Maharashtra Board Class 12 Chemistry Question Paper with Solutions(Memory Based)

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.

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 (often hydrogen) and an oxidizing agent (often oxygen) into electricity through a pair of redox reactions.
In a standard Hydrogen-Oxygen ($H_2 - O_2$) fuel cell, the electrolyte serves as the medium for the movement of ions between the electrodes.

Step 2: Detailed Explanation:
The most commonly used electrolyte in these cells is a concentrated solution of potassium hydroxide (KOH) because it provides high ionic conductivity and facilitates the alkaline medium required for the reaction.
The electrode reactions are:
At Anode: $2H_2(g) + 4OH^-(aq) \rightarrow 4H_2O(l) + 4e^-$
At Cathode: $O_2(g) + 2H_2O(l) + 4e^- \rightarrow 4OH^-(aq)$
The hydroxyl ions (OH^-) are supplied by the aqueous KOH electrolyte.

Step 3: Final Answer:
Therefore, the electrolyte used is aqueous KOH.

Quick Tip

Remember that "Alkaline Fuel Cells" (AFCs) specifically use aqueous potassium hydroxide as the electrolyte because it has the highest conductivity among the alkali metal hydroxides.

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 of an atom is the charge it would carry if all bonds to it were completely ionic.
The sum of oxidation states of all atoms in a neutral molecule must equal zero.

Step 2: Key Formula or Approach:
The chemical formula $HOBrO_2$ can be rewritten as $HBrO_3$ (Bromic acid).
Let the oxidation state of Bromine (Br) be x.
Standard oxidation states:
Hydrogen $(H) = +1$
Oxygen $(O) = -2$

Step 3: Detailed Explanation:
Applying the rule for the neutral molecule $HBrO_3$:

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

$$1 + x - 6 = 0$$

$$x - 5 = 0$$

$$x = +5$$

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

> **Quick Tip**
>
> Always simplify the molecular formula first. $HOBrO_n$ represents halic acids where the oxidation state of the halogen is usually $(2n + 1) - 2$ (accounting for the H). For $n = 2$, it is $2(2) + 1 = 5$.

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 methyl cyanide (CH_3CN).
It contains two carbon atoms. The synthesis involves increasing the carbon chain length starting from an alkyl halide.

Step 2: Key Formula or Approach:
Reaction of alkyl halides with potassium cyanide (KCN) yields alkyl cyanides (nitriles), whereas reaction with silver cyanide ($AgCN$) yields alkyl isocyanides.

Step 3: Detailed Explanation:
To obtain CH_3CN (2 carbons), we must start with an alkyl halide containing 1 carbon atom, which is methyl chloride (CH_3Cl).
The reaction is:

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

If we used ethyl chloride (C_2H_5Cl), the product would be propionitrile (C_2H_5CN).
If we used $AgCN$, the product would be methyl isocyanide (CH_3NC).

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

> Quick Tip
>
> KCN is ionic and provides CN^- ions leading to Cyanides (C-linkage). AgCN is covalent and attacks via Nitrogen leading to Isocyanides (N-linkage). Always count the total carbons in the final nitrile name.

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

Solution:

Step 1: Understanding the Concept:
Solutions are classified based on the physical state of the solute and the solvent.
Carbonated water (such as soda water) consists of Carbon Dioxide (CO_2) dissolved in water (H_2O) under pressure.

Step 2: Detailed Explanation:
In carbonated water:
The solute is Carbon Dioxide (CO_2), which is a gas.
The solvent is water (H_2O), which is a liquid.
Since a gas is dissolved in a liquid, it is a "gas in liquid" type of solution.

Step 3: Final Answer:
Carbonated water is an example of a gas in liquid solution.

> Quick Tip
>
> Henry's Law describes the solubility of gases in liquids, which is the foundational principle for the manufacturing of carbonated beverages.

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 unit for the rate constant k is given by:

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

where n is the order of the reaction.

Step 3: Detailed Explanation:
The given unit is "per second" or s^{-1}.
Substituting the general formula:

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

For the term $(\text{mol L}^{-1})^{1-n}$ to be equal to 1 (unity), the exponent must be zero.

$$1 - n = 0$$

$$n = 1$$

This indicates a first-order reaction.

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

Quick Tip

For a quick check:
0th order: mol $\text{L}^{-1}s^{-1}$
1st order: s^{-1}
2nd order: L $\text{mol}^{-1}s^{-1}$

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, the change in internal energy (ΔU) of a system is the sum of the heat (q) exchanged and the work (w) done.

Step 2: Key Formula or Approach:

$$\Delta U = q + w$$

Sign conventions (IUPAC):
Heat released by the system: $q = -ve$
Work done by the system on surroundings: $w = -ve$

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

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

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

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

Quick Tip

Always look for keywords like "released" or "by the system" to assign a negative sign, and "absorbed" or "on the system" for a positive sign in chemistry thermodynamics.

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:
Isomerism in coordination compounds arises when compounds have the same molecular formula but different arrangements of atoms.

Step 2: Detailed Explanation:
Linkage isomerism occurs when an ambidentate ligand is present in the complex.
An ambidentate ligand is a ligand that has more than one donor atom but coordinates through only one atom at a time.
In the given complexes, the ligand is the nitrite ion (NO_2^-).
1. In $[Co(NH_3)_5(NO_2)]^{2+}$, the ligand is bonded through the Nitrogen atom (nitro-N).
2. In $[Co(NH_3)_5(ONO)]^{2+}$, the ligand is bonded through the Oxygen atom (nitrito-O).
Since the difference is in the mode of attachment (linkage) of the ligand to the metal, they are linkage isomers.

Step 3: Final Answer:
They are linkage isomers.

Quick Tip

Look for ligands like NO_2^-/ONO^-, SCN^-/NCS^-, 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) $NH_3 < R-NH_2 > R_2NH > R_3N$
(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:
The basicity of amines depends on the availability of the lone pair of electrons on the Nitrogen atom.
Factors affecting basicity include:
1. Inductive effect (+I effect of alkyl groups increases electron density).
2. Solvation effect (hydrogen bonding with water stabilizes the cation).
3. Steric hindrance (bulky groups hinder the approach of protons).

Step 2: Detailed Explanation:
In the gas phase, the order is strictly $3^\circ > 2^\circ > 1^\circ > NH_3$.
However, in aqueous solution, the interplay of the +I effect and solvation/steric factors makes the secondary (2°) amine the most basic.
For Methyl groups ($R = CH_3$): $(CH_3)_2NH > CH_3NH_2 > (CH_3)_3N > NH_3$
For Ethyl groups ($R = C_2H_5$): $(C_2H_5)_2NH > (C_2H_5)_3N > C_2H_5NH_2 > NH_3$
In general, ammonia (NH_3) is always the least basic because it lacks the +I effect of alkyl groups. The secondary amine (R_2NH) is generally the most basic.
Option (d) correctly places NH_3 at the bottom and R_2NH as greater than RNH_2 and R_3N.

Step 3: Final Answer:
The order is $NH_3 < R - NH_2 < R_2NH > R_3N$.

Quick Tip

Remember the "213" rule for methyl amines and "231" rule for ethyl amines in aqueous solution. In both cases, the 2° amine is the strongest base.

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 (IE_1) is the energy required to remove the first electron from an isolated gaseous atom.
In a transition series, IE_1 generally increases from left to right due to increasing nuclear charge and decreasing atomic size.

Step 2: Detailed Explanation:
Zinc (Zn) is the last element of the 3d series.
Electronic configuration of Zn: $[Ar]3d^{10}4s^2$.
In Zinc, both the 3d and 4s subshells are completely filled, which provides extra stability.
Additionally, because Zinc is at the end of the series, it has a high effective nuclear charge acting on its valence electrons.
Removing an electron from the stable, fully-filled $4s^2$ orbital of Zinc requires significantly more energy compared to elements like Sc, Co, or Cu.

Step 3: Final Answer: Zinc (Zn) has the highest first ionization enthalpy among the given options.

Quick Tip

Full-filled ($d^{10}s^2$) and half-filled (d^5s^1) configurations often show deviations in IE trends. Zn is particularly high because the electron is removed from a stable $4s^2$ shell with a high nuclear charge.

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.

$$HCl \rightarrow H^+ + Cl^-$$

The concentration of H^+ ions is equal to the concentration of the acid for a monoprotic strong acid.

Step 2: Key Formula or Approach:
1. $pH = -\log[H^+]$
2. $pH + pOH = 14$ (at 298 K)

Step 3: Detailed Explanation:
Given: $[HCl] = 0.01$ M $= 10^{-2}$ M
Therefore, $[H^+] = 10^{-2}$ 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**
>
> Don't confuse pH and pOH. For acids, first find the pH from $[H^+]$, then subtract from 14 to get pOH.

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 is an alkaline earth metal (Group 2) and Selenium is a chalcogen (Group 16). Metals react with non-metals to form binary ionic compounds.

Step 2: Detailed Explanation:
Magnesium has a valency of +2 (Mg^{2+}).
Selenium has a valency of -2 (Se^{2-}) when forming selenides.
The reaction is:

$$Mg + Se \rightarrow MgSe$$

The name of the resulting compound $MgSe$ is Magnesium selenide.

Step 4: Final Answer:
The name of the product is Magnesium selenide.

Quick Tip

Binary compounds of metals with Group 16 elements end in "-ide" (e.g., Oxide, Sulfide, Selenide, Telluride).

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

Correct Answer: m^{-1} (per meter)

Solution:

Step 1: Understanding the Concept:
The cell constant (G^*) of a conductivity cell is defined as the ratio of the distance between the electrodes (l) to the area of cross-section of the electrodes (a).

Step 2: Key Formula or Approach:

$$G^* = \frac{l}{a}$$

Step 3: Detailed Explanation:
In the SI system:
The unit of length (l) is meters (m).
The unit of area (a) is square meters (m^2).
Substituting into the formula:

$$\text{Unit of } G^* = \frac{m}{m^2} = m^{-1}$$

(Note: cm^{-1} is frequently used in laboratories, but m^{-1} is the standard SI unit).

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

Quick Tip

Always distinguish between common units (cm^{-1}) and SI units (m^{-1}) in competitive exams.

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

Correct Answer: Promethium

Solution:

Step 1: Understanding the Concept:
The lanthanide series consists of 14 elements from Cerium ($Z = 58$) to Lutetium ($Z = 71$). Most lanthanides are non-radioactive and occur naturally.

Step 2: Detailed Explanation:
Promethium (Pm, atomic number 61) is the only lanthanide element that does not have any stable isotopes. It is produced synthetically and is radioactive.

Step 3: Final Answer:
The radioactive element in the lanthanide series is Promethium.

> **Quick Tip**
>
> Remember: Promethium is the "odd one out" in the lanthanide series because it is synthetic and radioactive, whereas all actinoids are radioactive.

2(iv). Complete the following reaction :
Phenol + $3H_2 \xrightarrow[433K]{Nickel} ?$

Correct Answer: Cyclohexanol

Solution:

Step 1: Understanding the Concept:
The reaction is the catalytic hydrogenation of phenol. Phenol is an aromatic compound containing a benzene ring.

Step 2: Detailed Explanation:
When phenol is treated with hydrogen gas in the presence of a Nickel catalyst at a temperature around 433 K, the aromatic ring undergoes complete reduction (addition of hydrogen).
The three double bonds of the benzene ring are saturated.
The reaction is:

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

The product formed is a cyclic secondary alcohol called Cyclohexanol.

Step 3: Final Answer:
The product is Cyclohexanol.

Quick Tip

Catalytic hydrogenation of any benzene derivative using Ni/Heat usually results in the corresponding cyclohexane derivative.

2(v). Write the IUPAC name of :
2-hydroxybenzaldehyde (structure shown in image)

Correct Answer: 2-Hydroxybenzaldehyde

Solution:

Step 1: Understanding the Concept:
The given compound has a benzene ring with two functional groups: an aldehyde group ($-CHO$) and a hydroxyl group ($-OH$).

Step 2: Detailed Explanation:
According to IUPAC priority rules:
1. The aldehyde group ($-CHO$) has higher priority than the hydroxyl group ($-OH$).
2. Therefore, the parent compound is benzaldehyde.
3. The Carbon atom attached to the $-CHO$ group is numbered 1.
4. The Carbon atom attached to the $-OH$ group gets the next lowest possible number, which is 2.
The $-OH$ group is treated as a substituent called "hydroxy".
The name becomes 2-hydroxybenzaldehyde. (Commonly known as Salicylaldehyde).

Step 3: Final Answer:
The IUPAC name is 2-Hydroxybenzaldehyde.

Quick Tip

Priority order of functional groups is crucial: $-COOH > -SO_3H > -COOR > -COX > -CONH_2 > -CN > -CHO >> C = O > -OH > -NH_2$.

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

Correct Answer: 175.01 pm (approx. 175 pm)

Solution:

Step 1: Understanding the Concept:
In a face-centered cubic (fcc) lattice, the atoms touch each other along the face diagonal.

Step 2: Key Formula or Approach:
For an fcc unit cell:

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

or

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

where r is the radius of the atom and a is the edge length.

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

$$r = \frac{495}{2 \times 1.4142}$$

$$r = \frac{495}{2.8284}$$

$$r \approx 175.01 \text{ pm}$$

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

Quick Tip

Remember relations for cubic systems:
Simple Cubic: $a = 2r$
BCC: $a = \frac{4r}{\sqrt{3}}$
FCC: $a = \frac{4r}{\sqrt{2}} = 2\sqrt{2}r$

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

Correct Answer: Polytetrafluoroethene (PTFE)

Solution:

Step 1: Understanding the Concept:
Teflon is a synthetic fluoropolymer of tetrafluoroethene. It is well-known for its non-reactive and non-stick properties.

Step 2: Detailed Explanation:
The monomer for Teflon is tetrafluoroethene ($CF_2 = CF_2$).
When it undergoes polymerization under high pressure and in the presence of a catalyst, it forms the polymer:

$$n(CF_2 = CF_2) \rightarrow [-CF_2 - CF_2-]_n$$

The name of this polymer is Polytetrafluoroethene.

Step 3: Final Answer:
The chemical name of Teflon is Polytetrafluoroethene.

> Quick Tip
>
> Teflon is chemically inert and has high thermal stability, which is why it is used for coating non-stick frying pans and as a lubricant.

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

Correct Answer: Silver nanoparticles (Ag-NPs)

Solution:

Step 1: Understanding the Concept:
Nanotechnology utilizes materials at the nanoscale (1-100 nm). Certain metal nanoparticles exhibit enhanced antimicrobial properties.

Step 2: Detailed Explanation:
Silver nanoparticles are widely recognized for their potent antibacterial, antifungal, and antiviral properties.
They release silver ions (Ag^+) which interact with the bacterial cell wall and plasma membrane, causing cell death.
They are used in water purifiers, surgical instruments, and bandages to prevent infections.

Step 3: Final Answer:
Silver nanoparticles are used as highly effective bacterial disinfectants.

Quick Tip

Silver has been used since ancient times for its medicinal properties; the "nano" form simply provides a much larger surface area for reaction, making it more efficient.

3(a). Define : Isomorphism

Correct Answer: Two or more substances having the same crystal structure are said to be isomorphous and the phenomenon is called isomorphism.

Solution:

Step 1: Understanding the Concept:
Isomorphism is a phenomenon where different chemical substances crystallize in the same structural form.
This usually happens when the substances have the same atomic ratio and similar chemical properties.

Step 2: Detailed Explanation:
In isomorphous substances, the constituent atoms or ions are arranged in an identical manner in the crystal lattice.
A key requirement is that the ratio of atoms in the chemical formula must be the same.
For example:
1. NaF and MgO (Atomic ratio 1:1)
2. K_2SO_4 and K_2SeO_4 (Atomic ratio 2:1:4)
These pairs have similar crystal shapes because the sizes and arrangement of their ions are comparable.

Step 3: Final Answer:
Isomorphism is defined as the phenomenon in which two or more substances possess the same crystal structure.

Quick Tip

Isomorphism depends on the "Atomic Ratio". If two compounds have different atomic ratios (e.g., NaCl and $CaCl_2$), they cannot be isomorphous.

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 arrangement of particles. This large-scale structure is built by repeating a fundamental building block in three dimensions.

Step 2: Detailed Explanation:
The unit cell is the basic functional unit of the crystal.
When a unit cell is translated (repeated) in different directions, it generates the entire space lattice.
It is characterized by its dimensions along the three axes (a, b, c) and the angles between them (α, β, γ).

Step 3: Final Answer:
A unit cell is the smallest repeating structural unit of a crystalline solid that, when repeated in all directions, produces the complete crystal lattice.

> Quick Tip
>
> Think of a unit cell like a single brick in a large brick wall. The wall is the crystal lattice, and the individual brick is the unit cell.

4(i). Explain the trends in the following properties of group 17 elements : Atomic radii

Correct Answer: Atomic radii of group 17 elements increase down the group from Fluorine to Astatine.

Solution:

Step 1: Understanding the Concept:
Atomic radius is the distance from the center of the nucleus to the outermost shell containing electrons.

Step 2: Detailed Explanation:
In Group 17 (Halogens), as we move down the group from F to Cl, Br, I, and At:
1. A new principal energy level (shell) is added at each successive element.
2. Although the nuclear charge increases, the effect of adding a new shell is more dominant.
3. The increased distance of the outermost electrons from the nucleus and the shielding effect of inner electrons result in an increase in the size of the atom.
Order: $F < Cl < Br < I < At$.

Step 3: Final Answer:
The atomic radii increase down the group due to the addition of new electronic shells.

Quick Tip

Down the group: Number of shells increases → Shielding effect increases → Effective nuclear charge decreases → Atomic size increases.

4(ii). Explain the trends in the following properties of group 17 elements : Electronegativity

Correct Answer: Electronegativity decreases down the group 17.

Solution:

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

Step 2: Detailed Explanation:
As we move down Group 17:
1. The atomic size increases, which means the shared pair of electrons is further away from the nucleus.
2. The effective nuclear attraction on the shared pair decreases.
3. Consequently, the ability of the atom to attract electrons decreases.
Fluorine is the most electronegative element in the entire periodic table.
Order: $F > Cl > Br > I$.

Step 3: Final Answer:
Electronegativity decreases down the group as the atomic size increases.

Quick Tip

Electronegativity is inversely proportional to atomic size. Smaller atoms have higher electronegativity.

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5. Explain Homoleptic and Heteroleptic complexes with example.

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

Solution:

Step 1: Understanding the Concept:
Coordination complexes are classified based on the variety of ligands attached to the central metal atom or ion.

Step 2: Detailed Explanation:
1. Homoleptic Complexes:
These are complexes in which the metal is bound to only one kind of donor groups or ligands.
Example: $[Co(NH_3)_6]^{3+}$. Here, all six ligands are ammonia (NH_3).
Another example: $[Fe(CN)_6]^{4-}$.

2. Heteroleptic Complexes:
These are complexes in which the metal is bound to more than one kind of donor groups or ligands.
Example: $[Co(NH_3)_4Cl_2]^+$. Here, there are two types of ligands: four ammonia molecules and two chloride ions.
Another example: $[Pt(NH_3)_2Cl_2]$.

Step 3: Final Answer:
Homoleptic complexes have identical ligands (e.g., $[Co(NH_3)_6]^{3+}$), whereas heteroleptic complexes have different types of ligands (e.g., $[Co(NH_3)_4Cl_2]^+$).

Quick Tip

Prefix "Homo-" means same, and "Hetero-" means different. This applies to the nature of the ligands surrounding the metal.

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

Correct Answer: Glucose is oxidized to gluconic acid by bromine water.

Solution:

Step 1: Understanding the Concept:
Bromine water (Br_2/H_2O) is a mild oxidizing agent. It specifically oxidizes the aldehyde group ($-CHO$) of glucose without affecting the hydroxyl groups.

Step 2: Detailed Explanation:
Glucose contains one aldehyde group and five hydroxyl groups. When treated with bromine water, the aldehyde group is oxidized to a carboxylic acid group ($-COOH$).
The product formed is gluconic acid.
Reaction:

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

This reaction confirms the presence of an aldehyde group in the open-chain structure of glucose.

Step 3: Final Answer:
Glucose reacts with bromine water to form gluconic acid.

> **Quick Tip**
>
> Bromine water is "mild". If a strong oxidizing agent like conc. HNO_3 were used, both the aldehyde and the primary alcohol group would be oxidized to form saccharic acid.

6(b). Define – Enantiomers

Correct Answer: Optical isomers which are non-superimposable mirror images of each other are called enantiomers.

Solution:

Step 1: Understanding the Concept:
Enantiomers are a type of stereoisomers that occur in molecules containing a chiral center (a carbon atom bonded to four different groups).

Step 2: Detailed Explanation:
Enantiomers have identical physical properties like melting point, boiling point, and solubility, but they differ in two ways:
1. They rotate the plane of plane-polarized light in opposite directions (dextrorotatory and laevorotatory).
2. They react differently with other chiral reagents.
A classic example is d-lactic acid and l-lactic acid.

Step 3: Final Answer:
Enantiomers are optical isomers that are non-superimposable mirror images of each other.

> **Quick Tip**
>
> Think of your left and right hands. They are mirror images but cannot be perfectly superimposed on each other. This is the essence of chirality and enantiomerism.

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).
In a one-dimensional (1D) nanostructure, two dimensions are in the nanoscale, while one dimension is outside it (usually longer).

Step 2: Detailed Explanation:
One-dimensional nanostructures are those where electrons are confined in two directions and free to move in only one direction.
Common examples include:
1. Nanowires: Long, wire-like structures with diameters less than 100 nm.
2. Nanorods: Similar to nanowires but typically shorter in length.
3. Carbon Nanotubes (CNTs) are also often considered 1D structures.

Step 3: Final Answer:
Examples of 1D nanostructures are nanowires and nanorods.

Quick Tip

0D = all dimensions ¡ 100nm (e.g. quantum dots).
1D = two dimensions ¡ 100nm (e.g. nanowires).
2D = one dimension ¡ 100nm (e.g. thin films/graphene).

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 generally quite stable. However, they can be cleaved (hydrolyzed) by heating them with dilute sulfuric acid under pressure.

Step 2: Detailed Explanation:
Hydrolysis of an unsymmetrical ether like ethyl methyl ether ($CH_3 - O - C_2H_5$) results in the formation of two different alcohols.
The bond between the Oxygen and the alkyl groups is broken, and water adds across it.
The reaction is:

$$CH_3 - O - C_2H_5 + H_2O \xrightarrow{\text{dil. } H_2SO_4, \Delta, \text{pressure}} CH_3OH + C_2H_5OH$$

Products: Methanol and Ethanol.

Step 3: Final Answer:
The hydrolysis of ethyl methyl ether yields methanol and ethanol.

> Quick Tip
>
> Ethers are more commonly cleaved using hot concentrated HI or HBr. Hydrolysis with water requires high temperature and pressure with an acid catalyst.

---

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^{-1} mol^{-1} **]**

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 in the solution.

Step 2: Key Formula or Approach:
The formula for osmotic pressure is:

$$\pi = \frac{W_2 RT}{M_2 V}$$

Where:
W_2 = mass of solute (0.822 g)
R = gas constant ($0.08205 \text{ dm}^3 \cdot \text{atm} \cdot \text{K}^{-1} \cdot \text{mol}^{-1}$)
T = temperature (298 K)
M_2 = molar mass of solute (342 g/mol)
V = volume of solution in Liters (dm^3)

Step 3: Detailed Explanation:
First, convert volume to liters:

$$V = 300 \text{ mL} = 0.3 \text{ L} = 0.3 \text{ dm}^3$$

Now, substitute the values into the formula:

$$\pi = \frac{0.822 \times 0.08205 \times 298}{342 \times 0.3}$$

$$\pi = \frac{20.0988}{102.6}$$

$$\pi \approx 0.19589 \text{ atm}$$

Rounding to three decimal places: $\pi = 0.196$ atm.

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

> **Quick Tip**
>
> Always ensure the units of Volume (V) match the units of the Gas Constant (R). If R is in dm^3, V must be in Liters.

---

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

Correct Answer: (a) $\Delta U = q_v$, (b) $\Delta U = w$

Solution:

Step 1: Understanding the Concept:
The First Law of Thermodynamics is stated as: $\Delta U = q + w$.
Different thermodynamic processes impose constraints on q or w.

Step 2: Detailed Explanation:
(a) Isochoric process:
In an isochoric process, the volume remains constant ($\Delta V = 0$).
Work done is given by $w = -P_{ext}\Delta V$. Since $\Delta V = 0$, $w = 0$.
Substituting in the first law:

$$\Delta U = q + 0 \Rightarrow \Delta U = q_v$$

This means the change in internal energy is equal to the heat exchanged at constant volume.

(b) Adiabatic process:
In an adiabatic process, there is no exchange of heat between the system and surroundings ($q = 0$).

Substituting in the first law:

$$\Delta U = 0 + w \Rightarrow \Delta U = w$$

This means the change in internal energy is equal to the adiabatic work done.

Step 3: Final Answer:
For Isochoric: $\Delta U = q_v$. For Adiabatic: $\Delta U = w$.

> **Quick Tip**
>
> Isochoric → constant volume → no work.
> Adiabatic → insulated system → no heat.

---

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

Correct Answer: Similarities: Both involve f-orbital filling and show +3 state. Differences: Lanthanoids are non-radioactive (except Pm), while all actinoids are radioactive.

Solution:

Step 1: Understanding the Concept:
Lanthanoids (4f series) and Actinoids (5f series) are inner transition elements placed at the bottom of the periodic table.

Step 2: Detailed Explanation:
Similarities:
1. In both series, the last electron enters the f-orbital of the anti-penultimate shell ($(n-2)f$).
2. Both show a common and stable oxidation state of +3.
3. Both show a regular decrease in atomic and ionic radii with increasing atomic number (Lanthanoid and Actinoid contraction).

Differences:
1. Radioactivity: Most lanthanoids are non-radioactive (except Promethium). All actinoids are radioactive.
2. Oxidation States: Lanthanoids show limited oxidation states (+2, +3, +4). Actinoids show a wide range of oxidation states (up to +7) because the energy difference between 5f, 6d, and 7s orbitals is small.
3. Complex Formation: Actinoids have a much greater tendency to form complexes than lanthanoids.

Step 3: Final Answer:
Similarities include the common +3 oxidation state and filling of f-orbitals. Differences include

radioactivity and the range of oxidation states.

Quick Tip

Lanthanoids = 4f filling. Actinoids = 5f filling. Transition from 4f to 5f leads to easier ionization and higher radioactivity in actinoids.

---

11. What is the action of following reagents on chlorobenzene? (i) conc. HNO_3, (ii) fuming H_2SO_4

Correct Answer: (i) Nitration yields o- and p-nitrochlorobenzene. (ii) Sulfonation yields o- and p-chlorobenzene sulfonic acid.

Solution:

Step 1: Understanding the Concept:
Chlorobenzene undergoes electrophilic substitution reactions. The Chlorine atom is ortho-para directing due to its +M effect (resonance effect).

Step 2: Detailed Explanation:
(i) Action of conc. HNO_3 (Nitration):
When chlorobenzene is heated with nitrating mixture (conc. HNO_3+ conc. H_2SO_4), it forms a mixture of 1-chloro-2-nitrobenzene (minor) and 1-chloro-4-nitrobenzene (major).
Reaction: $C_6H_5Cl \xrightarrow{conc. HNO_3/H_2SO_4} Cl - C_6H_4 - NO_2$

(ii) Action of fuming H_2SO_4 (Sulfonation):
When chlorobenzene is heated with fuming sulfuric acid, it undergoes sulfonation to form 2-chlorobenzene sulfonic acid (minor) and 4-chlorobenzene sulfonic acid (major).
Reaction: $C_6H_5Cl \xrightarrow{\text{fuming } H_2SO_4, \Delta} Cl - C_6H_4 - SO_3H$

Step 3: Final Answer:
Nitration gives nitro derivatives, and sulfonation gives sulfonic acid derivatives, primarily at the para position.

Quick Tip

For haloarenes, the para isomer is almost always the major product due to less steric hindrance compared to the ortho isomer.

---

12. Explain Cannizzaro reaction with suitable example.

Correct Answer: Aldehydes with no α-H atoms undergo self oxidation-reduction on heating with conc. alkali to give an alcohol and a carboxylate salt.

Solution:

Step 1: Understanding the Concept:
The Cannizzaro reaction is a disproportionation reaction (self-redox) of aldehydes that do not have an alpha-hydrogen atom.

Step 2: Detailed Explanation:
In the presence of a strong base (like 50**Example: Formaldehyde**
Two molecules of formaldehyde ($HCHO$) react with sodium hydroxide:

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

Products: Methanol (reduced product) and Sodium formate (oxidized product).

Example: Benzaldehyde

$$2C_6H_5CHO + KOH(\text{conc.}) \rightarrow C_6H_5CH_2OH + C_6H_5COOK$$

Products: Benzyl alcohol and Potassium benzoate.

Step 3: Final Answer:
Aldehydes without α-hydrogen atoms react with conc. alkali to form an alcohol and a salt of a carboxylic acid.

Quick Tip

Aldehydes WITH α-H (like Acetaldehyde) undergo Aldol Condensation. Aldehydes WITHOUT α-H (like Benzaldehyde or Formaldehyde) undergo Cannizzaro reaction.

---

13. A chemical reaction occurs in two steps :
(i) $NO_2Cl(g) \xrightarrow{\textbf{slow}} NO_2(g) + Cl(g)$
(ii) $NO_2Cl(g) + Cl(g) \xrightarrow{\textbf{fast}} NO_2(g) + Cl_2(g)$
(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:
For a multi-step reaction, the overall rate of the reaction is determined by the slowest step, known as the Rate Determining Step (RDS).

Step 2: Detailed Explanation:
(a) Rate Law:
The first step is labeled as "slow". Therefore, it is the RDS.
The reactants in the RDS are NO_2Cl. The rate law is written based on the stoichiometry of the RDS.

$$\text{Rate} = k[NO_2Cl]$$

(b) Reaction Intermediate:
A reaction intermediate is a species that is produced in one step and consumed in a subsequent step, and does not appear in the overall balanced equation.
In the given mechanism, atomic chlorine $Cl(g)$ is produced in step (i) and consumed in step (ii).
Therefore, $Cl(g)$ is the reaction intermediate.

Step 3: Final Answer:
Rate Law: $R = k[NO_2Cl]$. Intermediate: Cl.

> **Quick Tip**
>
> Intermediate vs. Catalyst: An intermediate is formed then consumed. A catalyst is consumed then regenerated. Both don't appear in the final balanced equation.

---

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

Correct Answer: 0.287 V

Solution:

Step 1: Understanding the Concept:
The potential of an electrode depends on the concentration of ions in the solution. This relationship is given by the Nernst equation.

Step 2: Key Formula or Approach:
The reduction half-reaction is: $Cu^{2+} + 2e^- \rightarrow Cu(s)$.
Number of electrons transferred, $n = 2$.

Nernst Equation:

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

Step 3: Detailed Explanation:
Given:
$E^\circ = 0.337$ V
$[Cu^{2+}] = 0.02$ M $= 2 \times 10^{-2}$ M
Substituting the values:

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

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

Since $\log(50) = \log(100/2) = \log(100) - \log(2) = 2 - 0.3010 = 1.6990$.

$$E = 0.337 - (0.0296 \times 1.6990)$$

$$E = 0.337 - 0.0503$$

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

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

Quick Tip

Note that when ion concentration is less than 1M, the reduction potential decreases for metal electrodes like Cu/Cu2+.

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

Correct Answer: $\frac{P_1^0 - P_1}{P_1^0} = \frac{W_2 \cdot M_1}{M_2 \cdot W_1}$

Solution:

Step 1: Understanding the Concept:
According to Raoult's law, the relative lowering of vapour pressure for a solution containing a non-volatile solute is equal to the mole fraction of the solute in the solution.

Step 2: Key Formula or Approach:
The relative lowering of vapour pressure is given by:

$$\frac{P_1^0 - P_1}{P_1^0} = x_2$$

Where P_1^0 is the vapour pressure of the pure solvent, P_1 is the vapour pressure of the solution, and x_2 is the mole fraction of the solute.

Step 3: Detailed Explanation:
Let n_1 and n_2 be the number of moles of solvent and solute respectively.
The mole fraction of solute is:

$$x_2 = \frac{n_2}{n_1 + n_2}$$

For dilute solutions, the number of moles of solute n_2 is very small compared to the number of moles of solvent n_1.
Thus, $n_1 + n_2 \approx n_1$.
Substituting this into the Raoult's law expression:

$$\frac{P_1^0 - P_1}{P_1^0} \approx \frac{n_2}{n_1}$$

We know that $n_2 = \frac{W_2}{M_2}$ and $n_1 = \frac{W_1}{M_1}$, where W is mass and M is molar mass.
Substituting these values:

$$\frac{P_1^0 - P_1}{P_1^0} = \frac{W_2/M_2}{W_1/M_1} = \frac{W_2 \cdot M_1}{M_2 \cdot W_1}$$

Step 4: Final Answer:
The final relationship is $M_2 = \frac{W_2 \cdot M_1 \cdot P_1^0}{W_1 \cdot (P_1^0 - P_1)}$.

Quick Tip

This formula is valid only for dilute solutions of non-electrolytes. If the solute dissociates or associates, the van't Hoff factor (i) must be included.

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

Correct Answer: The total entropy of an isolated system 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 2: Detailed Explanation:
There are several ways to state this law:
1. **Clausius Statement:** Heat cannot spontaneously flow from a colder body to a hotter body without the performance of external work.
2. **Kelvin-Planck Statement:** It is impossible to construct a heat engine that operates in a cycle and converts all the heat absorbed from a reservoir into work.
3. **Entropy Statement:** The total entropy of an isolated system always increases in a spontaneous process.

Step 3: Final Answer:
The Second Law states that any spontaneous process is accompanied by an increase in the total entropy of the universe.

Quick Tip

Remember: $\Delta S_{total} = \Delta S_{system} + \Delta S_{surroundings} > 0$ for any spontaneous process.

16(i). Convert, acetamide into ethyl amine.

Correct Answer: Reduction using $LiAlH_4$ in ether.

Solution:

Step 1: Understanding the Concept:
The conversion involves reducing an amide group ($-CONH_2$) to a primary amine group ($-CH_2NH_2$) while retaining the number of carbon atoms.

Step 2: Detailed Explanation: Acetamide (CH_3CONH_2) has two carbon atoms. Ethyl amine ($CH_3CH_2NH_2$) also has two carbon atoms.
Strong reducing agents like Lithium Aluminium Hydride ($LiAlH_4$) are used for this purpose.

Reaction:

$$CH_3CONH_2 + 4[H] \xrightarrow{\text{(i) } LiAlH_4\text{/ether, (ii) } H_3O^+} CH_3CH_2NH_2 + H_2O$$

Step 3: Final Answer:
Acetamide is converted to ethyl amine by reduction with $LiAlH_4$ in the presence of dry ether.

> Quick Tip
>
> Be careful! Hoffmann Bromamide degradation of acetamide would remove one carbon and yield methyl amine (CH_3NH_2). To keep the same number of carbons, use reduction.

16(ii). Explain amphoteric nature of water.

Correct Answer: Water acts as both an acid and a base.

Solution:

Step 1: Understanding the Concept:
Amphoteric substances are those that can react as both acids (proton donors) and bases (proton acceptors) depending on the reacting species.

Step 2: Detailed Explanation:
1. **Water as a base:** When water reacts with a stronger acid like HCl, it accepts a proton.

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

2. **Water as an acid:** When water reacts with a base like NH_3, it donates a proton.

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

Since water behaves as an acid in the presence of bases and as a base in the presence of acids, it is described as amphoteric or amphiprotic.

Step 3: Final Answer:
The ability of water to donate or accept protons makes it amphoteric.

Quick Tip

The self-ionization of water $H_2O + H_2O \rightleftharpoons H_3O^+ + OH^-$ is the most basic demonstration of its amphoteric nature.

17(i). Convert Ethanol into sodium ethoxide.

Correct Answer: Reaction with active Sodium metal.

Solution:

Step 1: Understanding the Concept:
Alcohols react with active metals like Sodium (Na) to form metal alkoxides and evolve hydrogen gas. This demonstrates the acidic nature of alcohols.

Step 2: Detailed Explanation:
When ethanol (C_2H_5OH) is treated with sodium metal, the acidic hydrogen of the hydroxyl group is replaced by the sodium ion.
Reaction:

$$2C_2H_5OH + 2Na \rightarrow 2C_2H_5ONa + H_2 \uparrow$$

The product formed is Sodium ethoxide.

Step 3: Final Answer:
Ethanol reacts with metallic sodium to give sodium ethoxide and hydrogen gas.

Quick Tip

This reaction is often used as a test for the presence of the $-OH$ group in organic compounds, as the evolution of H_2 gas causes brisk effervescence.

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

Correct Answer: Sulfonation at low temperature (288 K).

Solution:

Step 1: Understanding the Concept:
Phenol undergoes electrophilic substitution. The sulfonation of phenol is temperature-dependent.

Step 2: Detailed Explanation:
When phenol is treated with concentrated sulfuric acid (H_2SO_4) at room temperature or low temperature (around 288 K), the major product is ortho-phenol sulfonic acid.
At higher temperatures (373 K), the major product shifts to para-phenol sulfonic acid due to thermodynamic stability.
Reaction:

$$C_6H_5OH + \text{conc. } H_2SO_4 \xrightarrow{288K} \text{o-hydroxybenzene sulfonic acid}$$

Step 3: Final Answer:
Phenol is converted to o-phenol sulfonic acid by reacting it with conc. H_2SO_4 at 288 K.

Quick Tip

Remember: Low temperature favors kinetic control (ortho), while high temperature favors thermodynamic control (para).

17(iii). Convert Bromomethane into methoxyethane.

Correct Answer: Williamson's synthesis using sodium ethoxide.

Solution:

Step 1: Understanding the Concept:
The formation of an unsymmetrical ether from an alkyl halide and a sodium alkoxide is known as Williamson's synthesis.

Step 2: Detailed Explanation:
To prepare methoxyethane ($CH_3 - O - C_2H_5$) from bromomethane (CH_3Br), we react the halide with sodium ethoxide ($NaOC_2H_5$).
The alkoxide ion acts as a nucleophile and attacks the methyl halide via an S_N2 mechanism.
Reaction:

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

Step 3: Final Answer:
Bromomethane is heated with sodium ethoxide to produce methoxyethane.

> Quick Tip
>
> In Williamson's synthesis, always use the less sterically hindered alkyl halide (preferably methyl or primary) to avoid elimination as a side reaction.

18(i). What is peptide linkage?

Correct Answer: An amide bond formed between two amino acids.

Solution:

Step 1: Understanding the Concept:
Proteins are polymers made of amino acids. The linkage that joins these amino acids together is the peptide bond or peptide linkage.

Step 2: Detailed Explanation:
A peptide linkage is an amide bond ($-CO - NH-$) formed by the condensation reaction between the carboxyl group ($-COOH$) of one amino acid and the amino group ($-NH_2$) of another amino acid, with the elimination of a water molecule.

$$NH_2 - R_1 - COOH + NH_2 - R_2 - COOH \rightarrow NH_2 - R_1 - CONH - R_2 - COOH + H_2O$$

Step 3: Final Answer:
The peptide linkage is the covalent bond $-CO-NH-$ connecting amino acids in a polypeptide chain.

> Quick Tip
>
> A dipeptide contains two amino acids but only ONE peptide linkage. A tripeptide has three amino acids and TWO linkages.

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

Correct Answer: They are covalent, diamagnetic, and more reactive than parent halogens.

Solution:

Step 1: Understanding the Concept:
Interhalogen compounds are molecules containing two or more different halogen atoms (e.g., ICl, BrF_3, IF_7).

Step 2: Detailed Explanation:
Key characteristics include:
1. **Bonding:** They are essentially covalent compounds.
2. **Magnetism:** They are diamagnetic in nature because all electrons are paired.
3. **Reactivity:** They are generally more reactive than the individual halogens (except Fluorine) because the bond between two different halogens ($X - X'$) is weaker than the bond between two identical halogens ($X - X$).
4. **Physical State:** They can be gases, liquids, or solids at room temperature.
5. **Hydrolysis:** Upon hydrolysis, they yield a halide ion from the smaller halogen and an oxyhalide ion from the larger halogen.

Step 3: Final Answer:
Interhalogen compounds are covalent, polar, diamagnetic, and chemically more reactive than constituent halogens (excluding F_2).

> Quick Tip
>
> The general formula is XX'_n where $n = 1, 3, 5, 7$ and X is the larger, less electronegative halogen.

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

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

Solution:

Step 1: Understanding the Concept:
According to the Aufbau principle, the expected configuration would be $[Ar]\,3d^4\,4s^2$. However, certain elements show anomalies to gain extra stability.

Step 2: Detailed Explanation:
Chromium ($Z = 24$) exhibits an exceptional configuration. One electron from the $4s$ orbital shifts to the $3d$ orbital.
This results in a configuration of $[Ar]\,3d^5\,4s^1$.
This is because:
1. **Symmetry:** Half-filled subshells (d^5) are more symmetrical and therefore more stable.

2. **Exchange Energy:** A half-filled d subshell allows for maximum exchange of electron positions, leading to higher exchange energy and lower overall energy of the atom.

Step 3: Final Answer:
The observed electronic configuration of Cr is $1s^2 2s^2 2p^6 3s^2 3p^6 4s^1 3d^5$.

> **Quick Tip**
>
> Remember both Chromium ($Z = 24$) and Copper ($Z = 29$) follow this trend to achieve half-filled (d^5) and fully-filled (d^{10}) stability respectively.

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:
The magnetic moment of transition metal ions is calculated based on the number of unpaired electrons in their d-orbitals.

Step 2: Key Formula or Approach:
Spin-only formula: $\mu = \sqrt{n(n+2)}$ Bohr Magnetons (BM), where n is the number of unpaired electrons.

Step 3: Detailed Explanation:
Atomic number of Titanium (Ti) is 22.
Electronic configuration of Ti: $[Ar]\,3d^2\,4s^2$.
In Ti^{3+} ion, three electrons are removed (two from $4s$ and one from $3d$).
Configuration of Ti^{3+}: $[Ar]\,3d^1$.
Number of unpaired electrons, $n = 1$.

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

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

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

Quick Tip

A quick shortcut for BM values:
$n = 1 \rightarrow\sim 1.7 - 1.8$
$n = 2 \rightarrow\sim 2.7 - 2.8$
$n = 3 \rightarrow\sim 3.8 - 3.9$
Basically, the first digit is the number of unpaired electrons.

19(iii). Define Green chemistry.

Correct Answer: Design of chemical products and processes that reduce or eliminate the use and generation of hazardous substances.

Solution:

Step 1: Understanding the Concept:
Green chemistry is an approach to chemistry that focuses on environmental sustainability and safety.

Step 2: Detailed Explanation:
It is the utilization of a set of principles that reduces or eliminates the use or generation of hazardous substances in the design, manufacture, and application of chemical products.
It focuses on minimizing waste, utilizing renewable raw materials, and improving atom economy to make chemical production more "eco-friendly".

Step 3: Final Answer:
Green chemistry is the design of chemical processes that aim to reduce environmental pollution and waste.

Quick Tip

Remember the 12 Principles of Green Chemistry, with "Prevention of Waste" being the first and most fundamental principle.

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

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

Solution:

Step 1: Understanding the Concept:
Many vital biological functions depend on metal ions which exist as coordination complexes with various ligands in the body.

Step 2: Detailed Explanation:
1. **Hemoglobin:** A coordination complex of Iron (Fe^{2+}) found in red blood cells; it is responsible for oxygen transport.
2. **Chlorophyll:** A coordination complex of Magnesium (Mg^{2+}) found in plants; it is essential for photosynthesis.
3. **Vitamin B_{12}:** (Cyanocobalamin) A coordination complex of Cobalt (Co^{3+}); it is necessary for nerve tissue health and red blood cell production.

Step 3: Final Answer:
Key biological complexes include Chlorophyll (Mg), Hemoglobin (Fe), and Vitamin B_{12} (Co).

Quick Tip

Remember the central metal for each: Mg for green (plants), Fe for red (blood), and Co for B_{12}.

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:
For a chemical reaction involving gases, the work of expansion/compression 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 given reaction is: $SO_{2(g)} + \frac{1}{2}O_{2(g)} \rightarrow SO_{3(g)}$.
For 1 mole of SO_2, $\Delta n_g = 1 - (1 + 0.5) = -0.5$.
For 2 moles of SO_2, the reaction is: $2SO_{2(g)} + O_{2(g)} \rightarrow 2SO_{3(g)}$.
New $\Delta n_g = 2 - (2 + 1) = -1$.

Substituting into the work formula:

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

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

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

Step 4: Final Answer:
The work done is +2477.57 J. (Positive sign indicates work done on the system).

> **Quick Tip**
>
> Always check if the question asks for work done "by" or "on" the system. A positive value in $W = -\Delta nRT$ means work is done ON the system (compression).

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

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

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 product.

Step 2: Detailed Explanation:
The goal of green chemistry is to design syntheses where most of the reactant mass is converted into the final desired product, minimizing waste.
The formula is:

$$\%\text{ Atom Economy} = \frac{\text{Formula weight of desired product}}{\text{Sum of formula weights of all reactants used in the reaction}} \times 100$$

Step 3: Final Answer:
The formula is $\frac{\text{Mass of desired product}}{\text{Total mass of reactants}} \times 100$.

Quick Tip

High % atom economy means less waste is generated. Rearrangement and addition reactions usually have 100% atom economy.

21(ii). Convert : (a) Benzene into benzaldehyde, (b) Cyclohexene into adipic acid.

Correct Answer: (a) Gattermann-Koch reaction, (b) Oxidative cleavage using $KMnO_4$.

Solution:

Step 1: Understanding the Concept:
(a) Involves formylation of an aromatic ring.
(b) Involves strong oxidation and ring opening of an alkene.

Step 2: Detailed Explanation:
(a) Benzene to Benzaldehyde:
Benzene is treated with Carbon monoxide (CO) and Hydrogen chloride (HCl) in the presence of anhydrous Aluminium chloride ($AlCl_3$) and Cuprous chloride ($CuCl$).
Reaction: $C_6H_6 + CO + HCl \xrightarrow{AlCl_3/CuCl} C_6H_5CHO + HCl$

(b) Cyclohexene to Adipic acid:
Cyclohexene undergoes oxidative cleavage when treated with hot, acidified Potassium permanganate ($KMnO_4/H^+$). The double bond breaks and terminal carbons are oxidized to carboxylic acids.
Reaction: $C_6H_{10} \xrightarrow{KMnO_4,\Delta,H^+} HOOC - (CH_2)_4 - COOH$

Step 3: Final Answer:
(a) Use Gattermann-Koch reaction. (b) Use oxidative cleavage with hot acidic $KMnO_4$.

Quick Tip

Adipic acid is a precursor for Nylon-6,6. Its green synthesis often uses cyclohexene and hydrogen peroxide.

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

Correct Answer: Ring-opening polymerization of Caprolactam.

Solution:

Step 1: Understanding the Concept:
Nylon-6 is a polyamide formed from a single monomer, epsilon-caprolactam, through ring-opening polymerization.

Step 2: Detailed Explanation:
The monomer Caprolactam is heated with water at high temperatures (533 K to 543 K).
The water causes the ring to open, and the resulting amino acid chains polymerize to form Nylon-6.
Reaction:

$$\text{Caprolactam (7-membered ring)} \xrightarrow[533-543K]{H_2O} [-NH-(CH_2)_5-CO-]_n$$

Step 3: Final Answer:
Nylon-6 is prepared by heating caprolactam with water at about 533-543 K.

> **Quick Tip**
>
> The "6" in Nylon-6 represents the number of carbon atoms in the repeating monomer unit.

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: Sc^{3+} has a d^0 configuration (no $d-d$ transition), while Mn^{3+} has a d^4 configuration.

Solution:

Step 1: Understanding the Concept:
The color of transition metal ions is generally due to $d-d$ transitions of electrons. This requires the presence of partially filled d-orbitals.

Step 2: Detailed Explanation:
1. **For Sc^{3+}:**
Atomic number of Sc is 21. Configuration: $[Ar]\,3d^1\,4s^2$.
For Sc^{3+}, all three valence electrons are removed. Configuration: $[Ar]\,3d^0$.
Since the $3d$ subshell is empty, there are no electrons to undergo $d-d$ transitions. Thus, it is colourless.

2. **For Mn^{3+}:**
Atomic number of Mn is 25. Configuration: $[Ar]\,3d^5\,4s^2$.
For Mn^{3+}, three electrons are removed. Configuration: $[Ar]\,3d^4$.
It contains unpaired electrons in the d subshell. These electrons can absorb specific frequencies of visible light to jump between split d-orbital energy levels ($d-d$ transition). The reflected/transmitted light gives the salt its color.

Step 3: Final Answer:
Sc^{3+} is colourless due to empty d-orbitals (d^0), while Mn^{3+} is coloured due to partially filled d-orbitals (d^4).

Quick Tip

Any ion with d^0 or d^{10} configuration is colourless. Ions with d^1 to d^9 configurations are typically coloured.

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

Correct Answer: Metals possess primary and secondary valencies.

Solution:

Step 1: Understanding the Concept:
Alfred Werner proposed the first theory to explain the structures and properties of coordination compounds.

Step 2: Detailed Explanation:
The main postulates are:
1. **Two types of Valencies:** Metals in coordination compounds show two types of linkages: 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. **Spatial Arrangement:** Secondary valencies are directed toward fixed positions in space, giving a definite geometry to the complex (e.g., octahedral, tetrahedral).

Step 3: Final Answer:
Werner's theory identifies ionizable primary valency (oxidation state) and non-ionizable, directional secondary valency (coordination number).

Quick Tip

The number of secondary valencies is constant for a metal in a specific oxidation state.

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

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

Solution:

Step 1: Understanding the Concept:
Ketones react with 1,2-diols in the presence of dry HCl gas to form stable cyclic products known as cyclic ketals.

Step 2: Detailed Explanation:
When acetone reacts with ethane-1,2-diol (ethylene glycol), a water molecule is eliminated. The two hydroxyl groups of the glycol react with the carbonyl oxygen of the acetone.
Reaction:

$$CH_3 - CO - CH_3 + HO - CH_2 - CH_2 - OH \xrightarrow{\text{dry } HCl} \text{Acetone ethylene ketal} + H_2O$$

The product is a five-membered heterocyclic ring.

Step 3: Final Answer:
The reaction produces a cyclic ketal called acetone ethylene ketal.

Quick Tip

Cyclic acetals/ketals are used in organic synthesis as "protecting groups" for the carbonyl group because they are stable to bases.

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 is ammoniacal silver nitrate, a mild oxidizing agent. It oxidizes aldehydes but

not ketones.

Step 2: Detailed Explanation:
When acetaldehyde (CH_3CHO) is heated with Tollen's reagent, the aldehyde is oxidized to acetate ion, and the silver ions (Ag^+) are reduced to metallic silver (Ag).
The metallic silver deposits on the inner wall of the test tube, forming a shiny mirror.
Reaction:

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

Step 3: Final Answer:
Acetaldehyde reduces Tollen's reagent to give a bright silver mirror.

> Quick Tip
>
> Only aldehydes (aliphatic and aromatic) and alpha-hydroxy ketones give a positive Tollen's test. Simple ketones do not.

24(ii). Write the structure of zwitter ion of sulfanilic acid. Write the reaction between benzene diazonium chloride and phenol in alkaline medium.

Correct Answer: $^+NH_3 - C_6H_4 - SO_3^-$ and p-hydroxyazobenzene formation.

Solution:

Step 1: Understanding the Concept:
1. Sulfanilic acid contains both acidic ($-SO_3H$) and basic ($-NH_2$) groups, leading to internal salt formation.
2. Coupling reactions of diazonium salts occur with activated aromatic rings.

Step 2: Detailed Explanation:
Zwitter ion of Sulfanilic acid:
The proton from the sulfonic group is transferred to the amino group.
Structure: $^+NH_3 - C_6H_4 - SO_3^-$

Coupling with Phenol:
Benzene diazonium chloride reacts with phenol in a weakly alkaline medium (pH 9-10) at low temperature (273-278 K). The diazonium cation attacks the para-position of the phenoxide ion.
Reaction:

$$C_6H_5N_2^+Cl^- + C_6H_5OH \xrightarrow{OH^-} C_6H_5 - N = N - C_6H_4 - OH + H_2O + Cl^-$$

The product is p-hydroxyazobenzene, an orange-colored dye.

Step 3: Final Answer:
The zwitter ion is $^{+}H_3N - C_6H_4 - SO_3^-$. The phenol coupling produces an orange azo dye.

> **Quick Tip**
>
> Coupling with phenol happens at the para-position. If the para-position is blocked, it happens at the ortho-position.

25(i). Define : Common ion effect.

Correct Answer: The suppression of dissociation of a weak electrolyte by the addition of a strong electrolyte containing a common ion.

Solution:

Step 1: Understanding the Concept:
This effect is based on Le Chatelier's principle applied to ionic equilibria.

Step 2: Detailed Explanation:
When a strong electrolyte that provides an ion already present in the solution of a weak electrolyte is added, the equilibrium of the weak electrolyte shifts in the direction of the undissociated molecule.
Example: Adding CH_3COONa (strong) to CH_3COOH (weak). The increased concentration of CH_3COO^- ions drives the dissociation of acetic acid backwards.

$$CH_3COOH \rightleftharpoons CH_3COO^- + H^+$$

Step 3: Final Answer:
Common ion effect is the decrease in the degree of dissociation of a weak electrolyte upon adding a strong electrolyte with a common ion.

> **Quick Tip**
>
> Common ion effect is vital in qualitative analysis for the selective precipitation of group radicals.

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

Correct Answer: Acid hydrolysis of starch at high temperature and pressure.

Solution:

Step 1: Understanding the Concept:
Starch is a polysaccharide. Hydrolysis breaks the glycosidic bonds to yield its monomeric units (glucose).

Step 2: Detailed Explanation:
Commercially, glucose is prepared by boiling starch with dilute sulfuric acid (H_2SO_4) at 393 K under 2 to 3 atmospheres of pressure.
Reaction:

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

After hydrolysis, excess acid is neutralized with chalk ($CaCO_3$), and the glucose is crystallized from the concentrated solution.

Step 3: Final Answer:
Glucose is produced by boiling starch with dilute H_2SO_4 at 393 K and 2-3 atm pressure.

> **Quick Tip**
>
> This method produces glucose on an industrial scale. In the lab, it can be prepared from cane sugar (sucrose).

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-DNP (Brady's reagent) to form crystalline orange/yellow solids called 2,4-dinitrophenylhydrazones.

Step 2: Detailed Explanation:
This is a nucleophilic addition-elimination reaction. The $-NH_2$ group of the hydrazine reacts

with the $= O$ of the carbonyl group.
Acetaldehyde is CH_3CHO.
The resulting structure is:

$$CH_3 - CH = N - NH - \text{Benzene Ring with } - NO_2 \text{ at positions 2 and 4}$$

Step 4: Final Answer:
The structure is $CH_3 - CH = N - NH - C_6H_3(NO_2)_2$.

Quick Tip

2,4-DNP test is a general test for the presence of a carbonyl group ($C = O$).

26(ii). The rate of A + B → 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: $9.0\, mol^{-2}dm^6s^{-1}$

Solution:

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

Step 2: Key Formula or Approach:
Rate Law: $Rate = k[A]^x[B]^y$
Given: $x = 2$ (second order in A) and $y = 1$ (first order in B).
So, $Rate = k[A]^2[B]$.

Step 3: Detailed Explanation:
Substitute the given values:
$Rate = 3.6 \times 10^{-2}$
$[A] = 0.2$
$[B] = 0.1$

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

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

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

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

$$k = \frac{0.036}{0.004} = 9$$

Units: For a 3rd order reaction $(2 + 1)$, the unit is $mol^{-2}dm^6s^{-1}$.

Step 4: Final Answer:
The rate constant $k = 9.0\, mol^{-2}dm^6s^{-1}$.

> **Quick Tip**
>
> Always sum the individual orders to find the overall order $(2 + 1 = 3)$. This determines the units of the rate constant.

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

Correct Answer: Two or more solutions having the same osmotic pressure at a given temperature are called isotonic solutions.

Solution:

Step 1: Understanding the Concept:
Osmosis is the spontaneous flow of solvent molecules from a region of lower solute concentration to a region of higher solute concentration through a semipermeable membrane.
The pressure required to stop this flow is called osmotic pressure (π).

Step 2: Detailed Explanation:
When two solutions have exactly the same osmotic pressure, they are considered to be in osmotic equilibrium with each other.
This means that if these two solutions are separated by a semipermeable membrane, there will be no net movement of solvent between them because the "driving force" (osmotic pressure difference) is zero.
For dilute solutions of non-electrolytes at the same temperature T, being isotonic implies they have the same molar concentration $(M_1 = M_2)$.

Step 3: Final Answer:
Isotonic solutions are solutions that exert the same osmotic pressure at the same temperature.

Quick Tip

For competitive exams, remember that 0.9% (mass/volume) NaCl solution is isotonic with human blood. This is why saline drips are prepared at this specific concentration.

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

Correct Answer: The number of reacting species (atoms, ions, or molecules) taking part in an elementary reaction, which must collide simultaneously in order to bring about a chemical reaction, is called molecularity of the reaction.

Solution:

Step 1: Understanding the Concept:
Chemical reactions can occur in a single step (elementary) or multiple steps (complex). Molecularity is a theoretical concept strictly applicable to elementary reactions.

Step 2: Detailed Explanation:
Molecularity represents the stoichiometry of the rate-determining elementary step.
1. **Unimolecular:** Only one reacting species is involved (e.g., decomposition of O_2F_2).
2. **Bimolecular:** Two species collide simultaneously (e.g., $H_2 + I_2 \rightarrow 2HI$).
3. **Termolecular:** Three species collide at once. Reactions with molecularity greater than three are extremely rare because the probability of more than three molecules colliding at the exact same time and with proper orientation is very low.
Unlike "order of reaction", molecularity is always a whole number and cannot be zero or fractional.

Step 3: Final Answer:
Molecularity is the total number of reactant particles involved in an elementary step of a reaction.

Quick Tip

Never confuse Molecularity with Order. Molecularity is theoretical and only for elementary steps, while Order is experimental and applies to the overall reaction.

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

Correct Answer: Hess's Law states that the total enthalpy change for a chemical reaction is the same whether the reaction takes place in one step or in several steps.

Solution:

Step 1: Understanding the Concept:
Enthalpy (H) is a state function, meaning its value depends only on the initial and final states of the system, not on the path taken. Hess's Law is a direct consequence of this property.

Step 2: Detailed Explanation:
Consider a reaction where reactants A are converted to products B.
Path 1: Direct conversion:

$$A \rightarrow B \quad \Delta H = \Delta H_{direct}$$

Path 2: Indirect conversion through intermediates C and D:
Step 1: $A \rightarrow C \quad \Delta H_1$
Step 2: $C \rightarrow D \quad \Delta H_2$
Step 3: $D \rightarrow B \quad \Delta H_3$
According to Hess's Law:

$$\Delta H_{direct} = \Delta H_1 + \Delta H_2 + \Delta H_3$$

This law is extremely useful for calculating enthalpies of reactions that are difficult to measure experimentally, such as the enthalpy of formation of CO from C and O_2.

Step 3: Final Answer:
The total enthalpy change of a reaction is independent of the pathway followed, provided the initial and final states are the same.

Quick Tip

Treat thermochemical equations like algebraic equations. You can add, subtract, or multiply them by coefficients, and the corresponding ΔH values will follow the same operations.

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

Correct Answer: A Schottky defect is a point defect in ionic crystals where an equal number of cations and anions are missing from their lattice sites.

Solution:

Step 1: Understanding the Concept:
In an ideal crystal, every lattice site is occupied by the designated ion. Real crystals have defects. Schottky defect is a stoichiometric "vacancy" defect.

Step 2: Detailed Explanation:
In ionic solids, electrical neutrality must be maintained. Therefore, if a cation is missing from its site, an anion must also be missing.
Characteristics:
1. It occurs in ionic compounds where the coordination number is high.
2. It is seen in compounds where cations and anions are of similar sizes (e.g., $NaCl, KCl, CsCl$).
3. Because atoms are missing from the crystal, the density of the substance decreases.

Step 3: Final Answer:
A Schottky defect is a vacancy defect in ionic solids created by missing pairs of oppositely charged ions, leading to a decrease in density.

Quick Tip

Remember: Schottky = "Shot" (missing) ions. Since ions are literally gone from the lattice, the mass decreases while volume stays same, so density drops.

28(i)(b). Define : Ferromagnetism

Correct Answer: Ferromagnetism is the property of substances that are strongly attracted by a magnetic field and can be permanently magnetized.

Solution:

Step 1: Understanding the Concept:
Magnetic properties arise from the spin and orbital motion of electrons. In ferromagnetic materials, metal ions are grouped into small regions called domains.

Step 2: Detailed Explanation:
In an unmagnetized piece of ferromagnetic material, these domains are randomly oriented, and their magnetic moments cancel out.
When placed in an external magnetic field, all domains orient themselves in the direction of

the magnetic field. This produces a strong magnetic effect.
The characteristic feature of ferromagnetism is that this ordering of domains persists even after the external magnetic field is removed, turning the substance into a permanent magnet.
Common examples include Iron (Fe), Cobalt (Co), and Nickel (Ni).

Step 3: Final Answer:
Ferromagnetism is the phenomenon of spontaneous and permanent alignment of magnetic domains in a substance, resulting in strong magnetic attraction.

> **Quick Tip**
>
> At very high temperatures, ferromagnetic substances lose their permanent magnetism and become paramagnetic. The temperature at which this transition occurs is called the Curie temperature.

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 a polymer produced from ethylene. Unlike Low-Density Polyethylene (LDP), it requires specific low-pressure conditions and a specialized coordination catalyst.

Step 2: Detailed Explanation:
The polymerization of ethene into HDP is carried out at temperatures of $333\,K$ to $343\,K$ and under a pressure of $6 - 7$ atmospheres.
The catalyst used is the **Ziegler-Natta catalyst**, which is a combination of triethyl aluminium $[Al(C_2H_5)_3]$ and titanium tetrachloride $[TiCl_4]$.
This catalyst allows the formation of linear chains that pack closely together, resulting in high density and high tensile strength.

Step 3: Final Answer:
The catalyst used for High-Density Polyethylene (HDP) is the Ziegler-Natta catalyst.

Quick Tip

Karl Ziegler and Giulio Natta won the Nobel Prize in Chemistry in 1963 for this discovery, as it revolutionized the plastics industry.

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

Correct Answer: The IUPAC name is 2-methyl-1,3-butadiene, and its structure is $CH_2 = C(CH_3) - CH = CH_2$.

Solution:

Step 1: Understanding the Concept:
Natural rubber is a linear polymer of isoprene (cis-1,4-polyisoprene). Isoprene is the fundamental monomer unit.

Step 2: Detailed Explanation:
The isoprene molecule consists of a four-carbon chain with two double bonds (a conjugated diene) and a methyl group as a substituent.
IUPAC Name: 2-Methyl-1,3-butadiene.
Structure:

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

When it polymerizes, the double bonds shift to the center to form the polymer chain.

Step 3: Final Answer:
The chemical structure of the isoprene unit is $CH_2 = C(CH_3) - CH = CH_2$.

Quick Tip

Remember: Natural rubber is specifically the **cis**-isomer. The **trans**-isomer of polyisoprene is called Gutta-percha, 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:
The Effective Atomic Number (EAN) represents the total number of electrons surrounding the central metal atom/ion in a complex. Sidgwick proposed that complexes are more stable when the EAN equals the atomic number of the next noble gas.

Step 2: Key Formula or Approach:

$$\text{EAN} = Z - X + Y$$

Where:
Z = Atomic number of the metal.
X = Oxidation state of the metal.
Y = Electrons donated by ligands ($2 \times$ Coordination Number for monodentate ligands).

Step 3: Detailed Explanation:
1. **Find Oxidation State (X):**
In $[Fe(CN)_6]^{4-}$, let oxidation state of Fe be a.
$a + 6(-1) = -4$
$a - 6 = -4 \Rightarrow a = +2$. So, $X = 2$.
2. **Identify Coordination Number (CN):**
There are 6 CN^- ligands. CN = 6.
3. **Electrons donated (Y):**
$Y = 2 \times 6 = 12$.
4. **Calculate EAN:**

$$\text{EAN} = 26 - 2 + 12$$

$$\text{EAN} = 24 + 12 = 36$$

Step 4: Final Answer:
The Effective Atomic Number of Fe in the complex is 36, which corresponds to the noble gas Krypton (Kr).

Quick Tip

If the EAN equals 18, 36, 54, or 86, the complex is said to follow the EAN rule, indicating high stability.

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

Correct Answer: A lead accumulator consists of a lead anode, a lead dioxide-coated cathode, and 38% sulfuric acid as the electrolyte.

Solution:

Step 1: Understanding the Concept:
A lead accumulator (lead-acid battery) is a secondary electrochemical cell, meaning it can be recharged by passing an external electric current through it.

Step 2: Detailed Explanation:
A standard diagram involves the following components:
1. **Anode:** A grid of lead packed with finely divided spongy lead (Pb).
2. **Cathode:** A grid of lead packed with lead dioxide (PbO_2).
3. **Electrolyte:** Aqueous solution of sulfuric acid (H_2SO_4) with a density of $1.28\,g/mL$ (approx 38% by mass).
4. **Container:** Usually made of hard rubber or plastic.
During discharge, both electrodes are converted to lead sulfate ($PbSO_4$).
Cell Representation:
$Pb(s)|PbSO_4(s)|H_2SO_4(aq)|PbSO_4(s)|PbO_2(s)|Pb(grid)$

Step 3: Final Answer:
The lead accumulator uses Pb as anode, PbO_2 as cathode, and H_2SO_4 as electrolyte.

Quick Tip

Remember that during charging, the reactions are reversed, and the cell acts as an electrolytic cell. During discharging, it acts as a galvanic cell.

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

Correct Answer: High efficiency and eco-friendly nature (zero pollution).

Solution:

Step 1: Understanding the Concept:
A fuel cell converts the chemical energy of a fuel (hydrogen) and an oxidant (oxygen) directly into electrical energy through redox reactions.

Step 2: Detailed Explanation:
Two major advantages are:
1. **High Efficiency:** Unlike thermal power plants that have an efficiency of about 40%, fuel cells are much more efficient, converting about 70% of chemical energy into electricity. This is because they do not involve a heat engine cycle (Carnot cycle limitation).
2. **Environmentally Friendly:** The only byproduct of the reaction is water ($2H_2 + O_2 \rightarrow 2H_2O$). It does not emit harmful gases like CO_2, SO_2, or nitrogen oxides, making it a "green" power source. This water can even be purified and used by astronauts in space missions (e.g., Apollo mission).

Step 3: Final Answer:
The advantages are high thermodynamic efficiency and the production of water as the sole non-polluting product.

> Quick Tip
>
> Hydrogen is often called the "fuel of the future" because of its high energy density and low environmental impact when used in fuel cells.

30(i). Convert, ethanoic acid to ethanol.

Correct Answer: Reduction using $LiAlH_4$ or B_2H_6.

Solution:

Step 1: Understanding the Concept:
Converting a carboxylic acid to a primary alcohol is a reduction process. Carboxylic acids are difficult to reduce and require strong or specific reducing agents.

Step 2: Detailed Explanation:
Ethanoic acid (CH_3COOH) is reduced to ethanol (CH_3CH_2OH) using **Lithium Aluminium Hydride** ($LiAlH_4$) in dry ether, followed by acid hydrolysis.
Reaction:

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

Alternatively, **Diborane** (B_2H_6) can be used. It is often preferred because it specifically reduces the carboxyl group and does not easily reduce other functional groups like nitro or halo groups.
Note: Sodium borohydride ($NaBH_4$) cannot reduce carboxylic acids.

Step 3: Final Answer:
Ethanoic acid is converted to ethanol by reduction with $LiAlH_4$ in ether.

> Quick Tip
>
> For industrial purposes, acids are often converted to esters first and then reduced using catalytic hydrogenation (H_2/Ni), as $LiAlH_4$ is very expensive.

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

Correct Answer: It follows a second-order nucleophilic substitution (S_N2) mechanism.

Solution:

Step 1: Understanding the Concept:
Alkaline hydrolysis of primary alkyl halides like bromomethane (CH_3Br) involves the attack of a hydroxide ion (OH^-) as a nucleophile.

Step 2: Detailed Explanation:
The reaction occurs in a single concerted step.
1. **Backside Attack:** The nucleophile (OH^-) attacks the carbon atom from the side opposite to the leaving group (Br^-).
2. **Transition State:** A pentacoordinate transition state is formed where the bond to OH is partially formed and the bond to Br is partially broken. The carbon is sp^2 hybridized in this state.
3. **Product Formation:** The $C-Br$ bond breaks completely, and the $C-OH$ bond is fully established.
4. **Inversion of Configuration:** If the substrate were chiral, we would see "Walden Inversion", much like an umbrella turning inside out in a strong wind.
Rate Law: Rate $= k[CH_3Br][OH^-]$. It is a bimolecular, second-order reaction.

Step 3: Final Answer:
Alkaline hydrolysis of bromomethane is an S_N2 reaction involving a single-step transition state and inversion of configuration.

> Quick Tip
>
> Reactivity for S_N2 follows the order: Methyl $>$ 1° $>$ 2° $>$ 3°. This is due to steric hindrance; the nucleophile needs space to attack from the back.

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:
Acetic acid is a weak electrolyte. Its dissociation constant (K_a) is related to its concentration (C) and degree of dissociation (α) by Ostwald's dilution law.

Step 2: Key Formula or Approach:
For a weak acid:

$$K_a = \frac{C\alpha^2}{1-\alpha}$$

If α is very small ($< 5\%$), the formula can be simplified to:

$$K_a = C\alpha^2$$

Step 3: Detailed Explanation:
Given:
Degree of ionisation, $\alpha = 5\% = \frac{5}{100} = 0.05$.
Concentration, $C = \text{decimolar} = 0.1\,M = 10^{-1}\,M$.
Using the formula:

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

$$K_a = 10^{-1} \times 0.0025$$

$$K_a = 10^{-1} \times 2.5 \times 10^{-3}$$

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

Step 4: Final Answer:
The dissociation constant (K_a) of acetic acid is 2.5×10^{-4}.

Quick Tip

"Decimolar" means $0.1\,M$, "Centimolar" means $0.01\,M$, and "Millimolar" means $0.001\,M$. Knowing these terms is essential for solving concentration problems.

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

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

Solution:

Step 1: Understanding the Concept:
Epsom salt is a naturally occurring mineral used in health and agriculture. Sulfuric acid (H_2SO_4) is known as the "King of Chemicals" due to its industrial importance.

Step 2: Detailed Explanation:
1. **Epsom Salt:** The chemical formula for Epsom salt is Magnesium Sulfate Heptahydrate, written as $MgSO_4 \cdot 7H_2O$.
2. **Uses of H_2SO_4:**
(a) **Fertilizer Industry:** It is used to produce nitrogenous fertilizers like ammonium sulfate and phosphatic fertilizers like superphosphate of lime.
(b) **Petroleum Refining:** It is used in the refining of petroleum and as a drying/dehydrating agent in various organic syntheses.
(c) **Storage Batteries:** It is used as the electrolyte in lead-acid storage batteries (as discussed in Q. 29).

Step 3: Final Answer:
The formula is $MgSO_4 \cdot 7H_2O$. Primary uses include fertilizer production and as a battery acid.

Quick Tip

The strength of a country's economy can often be measured by its annual consumption of sulfuric acid because it is used in almost every manufacturing process.
