhydrazone of acetaldehyde.

Correct Answer: $CH_3 - CH = N - NH - C_6H_3(NO_2)_2$

Solution:

Step 1: Understanding the Concept:
Aldehydes react with 2,4-dinitrophenylhydrazine (2,4-DNP) to form crystalline solids called 2,4-dinitrophenylhydrazones.

Step 3: Detailed Explanation:
The reaction involves the loss of a water molecule from the carbonyl oxygen of the aldehyde and the two hydrogen atoms of the primary amino group of 2,4-DNP.
The structure consists of an ethylidene group linked to the nitrogen of the hydrazine moiety.
Chemical Formula:

$$CH_3 - CH = N - NH - C_6H_3(NO_2)_2$$

The benzene ring has nitro groups at the 2 and 4 positions relative to the point of attachment of the nitrogen atom.

Step 4: Final Answer:
The structure is the condensation product of acetaldehyde and 2,4-DNP.

> Quick Tip
>
> This is a standard qualitative test for the presence of a carbonyl group. The product is usually an orange or yellow precipitate.

26(ii). The rate of $A + B \rightarrow P$ is 3.6×10^{-2} mol/dm^3/s. When $[A] = 0.2$ M and $[B] = 0.1$ M. Calculate the rate constant if reaction is first order in B and second order in A.

Correct Answer: 9 L^2 mol^{-2} s^{-1}

Solution:

Step 1: Understanding the Concept:
The rate law expresses the relationship between the reaction rate and the concentrations of the reactants.

Step 2: Key Formula or Approach:

$$Rate = k[A]^2[B]^1$$

Step 3: Detailed Explanation:
Given:
$Rate = 3.6 \times 10^{-2}$ mol L^{-1} s^{-1}
$[A] = 0.2$ M
$[B] = 0.1$ M
Substitute into the rate law:

$$3.6 \times 10^{-2} = k(0.2)^2(0.1)$$

$$3.6 \times 10^{-2} = k(0.04)(0.1)$$

$$3.6 \times 10^{-2} = k(0.004)$$

$$k = \frac{3.6 \times 10^{-2}}{4 \times 10^{-3}} = \frac{36 \times 10^{-3}}{4 \times 10^{-3}}$$

$$k = 9$$

Units for 3rd order: $M^{-2}s^{-1} = L^2mol^{-2}s^{-1}$.

Step 4: Final Answer:
The rate constant is 9 L^2 mol^{-2} s^{-1}.

Quick Tip

Double check the exponents! "Second order in A" means concentration of A is squared.

Section D

27(i) (a). Define Isotonic solution.

Correct Answer: Solutions having the same osmotic pressure at the same temperature.

Solution:

Step 1: Understanding the Concept:
Osmotic pressure depends on the molarity of the solution. When two solutions are separated by a semi-permeable membrane and no net flow of solvent occurs, they are isotonic.

Step 3: Detailed Explanation:
Two solutions of different substances are called isotonic if they have the same molar concentration ($C_1 = C_2$) at the same temperature.
Since $\pi = CRT$, if concentrations and temperatures are the same, their osmotic pressures (π) will be identical.
Example: $0.91\%(w/v)$ $NaCl$ solution is isotonic with human red blood cells.

Step 4: Final Answer:
Isotonic solutions have equal osmotic pressure.

Quick Tip

Hypertonic solutions have higher osmotic pressure, and hypotonic solutions have lower osmotic pressure compared to a reference solution.

27(i) (b). Define Molecularity of reaction.

Correct Answer: Total number of reactant molecules taking part in an elementary chemical reaction.

Solution:

Step 1: Understanding the Concept:
Molecularity is a theoretical concept applicable only to elementary (single-step) reactions.

Step 3: Detailed Explanation:
Molecularity is the number of reacting species (atoms, ions, or molecules) that must collide simultaneously to bring about a chemical reaction.
It can be unimolecular (1), bimolecular (2), or trimolecular (3).
Molecularity is always a whole number and cannot be zero, negative, or fractional.

Step 4: Final Answer:
Molecularity is the number of species colliding in an elementary step.

Quick Tip

While "Order" is determined experimentally, "Molecularity" is derived from the reaction mechanism. For complex reactions, molecularity has no overall significance.

27(ii). State and explain Hess's law of constant heat summation.

Correct Answer: Total enthalpy change is independent of the path taken.

Solution:

Step 1: Understanding the Concept:
Hess's Law is a consequence of the fact that enthalpy (H) is a state function.

Step 3: Detailed Explanation:
Statement: The total enthalpy change for a chemical reaction is the same regardless of whether the reaction occurs in one step or in several steps.

Explanation: Consider a reaction $A \rightarrow D$ with enthalpy change ΔH.
If the reaction occurs via steps:
1. $A \rightarrow B$ (ΔH_1)
2. $B \rightarrow C$ (ΔH_2)
3. $C \rightarrow D$ (ΔH_3)
Then, according to Hess's Law:

$$\Delta H = \Delta H_1 + \Delta H_2 + \Delta H_3$$

This law allows us to calculate enthalpies of reactions that are difficult to measure directly by summing enthalpies of other known reactions.

Step 4: Final Answer:
Hess's Law states $\Delta H_{total} = \sum \Delta H_{steps}$.

> Quick Tip
>
> Treat thermochemical equations like algebraic equations; you can add, subtract, and multiply them.

28(i) (a). Define Schottky defect.

Correct Answer: Point defect where equal number of cations and anions are missing from the lattice.

Solution:

Step 1: Understanding the Concept:
Schottky defect is a stoichiometric defect found in highly ionic compounds where the size of cations and anions is similar.

Step 3: Detailed Explanation:
In an ionic crystal, if an equal number of cations and anions are missing from their regular lattice sites, it creates vacancies.
This maintains the electrical neutrality of the crystal.
Since mass decreases but volume remains the same, the density of the crystal decreases.
Example: $NaCl, KCl, CsCl$.

Step 4: Final Answer:
Schottky defect is a vacancy defect that reduces the density of ionic solids.

Quick Tip

Think: "Schottky = Shot key" (something is missing). Frenkel defect, on the other hand, involves an ion just moving to an interstitial site (density stays the same).

28(i) (b). Define Ferromagnetism.

Correct Answer: A property where substances are strongly attracted by a magnetic field and can be permanently magnetized.

Solution:

Step 1: Understanding the Concept:
Magnetism in solids arises from the alignment of magnetic moments of electrons. Ferromagnetism is the strongest form of magnetism.

Step 3: Detailed Explanation:
In ferromagnetic substances, the individual magnetic moments of atoms (domains) are spontaneously aligned in the same direction even in the absence of an external magnetic field.
When placed in a magnetic field, all these domains get oriented in the direction of the field, resulting in a very strong magnetic effect.
Unlike paramagnetic substances, ferromagnetic materials remain magnetized even after the external magnetic field is removed, making them suitable for permanent magnets.
Common examples include Iron (Fe), Cobalt (Co), Nickel (Ni), and Gadolinium (Gd).

Step 4: Final Answer:
Ferromagnetism is the characteristic of materials that exhibit spontaneous and permanent magnetization.

Quick Tip

Remember that ferromagnetism is temperature-dependent. Above a certain temperature called the Curie temperature, a ferromagnetic substance becomes paramagnetic.

28(ii). Write the name of catalyst used in preparation of HDP.

Correct Answer: Ziegler-Natta catalyst.

Solution:

Step 1: Understanding the Concept:
High-Density Polyethylene (HDP) is produced under low pressure and temperature compared to Low-Density Polyethylene (LDP), requiring a specialized coordination catalyst.

Step 3: Detailed Explanation:
HDP is synthesized by the polymerization of ethene in a hydrocarbon solvent at $333 - 343$ K and $6 - 7$ atm pressure.
The catalyst used is the Ziegler-Natta catalyst, which is a mixture of Triethylaluminium ($Al(C_2H_5)_3$) and Titanium tetrachloride ($TiCl_4$).
This catalyst allows for the formation of linear, closely packed polymer chains.

Step 4: Final Answer:
The catalyst is the Ziegler-Natta catalyst.

> Quick Tip
>
> Karl Ziegler and Giulio Natta won the Nobel Prize for this discovery, which revolutionized the polymer industry.

28(iii). Draw structure of isoprene unit of natural rubber.

Correct Answer: $CH_2 = C(CH_3) - CH = CH_2$

Solution:

Step 1: Understanding the Concept:
Natural rubber is a linear polymer of isoprene (2-methyl-1,3-butadiene). The isoprene unit is the basic building block (monomer) of the polymer chain.

Step 3: Detailed Explanation:
The IUPAC name for isoprene is 2-methylbuta-1,3-diene.
It consists of a four-carbon chain with double bonds at the first and third positions and a methyl group branching from the second carbon.
Structure:

$$\begin{array}{c} \mathrm{CH_3} \\ | \\ \mathrm{CH_2 = C - CH = CH_2} \end{array}$$

In natural rubber, these units are linked in a cis-1,4 configuration, which gives rubber its elastic properties.

Step 4: Final Answer:
The structure of the isoprene unit is 2-methyl-1,3-butadiene.

Quick Tip

While natural rubber is cis-polyisoprene, "Gutta-percha" is the trans-isomer of polyisoprene, which is non-elastic.

29(i). Calculate effective atomic number of Fe^{2+} in $[Fe(CN)_6]^{4-}$. [Given : ($Z = 26$)]

Correct Answer: 36

Solution:

Step 1: Understanding the Concept:
Effective Atomic Number (EAN) is the total number of electrons surrounding the central metal atom/ion in a complex.

Step 2: Key Formula or Approach:

$$EAN = Z - X + Y$$

Where:
$Z = 26$ (Atomic number)
$X = 2$ (Oxidation state of Fe)
$Y = 2 \times 6 = 12$ (Electrons donated by 6 cyanide ligands)

Step 3: Detailed Explanation:
1. Oxidation state of Fe: $x + 6(-1) = -4 \Rightarrow x = +2$.
2. Electrons in Fe atom = 26.
3. Electrons in Fe^{2+} ion $= 26 - 2 = 24$.
4. Electrons donated by 6 CN^- ligands $= 6 \times 2 = 12$.
5. $EAN = 24 + 12 = 36$.
Since 36 is the atomic number of the noble gas Krypton (Kr), this complex is very stable.

Step 4: Final Answer:
The EAN of Iron in the complex is 36.

Quick Tip

If the EAN equals the atomic number of the next noble gas (36, 54, 86), the complex usually obeys the EAN rule.

29(ii). Draw neat and labelled diagram of lead accumulator.

Correct Answer:

Solution:

Step 1: Understanding the Concept:
A lead accumulator (or lead-acid battery) is a secondary electrochemical cell that can be recharged. It consists of several cells connected in series.

Step 3: Detailed Explanation:
A standard diagram of a lead accumulator must include the following labels:
1. **Anode (-):** A series of lead (Pb) plates.
2. **Cathode (+):** A series of lead plates packed with lead dioxide (PbO_2).
3. **Electrolyte:** Aqueous solution of sulfuric acid (H_2SO_4) with a concentration of about 38% by mass and density of 1.28 g/mL.
4. **Container:** Usually made of hard rubber or acid-resistant plastic.
5. **Separators:** Insulating sheets placed between anode and cathode plates to prevent short circuits while allowing the flow of ions.
The plates are arranged in an alternating fashion and connected in parallel to increase the current capacity of the battery.

Step 4: Final Answer:
The lead accumulator consists of Pb anode, PbO_2 cathode, and dilute H_2SO_4 electrolyte.

> Quick Tip
>
> During discharging, the density of H_2SO_4 decreases because water is produced and acid is consumed. Recharging the battery restores the acid concentration.

29(iii). Write two advantages of hydrogen – oxygen fuel cell.

Correct Answer: High efficiency and pollution-free operation.

Solution:

Step 1: Understanding the Concept:
Fuel cells are electrochemical cells that convert the chemical energy of a fuel directly into electrical energy. The $H_2 - O_2$ fuel cell is the most common type.

Step 3: Detailed Explanation:
Two major advantages of the $H_2 - O_2$ fuel cell are:
1. **High Efficiency:** Unlike thermal power plants which have an efficiency of 35-40%, fuel cells can achieve an efficiency of about 70% in converting chemical energy to electrical energy.
2. **Pollution-Free:** The only product formed during the cell reaction is water (H_2O). No

harmful gases like CO_2, SO_x, or NO_x are released, making it an eco-friendly source of energy.
3. **Continuous Operation:** Unlike conventional batteries, a fuel cell provides electricity continuously as long as the fuel and oxidant are supplied.

Step 4: Final Answer:
The main advantages are high thermodynamic efficiency and the production of pure water as a byproduct.

> Quick Tip
>
> In the Apollo space program, $H_2 - O_2$ fuel cells provided both electricity for the spacecraft and drinking water for the astronauts.

30(i). Convert ethanoic acid into ethanol.

Correct Answer: Reduction with $LiAlH_4$.

Solution:

Step 1: Understanding the Concept:
Carboxylic acids are resistant to reduction and require strong reagents to be converted into primary alcohols.

Step 3: Detailed Explanation:
Ethanoic acid (CH_3COOH) is treated with Lithium Aluminium Hydride ($LiAlH_4$) in dry ether, followed by acid hydrolysis.
This process reduces the carboxyl group ($-COOH$) to a primary alcohol group ($-CH_2OH$).
Reaction:

$$CH_3COOH \xrightarrow[ii) H_3O^+]{i) LiAlH_4/\text{ether}} CH_3CH_2OH$$

Step 4: Final Answer:
Reduction of ethanoic acid yields ethanol.

> Quick Tip
>
> $NaBH_4$ is not strong enough to reduce carboxylic acids. Only $LiAlH_4$ or B_2H_6 can do this directly.

30(ii). Explain the mechanism of alkaline hydrolysis of bromomethane.

Correct Answer: Single-step S_N2 mechanism with inversion of configuration.

Solution:

Step 1: Understanding the Concept:
The hydrolysis of primary alkyl halides like bromomethane (CH_3Br) follows a second-order nucleophilic substitution (S_N2) mechanism.

Step 3: Detailed Explanation:
1. **Reaction:** $CH_3Br + OH^- \rightarrow CH_3OH + Br^-$.
2. **Mechanism:** This is a single-step concerted process.
3. **Attack:** The nucleophile (OH^-) attacks the carbon atom from the side opposite to the leaving group (Br^-) (back-side attack).
4. **Transition State:** A pentacoordinate transition state is formed where the $C - OH$ bond is partially formed and the $C - Br$ bond is partially broken.
5. **Result:** As the Br^- leaves, the configuration of the carbon atom is inverted (Walden Inversion), much like an umbrella turning inside out in a strong wind.

Step 4: Final Answer:
The mechanism is a one-step S_N2 process involving a transition state and Walden inversion.

> Quick Tip
>
> Rate $= k[CH_3Br][OH^-]$. The reaction is bimolecular because two species are involved in the rate-determining step.

31(i). Acetic acid is 5% ionised in its decimolar solution. Calculate the dissociation constant of acetic acid.

Correct Answer: 2.5×10^{-4}

Solution:

Step 1: Understanding the Concept:
Ostwald's dilution law relates the dissociation constant (K_a) of a weak acid to its concentration (C) and degree of dissociation (α).

Step 2: Key Formula or Approach:

$$K_a = C\alpha^2$$

(valid when $\alpha < 5\%$)

Step 3: Detailed Explanation:
Given:
Percentage ionisation = 5%
Degree of dissociation, $\alpha = 5/100 = 0.05$
Decimolar solution means $C = 0.1$ M
Now, calculate K_a:

$$K_a = 0.1 \times (0.05)^2$$

$$K_a = 0.1 \times 0.0025$$

$$K_a = 0.00025 = 2.5 \times 10^{-4}$$

Step 4: Final Answer:
The dissociation constant K_a is 2.5×10^{-4}.

Quick Tip

"Decimolar" is 0.1 M, "Centimolar" is 0.01 M, and "Millimolar" is 0.001 M. Always check these prefixes.

31(ii). Write chemical formula of epsom salt. Give two uses of H_2SO_4.

Correct Answer: $MgSO_4 \cdot 7H_2O$. Uses: Manufacture of fertilizers and in lead storage batteries.

Solution:

Step 1: Understanding the Concept:
Epsom salt is a hydrated magnesium sulfate. Sulfuric acid is known as the "King of Chemicals" due to its widespread industrial applications.

Step 3: Detailed Explanation:
1. **Epsom Salt:** The chemical formula is $MgSO_4 \cdot 7H_2O$ (Magnesium sulfate heptahydrate).
2. **Uses of H_2SO_4:**
• **Fertilizers:** It is used to manufacture ammonium sulfate and superphosphate of lime.

- **Batteries:** It is used as an electrolyte in lead-acid storage batteries (car batteries).
- **Refining:** Used in petroleum refining and as a dehydrating agent in labs.

Step 4: Final Answer:
Formula: $MgSO_4 \cdot 7H_2O$. Main uses include fertilizer production and battery electrolytes.

Quick Tip

In car batteries, the concentration of sulfuric acid used is typically around 38%.
