WBJEE Chemistry Sample Paper-13

Duration: 60 Minutes **Maximum Marks: 50**

Instructions

- This paper contains **40** Multiple Choice Questions divided into **3 Sections**.
- **Section 1 (Q1–Q30):** Each correct answer carries **+1 mark**. Incorrect answer: **−0.25** marks. Only **one** correct option.
- **Section 2 (Q31–Q35):** Each correct answer carries **+2 marks**. Incorrect answer: **−0.5** marks. Only **one** correct option.
- **Section 3 (Q36–Q40):** Each correct answer carries **+2 marks**. **No negative marking**. One or **more** correct options may be correct; full marks only if all correct options are marked.
- Use of mobile phones, smartwatches, or any electronic gadgets is strictly prohibited.

Section–A — 30 Questions × 1 Mark Each
(Negative Marking: −0.25) [Single Correct]

Q1. The radius of the first Bohr orbit of hydrogen atom is 0.529 Å. The radius of the third orbit will be:

(A) 1.587 Å

(B) 4.761 Å

(C) 9.261 Å

(D) 0.176 Å

Q2. For the reaction $N_2(g) + O_2(g) \rightarrow 2NO(g)$, $\Delta H > 0$ and $\Delta S > 0$. The reaction becomes spontaneous at:

(A) Low temperature only

(B) High temperature only

(C) All temperatures

(D) No temperature

Q3. The conductivity of a semiconductor increases with increase in temperature because:

(A) Number of free electrons increases

(B) Collision frequency decreases

(C) Ionic mobility increases

(D) Resistance becomes infinite

Q4. The major product formed when phenol is treated with dilute HNO_3 is:

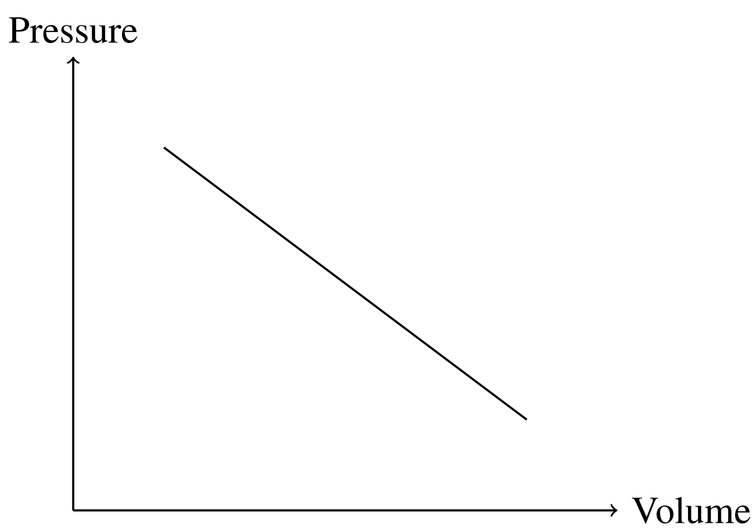
(A) Nitrobenzene

(B) m-nitrophenol

(C) Mixture of o- and p-nitrophenol

(D) Picric acid

Q5. Refer to the following graph:



The graph represents:

(A) Charles' law

(B) Boyle's law

(C) Gay-Lussac law

(D) Avogadro law

Q6. The oxidation state of Co in $[Co(NH_3)_5Cl]Cl_2$ is:

(A) +1

(B) +2

(C) +3

(D) +4

Q7. The osmotic pressure of a solution depends upon:

(A) Nature of solvent only

(B) Number of solute particles

(C) Temperature only

(D) Volume only

Q8. Which among the following molecules has the highest bond angle?

(A) NH_3

(B) H_2O

(C) CH_4

(D) BF_3

Q9. Refer to the following orbital filling:

$$\uparrow\downarrow \quad \uparrow\downarrow \quad \uparrow$$

The total spin quantum number is:

(A) 0

(B) $1/2$

(C) 1

(D) $3/2$

Q10. Which compound gives white precipitate immediately with alcoholic $AgNO_3$?

(A) Chlorobenzene

(B) Vinyl chloride

(C) tert-Butyl bromide

(D) Fluorobenzene

Q11. The process of converting a precipitate into colloidal solution by shaking with dispersion medium is called:

(A) Coagulation

(B) Peptisation

(C) Dialysis

(D) Electrophoresis

Q12. For a first-order reaction, the graph between $\log[A]$ and time is:

(A) Straight line with positive slope

(B) Straight line with negative slope

(C) Parabola

(D) Hyperbola

Q13. The major product formed on catalytic hydrogenation of benzene is:

(A) Cyclohexane

(B) Cyclohexene

(C) Hexane

(D) Benzyl alcohol

Q14. Refer to the following cell representation:

$$\text{Zn} \mid \text{Zn}^{2+} \parallel \text{H}^+ \mid \text{H}_2 \mid \text{Pt}$$

The standard emf of the cell is closest to:

(A) $0.76\,V$

(B) $1.10\,V$

(C) $0.34\,V$

(D) $1.52\,V$

Q15. Which transition element shows maximum number of oxidation states?

(A) Cr

(B) Mn

(C) Fe

(D) Cu

Q16. The monomeric unit of natural rubber is:

(A) Isoprene

(B) Styrene

(C) Ethene

(D) Vinyl chloride

Q17. The conjugate base of HSO_4^- is:

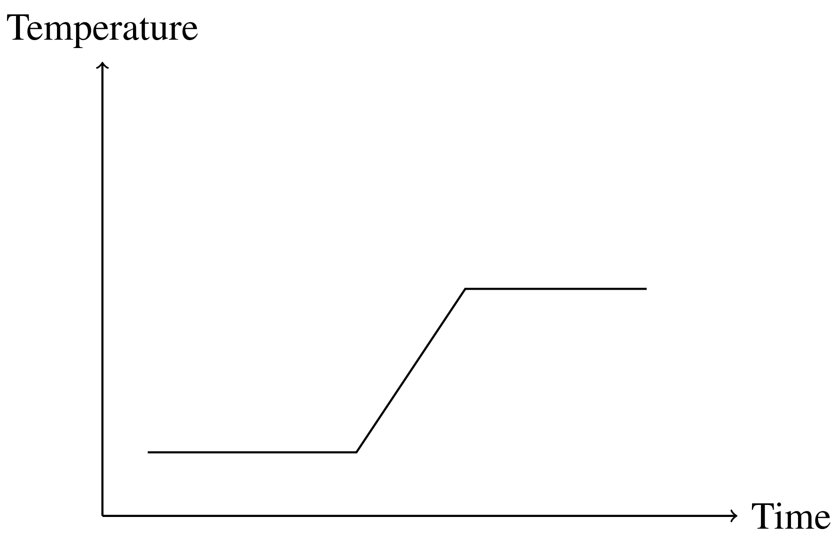
(A) H_2SO_4

(B) SO_4^{2-}

(C) SO_3^{2-}

(D) HSO_3^-

Q18. Refer to the following heating curve:



The horizontal portion indicates:

(A) Rise in temperature

(B) Constant kinetic energy

(C) Phase transition

(D) Decrease in entropy

Q19. Acetaldehyde on reaction with excess ethanol in presence of dry HCl forms:

(A) Hemiacetal

(B) Acetal

(C) Ester

(D) Ether

Q20. For an isolated system, the value of $\Delta S_{universe}$ is:

(A) Negative

(B) Positive

(C) Zero

(D) Infinite

Q21. The hybridisation of carbon in diamond is:

(A) sp

(B) sp^2

(C) sp^3

(D) dsp^2

Q22. Which of the following hydrides has maximum boiling point?

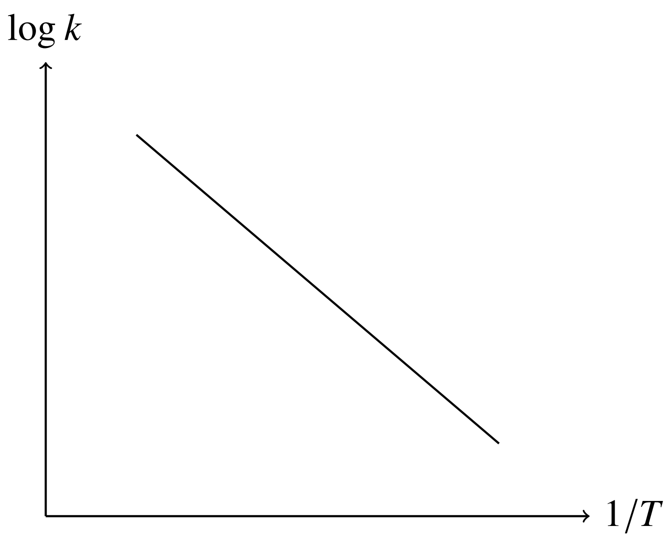
(A) NH_3

(B) PH_3

(C) AsH_3

(D) SbH_3

Q23. Refer to the following graph:



The slope of the graph is equal to:

(A) $-E_a/2.303R$

(B) E_a/R

(C) RT/E_a

(D) $-RT/E_a$

Q24. Phenol is more acidic than ethanol because:

(A) Ethanol has hydrogen bonding

(B) Phenoxide ion is resonance stabilised

(C) Ethoxide ion is resonance stabilised

(D) Phenol has weaker O-H bond

Q25. The packing efficiency in face-centred cubic lattice is:

(A) 52%

(B) 68%

(C) 74%

(D) 84%

Q26. Which ligand among the following is ambidentate?

(A) NH_3

(B) H_2O

(C) SCN^-

(D) EDTA

Q27. The relation between Gibbs free energy and emf is:

(A) $\Delta G = nFE$

(B) $\Delta G = -nFE$

(C) $\Delta G = FE/n$

(D) $\Delta G = -FE/n$

Q28. Which compound does not undergo aldol condensation?

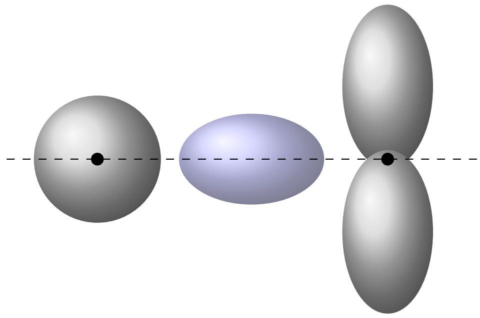
(A) Acetaldehyde

(B) Benzaldehyde

(C) Propanal

(D) Acetone

Q29. Refer to the following overlap:



s-p head-on overlap (σ bond)

The bond formed is:

(A) $p\pi - p\pi$

(B) $s - s\,\sigma$

(C) $s - p\,\sigma$

(D) Ionic bond

Q30. The number of moles present in 22 g of CO_2 is:

(A) 0.25

(B) 0.5

(C) 1

(D) 2

Section–B — 5 Questions × 1 Mark Each
(Negative Marking: −0.5) [Single Correct]

Q31. A catalyst increases the rate of reaction by:

(A) Increasing collision frequency

(B) Lowering activation energy

(C) Increasing enthalpy change

(D) Shifting equilibrium

Q32. Which reagent converts chlorobenzene to phenol under drastic conditions?

(A) Dilute NaOH

(B) Fused NaOH at high temperature and pressure

(C) Aqueous KOH at room temperature

(D) $NaHCO_3$

Q33. Raoult's law is applicable to:

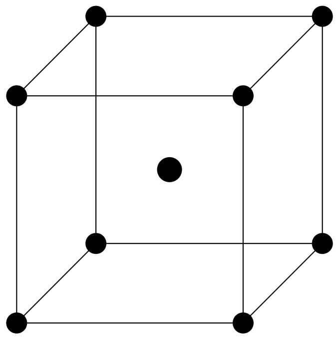
(A) Ideal solutions

(B) Non-ideal solutions only

(C) Electrolytic solutions only

(D) Colloidal solutions

Q34. Refer to the following crystal structure:



The crystal system is:

(A) Simple cubic

(B) Face-centred cubic

(C) Body-centred cubic

(D) Hexagonal close packed

Q35. Aniline reacts with bromine water to form:

(A) Bromobenzene

(B) *o*-bromoaniline

(C) 2,4,6-tribromoaniline

(D) Nitrobenzene

Section C — 5 Questions × 2 Marks Each (No Negative Marking) [One or More Correct]

Q36. Which of the following molecules are linear?

(A) CO_2

(B) $BeCl_2$

(C) SO_2

(D) HCN

Q37. Which of the following species contain unpaired electrons?

(A) O_2

(B) NO

(C) N_2

(D) NO_2

Q38. Which of the following compounds give positive Fehling's test?

(A) Methanal

(B) Ethanal

(C) Benzaldehyde

(D) Glucose

Q39. Which statements regarding colloids are correct?

(A) Colloidal particles show Brownian motion

(B) Colloids pass through parchment paper

(C) Tyndall effect is shown by colloids

(D) Colloids are homogeneous systems

Q40. Which of the following compounds can exhibit geometrical isomerism?

(A) But-2-ene

(B) $[Pt(NH_3)_2Cl_2]$

(C) Hex-3-ene

(D) 1,2-dichloroethene

Detailed Solutions

Q1.

Solution

Concept: The radius of the n-th Bohr orbit in a hydrogen atom is given by the formula $r_n = n^2 \cdot r_1$, where r_1 is the radius of the first Bohr orbit and n is the principal quantum number.

Solution: Step 1: Identify the given information.
The radius of the first Bohr orbit ($n = 1$) is $r_1 = 0.529$ Å.
We need to find the radius of the third orbit ($n = 3$).

Step 2: Apply the formula for the radius of the n-th Bohr orbit.
$r_n = n^2 \cdot r_1$

Step 3: Substitute the values of n and r_1.
For the third orbit, $n = 3$:
$r_3 = (3)^2 \cdot 0.529$ Å
$r_3 = 9 \cdot 0.529$ Å

Step 4: Calculate the final value.
$r_3 = 4.761$ Å

Therefore, the radius of the third orbit will be 4.761 Å.

Option A (1.587 Å) would be the result of multiplying by 3 instead of 3^2.
Option C (9.261 Å) seems to be $3^3 \cdot 0.529$, which is incorrect.
Option D (0.176 Å) is significantly smaller and not derived from the formula.

Final Answer: 4.761 Å

Answer: (A)

Go Back to Question 1

Q2.

Solution

Concept: The spontaneity of a reaction is determined by the Gibbs Free Energy change (ΔG), which is related to enthalpy change (ΔH) and entropy change (ΔS) by the equation:
$\Delta G = \Delta H - T\Delta S$
where T is the temperature in Kelvin.
A reaction is spontaneous when $\Delta G < 0$.

Solution: For the reaction:

$$N_2(g) + O_2(g) \rightarrow 2NO(g)$$

we are given:

$$\Delta H > 0, \qquad \Delta S > 0$$

Using Gibbs free energy equation:

$$\Delta G = \Delta H - T\Delta S$$

For spontaneity:

$$\Delta G < 0$$

So,

$$\Delta H < T\Delta S$$

Since both ΔH and ΔS are positive, the term $T\Delta S$ increases with temperature. At high temperature, $T\Delta S$ becomes greater than ΔH, making ΔG negative.

Therefore, the reaction is spontaneous only at high temperature.

Final Answer: High temperature only

Answer: (B)

Go Back to Question 2

Q3.

Solution

Concept: Semiconductors are materials whose electrical conductivity is intermediate between that of conductors and insulators. Their conductivity is highly dependent on temperature.

Solution: Step 1: Understand the nature of semiconductors.
In semiconductors (like silicon or germanium), electrical conduction occurs due to the movement of free electrons and holes. At absolute zero temperature, pure semiconductors behave like insulators.

Step 2: Analyze the effect of temperature on semiconductors.
When the temperature of a semiconductor increases, the thermal energy provided to the material increases. This energy can break some of the covalent bonds holding the electrons. When a covalent bond breaks, an electron is released, becoming a free electron, and a vacancy is created in the covalent bond, which acts as a "hole." Both free electrons and holes are charge carriers.

Step 3: Relate the increase in charge carriers to conductivity.
The increase in temperature leads to a significant increase in the number of free electrons and holes (charge carriers). The conductivity of a material is directly proportional to the number of charge carriers and their mobility. While increased temperature can also increase collision frequency and reduce mobility, the increase in the number of charge carriers in semiconductors is the dominant factor.

Step 4: Evaluate the given options.
A. Number of free electrons increases: This is the primary reason. Increased temperature provides energy to break covalent bonds, creating more free electrons and holes (which are considered positive charge carriers).
B. Collision frequency decreases: This is incorrect. Collision frequency generally increases with temperature.
C. Ionic mobility increases: This is relevant for electrolytes, not for solid semiconductors where conduction is by electrons and holes.
D. Resistance becomes infinite: This is incorrect. Conductivity (and thus decreases resistance) increases with temperature in semiconductors.

Final Answer: Number of free electrons increases

Answer: (A)

Go Back to Question 3

Q4.

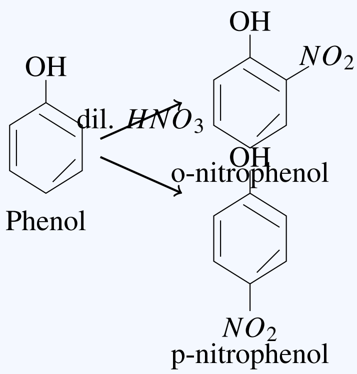
Solution

Concept: The $-OH$ group in phenol activates the benzene ring and directs electrophilic substitution to the ortho and para positions. On nitration:
- Dilute HNO_3 gives ortho- and para-nitrophenol.
- Concentrated HNO_3 gives picric acid (2,4,6-trinitrophenol).

Solution: Step 1: Understand the effect of the hydroxyl group in phenol.
The $-OH$ group in phenol is an activating group and directs incoming electrophiles to the ortho and para positions of the benzene ring.

Step 2: Reaction with dilute nitric acid.
When phenol is treated with dilute HNO_3, nitration occurs through electrophilic aromatic substitution. The electrophile involved is the nitronium ion (NO_2^+).

Step 3: Formation of products.
Since the $-OH$ group is ortho and para-directing, nitration occurs mainly at these positions, producing a mixture of: - ortho-nitrophenol
- para-nitrophenol



Step 4: Evaluate the other options.
A. Nitrobenzene: This would be the product if benzene were nitrated, not phenol.
B. m-nitrophenol: The -OH group is an ortho, para-director, so meta substitution is not favored.
D. Picric acid (2,4,6-trinitrophenol): This is formed when phenol is treated with concentrated nitric acid, which is a stronger nitrating agent and leads to polynitration.

Final Answer: Mixture of o- and p-nitrophenol

Answer: (C)

Go Back to Question 4

Q5.

Solution

Concept: The graph plots Pressure (on the y-axis) against Volume (on the x-axis). We need to identify which gas law this inverse relationship represents.

Solution: Step 1: Analyze the graph.
The graph shows that as Volume increases, Pressure decreases. This indicates an inverse relationship between Pressure and Volume. The curve is hyperbolic in shape, suggesting that the product PV remains constant.

Step 2: Recall the gas laws.
- Charles's Law: $V \propto T$ at constant pressure.
- Boyle's Law: PV = constant at constant temperature.
- Gay-Lussac's Law: $P \propto T$ at constant volume.
- Avogadro's Law: $V \propto n$ at constant temperature and pressure.

Step 3: Match the graph with the correct law.
A Pressure vs Volume graph showing an inverse curve corresponds to Boyle's Law. According to Boyle's Law, when temperature is constant:

$$P \propto \frac{1}{V}$$

or

$$PV = \text{constant}$$

Thus, as volume increases, pressure decreases proportionally.

Step 4: Evaluate the options.
(A) Charles' law — Incorrect
(B) Boyle's law — Correct
(C) Gay-Lussac law — Incorrect
(D) Avogadro law — Incorrect

Final Answer: Boyle's law

Answer: (B)

Go Back to Question 5

Q6.

Solution

Concept: The oxidation state of a central metal atom in a coordination complex can be determined by considering the charges of the ligands and the counterions.

Solution: Step 1: Identify the components of the coordination complex.
The complex is $[Co(NH_3)_5Cl]Cl_2$. It consists of a coordination sphere $[Co(NH_3)_5Cl]$ and two chloride counterions (Cl^-).

Step 2: Assign charges to known species.
- Ammonia (NH_3) is a neutral ligand, so its charge is 0. - Chloride (Cl^-) is a halide ion, and its charge is -1. The two outer chloride ions are counterions, so they carry a charge of -1 each.

Step 3: Determine the charge of the coordination sphere.
The overall charge of the complex must be neutral. The two Cl^- counterions contribute a total charge of $2 \times (-1) = -2$. Therefore, the coordination sphere $[Co(NH_3)_5Cl]$ must have a charge of +2 to balance the -2 charge from the counterions. So, $[Co(NH_3)_5Cl]^{2+}$

Step 4: Determine the oxidation state of the central metal atom (Co).
Let the oxidation state of Cobalt (Co) be x. In the coordination sphere $[Co(NH_3)_5Cl]^{2+}$: Oxidation state of Co + (Sum of oxidation states of ligands) = Charge of the complex $x + (5 \times \text{charge of } NH_3) + (\text{charge of } Cl) = +2$ $x + (5 \times 0) + (-1) = +2$ $x + 0 - 1 = +2$ $x - 1 = +2$ $x = +2 + 1$ $x = +3$

Thus, the oxidation state of Cobalt (Co) in the complex is +3.

Final Answer: $\boxed{+3}$

Answer: (C)

Go Back to Question 6

Q7.

Solution

Concept: Osmotic pressure (Π) is a colligative property, meaning it depends on the concentration (number) of solute particles in a solution, rather than on their identity. The relationship is described by the van't Hoff equation.

Solution: Step 1: Recall the definition of osmotic pressure.
Osmotic pressure is the minimum pressure that must be applied to a solution to prevent the inward flow of solvent through a semipermeable membrane. It is a colligative property.

Step 2: Recall the van't Hoff equation.
The osmotic pressure is given by:

$$\Pi = iMRT$$

where:

$$\Pi = \text{Osmotic pressure}$$

$$i = \text{van't Hoff factor}$$

$$M = \text{Molar concentration}$$

$$R = \text{Gas constant}$$

$$T = \text{Absolute temperature}$$

Step 3: Analyze the factors affecting osmotic pressure.
From the equation, osmotic pressure depends on:

- Number of solute particles (i)
- Concentration of the solution (M)
- Temperature (T)

Since osmotic pressure is a colligative property, its most important dependence is on the *number of solute particles* present in the solution.

Step 4: Evaluate the options.
(A) Nature of solvent only — Incorrect
(B) Number of solute particles — Correct
(C) Temperature only — Incorrect
(D) Volume only — Incorrect

Final Answer: Number of solute particles

Answer: (B)

Go Back to Question 7

Q8.

Solution

Concept: The bond angle in a molecule is determined by its molecular geometry, which is predicted by Valence Shell Electron Pair Repulsion (VSEPR) theory. The presence of lone pairs on the central atom influences the bond angles, typically reducing them from the ideal values.

Solution: Using VSEPR theory, the bond angle depends on the molecular geometry and the presence of lone pairs. Lone pairs cause greater repulsion and reduce bond angles.

$$H_2O : 104.5^\circ$$

(Bent shape with two lone pairs)

$$NH_3 : 107^\circ$$

(Trigonal pyramidal with one lone pair)

$$CH_4 : 109.5^\circ$$

(Tetrahedral with no lone pairs)

$$BF_3 : 120^\circ$$

(Trigonal planar with no lone pairs)
Comparing these values:

$$104.5^\circ < 107^\circ < 109.5^\circ < 120^\circ$$

Thus, BF_3 has the maximum bond angle.

Final Answer:

$$\boxed{BF_3}$$

Answer: (D)

Go Back to Question 8

Q9.

Solution

Concept: The total spin quantum number (S) for a system of electrons is the sum of the spin quantum numbers of individual electrons. The spin quantum number (m_s) for an electron is either $+1/2$ (spin up, $\uparrow$) or $-1/2$ (spin down, $\downarrow$). The total spin quantum number is calculated as the sum of the individual m_s values.

Solution: The given orbital filling is:

$$\uparrow\downarrow \quad \uparrow\downarrow \quad \uparrow$$

Step 1: Identify the spin of each electron.
Each $\uparrow$ electron has spin quantum number:

$$m_s = +\frac{1}{2}$$

Each $\downarrow$ electron has spin quantum number:

$$m_s = -\frac{1}{2}$$

So, the five electrons have spins:

$$+\frac{1}{2}, \ -\frac{1}{2}, \ +\frac{1}{2}, \ -\frac{1}{2}, \ +\frac{1}{2}$$

Step 2: Add the spin quantum numbers.

$$S = \left(+\frac{1}{2} - \frac{1}{2}\right) + \left(+\frac{1}{2} - \frac{1}{2}\right) + \frac{1}{2}$$

$$S = 0 + 0 + \frac{1}{2}$$

$$S = \frac{1}{2}$$

Thus, the total spin quantum number is:

$$\boxed{\frac{1}{2}}$$

Answer: (B)

Go Back to Question 9

Q10.

Solution

Concept: Alcoholic silver nitrate ($AgNO_3$) is a reagent used to test for the presence of halogen atoms that can undergo nucleophilic substitution or elimination to form a carbocation or an intermediate that reacts with silver ions to form a precipitate of silver halide (AgX). The ease of formation of AgX depends on the stability of the intermediate or the nature of the C-X bond. Generally, AgX precipitates immediately with primary and secondary alkyl halides, tertiary alkyl halides (via S_N1), and with halides that can easily form carbocations or undergo elimination. Aryl halides and vinyl halides are unreactive under these conditions.

Solution: Step 1: Analyze the reactivity of each given compound with alcoholic $AgNO_3$.
Alcoholic $AgNO_3$ typically tests for the presence of ionizable halide ions. The reaction involves the halide leaving to form a carbocation (or some reactive intermediate) which then reacts with Ag^+ to form AgX precipitate.

Step 2: Evaluate each option:
A. Chlorobenzene: This is an aryl halide. The C-Cl bond is very strong due to resonance with the benzene ring and the electronegativity of the sp2 hybridized carbon. It does not readily undergo nucleophilic substitution or form a stable carbocation. Thus, it will not give a precipitate immediately with alcoholic $AgNO_3$.

B. Vinyl chloride: This is a vinyl halide. The chlorine atom is attached to an sp2 hybridized carbon atom of a double bond. Similar to aryl halides, the C-Cl bond is strong, and it does not readily undergo nucleophilic substitution or form a stable carbocation. Thus, it will not give a precipitate.

C. tert-Butyl bromide: This is a tertiary alkyl halide. Tertiary alkyl halides readily undergo S_N1 reactions because they form stable tertiary carbocations. The bromide ion leaves to form the tert-butyl carbocation, which then reacts with Ag^+ to form $AgBr$ precipitate immediately.
$(CH_3)_3C - Br \xrightarrow{S_N1} (CH_3)_3C^+ + Br^-$
$Br^- + Ag^+ \longrightarrow AgBr(s)$ (white precipitate)

D. Fluorobenzene: This is an aryl halide with fluorine. The C-F bond is one of the strongest covalent bonds, and fluorine is highly electronegative. Aryl fluorides are extremely unreactive towards nucleophilic substitution. Thus, it will not give a precipitate.

Step 3: Conclude based on reactivity.
Tertiary alkyl halides like tert-butyl bromide are the most reactive among the given options towards alcoholic $AgNO_3$ and will yield a white precipitate of silver bromide immediately.

Final Answer: tert-Butyl bromide

Answer: (C)

Go Back to Question 10

Q11.

Solution

Concept: This question asks about the process of converting a precipitate into a colloidal solution. This involves breaking down the larger particles of the precipitate into smaller colloidal-sized particles and stabilizing them in the dispersion medium.

Solution: Step 1: Understand the definition of each term.
Coagulation: The process where dispersed colloidal particles aggregate and settle down, leading to the formation of a precipitate. This is the reverse of what we are looking for.
Peptisation: The process by which a freshly prepared precipitate is converted into a colloidal solution by treating it with a suitable electrolyte (dispersion medium with an ion that gets adsorbed on the surface of the precipitate) and shaking. This process stabilizes the colloidal particles.
Dialysis: A process of separating colloidal particles from dissolved ions or small molecules by selective diffusion through a semipermeable membrane. It is used to purify colloidal solutions.
Electrophoresis: The movement of colloidal particles under the influence of an electric field. It is used to determine the charge on colloidal particles.

Step 2: Identify the process that matches the description.
The question describes converting a precipitate into a colloidal solution by shaking with a dispersion medium. This precisely matches the definition of peptisation. For example, when freshly precipitated ferric hydroxide is shaken with a solution of ferric chloride, peptisation occurs, forming colloidal ferric hydroxide.

Final Answer: Peptisation

Answer: (B)

Go Back to Question 11

Q12.

Solution

Concept: The integrated rate law for a first-order reaction relates the concentration of the reactant to time. Different forms of this law yield different graphical representations.

Solution: For a first-order reaction, the integrated rate law is:

$$\ln[A]_t = \ln[A]_0 - kt$$

Using the relation:

$$\ln x = 2.303 \log x$$

we get:

$$\log[A]_t = \log[A]_0 - \frac{k}{2.303}t$$

This equation is of the form:

$$y = mx + c$$

where:

$$y = \log[A]_t, \qquad x = t$$

and the slope is:

$$m = -\frac{k}{2.303}$$

Since the slope is negative, the graph of $\log[A]$ versus time is a straight line with negative slope.

Final Answer:

$$\boxed{\text{Straight line with negative slope}}$$

Answer: (B)

Go Back to Question 12

Q13.

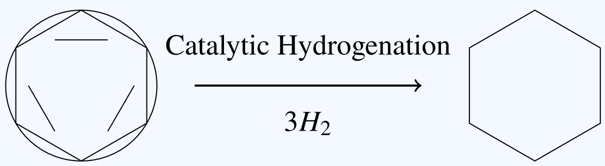
Solution

Concept: Catalytic hydrogenation of benzene involves the addition of hydrogen across the double bonds of the aromatic ring under the influence of a catalyst. This process saturates the ring, transforming it into an alkane.

Solution: Step 1: Understand the process of catalytic hydrogenation of benzene.
Benzene (C_6H_6) is an aromatic hydrocarbon with three delocalized double bonds. Catalytic hydrogenation, typically using catalysts like Nickel (Ni), Platinum (Pt), or Palladium (Pd) under pressure and heat, adds hydrogen (H_2) to these double bonds.

Step 2: Describe the reaction.
The addition of hydrogen to each double bond converts it into a single bond. Since benzene has three double bonds, it will react with three molecules of hydrogen gas ($3H_2$).
$C_6H_6 + 3H_2 \xrightarrow{Catalyst} C_6H_{12}$

Step 3: Identify the product.
The resulting molecule, C_6H_{12}, is a saturated cyclic hydrocarbon. This saturated cyclic hydrocarbon derived from benzene is cyclohexane.



C_6H_6 C_6H_{12} (Cyclohexane)

Step 4: Evaluate the options.
A. Cyclohexane: This is the correct product.
B. Cyclohexene: This is a partially hydrogenated product (with one double bond remaining), which would be formed if only one or two molecules of H_2 reacted.
C. Hexane: This is a saturated straight-chain alkane, not a cyclic compound.
D. Benzyl alcohol: This is an alcohol and would be formed from reactions involving a benzene ring with a substituent or from reactions other than simple catalytic hydrogenation.

Final Answer: Cyclohexane

Answer: (A)

Go Back to Question 13

Q14.

Solution

Concept: The standard emf of an electrochemical cell is calculated using the standard electrode potentials of the reduction half-reactions at the cathode and anode. The cell representation indicates the anode and cathode compartments. The standard emf (E°_{cell}) is given by $E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$ (where both are standard reduction potentials).

Solution: Step 1: Identify the anode and cathode from the cell representation.
The cell representation is Zn | Zn^{2+} || H^+ | H_2 | Pt.
The left side represents the anode compartment (oxidation occurs here): Zn | Zn^{2+} indicates the oxidation of zinc: $Zn(s) \rightarrow Zn^{2+}(aq) + 2e^-$.
The right side represents the cathode compartment (reduction occurs here): H^+ | H_2 | Pt indicates the reduction of hydrogen ions: $2H^+(aq) + 2e^- \rightarrow H_2(g)$. The platinum (Pt) electrode is inert and serves as a surface for the reaction.

Step 2: Find the standard reduction potentials (E°) for the relevant half-reactions.
We need the standard reduction potentials for:
- $Zn^{2+} + 2e^- \rightarrow Zn$
- $2H^+ + 2e^- \rightarrow H_2$

Standard reduction potentials at 25°C:
- $E^\circ(Zn^{2+}/Zn) = -0.76\,V$
- $E^\circ(H^+/H_2) = 0.00\,V$ (This is the standard hydrogen electrode, SHE)

Step 3: Calculate the standard emf of the cell (E°_{cell}).
The standard emf of the cell is calculated as:
$E^\circ_{cell} = E^\circ_{cathode} - E^\circ_{anode}$

Here, the cathode is the SHE (H^+/H_2), so $E^\circ_{cathode} = 0.00\,V$.
The anode is the Zn/Zn^{2+} half-cell. The oxidation reaction is $Zn \rightarrow Zn^{2+} + 2e^-$. The standard reduction potential for the reverse reaction ($Zn^{2+} + 2e^- \rightarrow Zn$) is $E^\circ_{anode} = -0.76\,V$.

$E^\circ_{cell} = E^\circ(H^+/H_2) - E^\circ(Zn^{2+}/Zn)$
$E^\circ_{cell} = 0.00\,V - (-0.76\,V)$
$E^\circ_{cell} = 0.00\,V + 0.76\,V$
$E^\circ_{cell} = 0.76\,V$

Step 4: Choose the closest option.
The calculated standard emf is $0.76\,V$.

Final Answer: 0.76 V

Answer: (A)

Go Back to Question 14

Q15.

Solution

Concept: Transition elements exhibit variable oxidation states due to the involvement of both ns and $(n-1)d$ electrons in chemical bonding. The number of accessible oxidation states depends on the availability of these electrons and their ease of removal. Elements with more unpaired electrons and a smaller energy difference between ns and $(n-1)d$ orbitals tend to show a wider range of oxidation states.

Solution: Step 1: Determine the electronic configuration of the transition elements listed.
- Cr (Chromium): Atomic number 24. Electronic configuration: $[Ar]3d^5 4s^1$. It has 5 unpaired d electrons and 1 s electron.
- Mn (Manganese): Atomic number 25. Electronic configuration: $[Ar]3d^5 4s^2$. It has 5 unpaired d electrons and 2 s electrons.
- Fe (Iron): Atomic number 26. Electronic configuration: $[Ar]3d^6 4s^2$. It has 4 unpaired d electrons and 2 s electrons.
- Cu (Copper): Atomic number 29. Electronic configuration: $[Ar]3d^{10} 4s^1$. It has 0 unpaired d electrons and 1 s electron.

Step 2: Identify the common and maximum oxidation states.
- Cr: Common oxidation states: +2, +3, +6. It can exhibit oxidation states from +1 to +6.
- Mn: Common oxidation states: +2, +3, +4, +6, +7. It can exhibit oxidation states from +2 to +7.
- Fe: Common oxidation states: +2, +3. It can exhibit oxidation states from +2 to +6, but +2 and +3 are most common.
- Cu: Common oxidation states: +1, +2. It can exhibit oxidation states from +1 to +2.

Step 3: Compare the range of oxidation states.
Manganese (Mn) exhibits the widest range of oxidation states, from +2 to +7, totaling 6 common oxidation states in this range. Chromium also shows a wide range, but Mn's +7 state is particularly notable. Iron's range is also significant but generally lower than Mn. Copper's range is quite limited.

Step 4: Conclude which element shows the maximum number of oxidation states.
Manganese (Mn) shows the maximum number of oxidation states among the given options. This is due to the availability of all 5 electrons from the 3d subshell and both electrons from the 4s subshell, leading to oxidation states from +2 ($3d^5 4s^0$) to +7 ($3d^0 4s^0$).

Final Answer: $\boxed{\text{Mn}}$

Answer: (B)

Go Back to Question 15

Q16.

Solution

Concept: Natural rubber is a polymer. Polymers are large molecules made up of repeating structural units called monomers. Identifying the monomer is key to understanding the structure and properties of the polymer.

Solution: Step 1: Understand the nature of natural rubber.
Natural rubber is a polymer derived from latex, which is produced by certain plants. It is an elastomer, meaning it can be stretched and returned to its original shape.

Step 2: Identify the monomer unit of natural rubber.
Natural rubber is a polymer of isoprene. Isoprene, also known as 2-methylbuta-1,3-diene, is a diene (contains two double bonds). The polymerization of isoprene units forms polyisoprene, which is the chemical structure of natural rubber.

$$\text{Monomer: Isoprene (2-methylbuta-1,3-diene)} \quad CH_2 = C(CH_3) - CH = CH_2$$

When isoprene polymerizes, the double bonds rearrange, and the units link together to form a long chain. The cis-1,4-polymerization of isoprene yields natural rubber.

$$n\,(\mathrm{CH_2 = C(CH_3) - CH = CH_2}) \xrightarrow{\text{Polymerization}} -[\mathrm{CH_2 - C(CH_3) = CH - CH_2}]-_n$$

Step 3: Evaluate the options.
A. Isoprene: This is the correct monomer.
B. Styrene: The polymer of styrene is polystyrene.
C. Ethene: The polymer of ethene is polyethene (polyethylene).
D. Vinyl chloride: The polymer of vinyl chloride is polyvinyl chloride (PVC).

Final Answer: Isoprene

Answer: (A)

Go Back to Question 16

Q17.

Solution

Concept: A conjugate base is formed when an acid donates a proton (H^+). According to the Brønsted-Lowry acid-base theory, an acid is a proton donor, and a base is a proton acceptor.

Solution: Step 1: Identify the acid.
The given species is HSO_4^-. We are asked to find its conjugate base.

Step 2: Understand how to form a conjugate base.
To find the conjugate base of an acid, remove one proton (H^+) from the acid and decrease its charge by one unit.

Step 3: Apply the rule to HSO_4^-.
When we remove one proton (H^+) from HSO_4^-:
- The H atom is removed.
- The remaining species is SO_4.
- The original charge of HSO_4^- is -1. When a proton (+1 charge) is removed, the charge of the remaining species becomes $(-1) - (+1) = -2$.

So, the conjugate base is SO_4^{2-}.

Step 4: Write the acid-base reaction.
$HSO_4^- \rightleftharpoons H^+ + SO_4^{2-}$
Here, HSO_4^- acts as an acid (proton donor) and SO_4^{2-} acts as its conjugate base.

Step 5: Evaluate the options.
A. H_2SO_4: This is the acid for which HSO_4^- is the conjugate base.
B. SO_4^{2-}: This is the correct conjugate base.
C. SO_3^{2-}: This is the sulfite ion, which is related to sulfurous acid (H_2SO_3).
D. HSO_3^-: This is the bisulfite or hydrogen sulfite ion, the conjugate base of sulfurous acid (H_2SO_3).

Final Answer: $\boxed{SO_4^{2-}}$

Answer: (B)

Go Back to Question 17

Q18.

Solution

Concept: A heating curve illustrates how the temperature of a substance changes as heat is added over time. During phase transitions (like melting or boiling), the added heat energy is used to overcome intermolecular forces rather than increasing the kinetic energy of the molecules, resulting in a constant temperature.

Solution: Step 1: Analyze the heating curve.
The graph shows temperature on the y-axis and time (or heat added) on the x-axis.
- The first inclined segment (from time 0.5 to 2.8) shows an increase in temperature. This represents the substance in a single phase (e.g., solid) being heated.
- The first horizontal segment (from time 2.8 to 4) shows that the temperature remains constant while heat is being added.
- The second inclined segment (from time 4 to 6) shows another increase in temperature, indicating the substance is now in a different phase (e.g., liquid) and is being heated.

Step 2: Interpret the horizontal segment.
A horizontal line on a heating curve means that the temperature is not changing, even though heat is being supplied. This energy input is used to break intermolecular bonds and change the state of matter from one phase to another. This process is called a phase transition.

Step 3: Relate the phase transition to the options.
- Rise in temperature: This occurs during the inclined segments, not the horizontal ones.
- Constant kinetic energy: While kinetic energy is related to temperature, during a phase transition, the potential energy of the molecules changes significantly as bonds are broken or formed, while the average kinetic energy (and thus temperature) remains constant. However, "phase transition" is a more direct description of what the horizontal line represents.
- Phase transition: This is exactly what happens during a phase change (e.g., melting of solid to liquid, or boiling of liquid to gas). The heat absorbed is called latent heat and is used to change the potential energy of the molecules.
- Decrease in entropy: Entropy generally increases with temperature and during phase transitions (e.g., solid to liquid, liquid to gas). So, a decrease in entropy is incorrect.

The horizontal portion of the heating curve signifies a phase transition occurring at a constant temperature.

Final Answer: Phase transition

Answer: (C)

Go Back to Question 18

Q19.

Solution

Concept: Aldehydes react with alcohols in the presence of an acid catalyst to form acetals. The reaction proceeds in two steps: first, the formation of a hemiacetal, and then the conversion of the hemiacetal to an acetal by reaction with another molecule of alcohol.

Solution: Step 1: Understand the reaction between aldehydes and alcohols.
Acetaldehyde reacts with alcohols to form acetals. This reaction is acid-catalyzed.

Step 2: Consider the reaction of acetaldehyde with ethanol.
Acetaldehyde is CH_3CHO. Ethanol is CH_3CH_2OH. The reaction in the presence of dry HCl (acid catalyst) proceeds as follows:

First step: Formation of Hemiacetal
Acetaldehyde reacts with one molecule of ethanol to form a hemiacetal.
$CH_3CHO + CH_3CH_2OH \xrightarrow{HCl} CH_3CH(OH)OCH_2CH_3$ (Acetaldehyde ethyl hemiacetal)
The hemiacetal has a structure with a carbon atom bonded to both an -OH group and an -OR group.

Second step: Formation of Acetal
The hemiacetal reacts with a second molecule of ethanol in the presence of dry HCl to form an acetal. The -OH group of the hemiacetal is replaced by another -OCH2CH3 group.
$CH_3CH(OH)OCH_2CH_3 + CH_3CH_2OH \xrightarrow{HCl} CH_3CH(OCH_2CH_3)_2 + H_2O$ (Acetaldehyde diethyl acetal)

The question states "excess ethanol," which ensures that the reaction goes to completion, forming the acetal.

Step 3: Evaluate the options.
A. Hemiacetal: This is an intermediate product, not the final product with excess ethanol.
B. Acetal: This is the final product formed when an aldehyde reacts with excess alcohol in the presence of an acid catalyst.
C. Ester: Esters are formed from the reaction of carboxylic acids with alcohols.
D. Ether: Ethers are formed from the dehydration of alcohols.

Final Answer: Acetal

Answer: (B)

Go Back to Question 19

Q20.

Solution

Concept: The second law of thermodynamics states that for any spontaneous process, the entropy of the universe ($S_{universe}$) increases. For a process occurring in an isolated system, the system and its surroundings are the same, meaning there is no exchange of heat or matter with the surroundings. Therefore, for an isolated system, the change in entropy of the universe is equal to the change in entropy of the system itself.

Solution: Step 1: Recall the definition of an isolated system.
An isolated system exchanges neither matter nor energy with its surroundings.

Step 2: Use the entropy relation.

$$\Delta S_{\text{universe}} = \Delta S_{\text{system}} + \Delta S_{\text{surroundings}}$$

For an isolated system:

$$\Delta S_{\text{surroundings}} = 0$$

Hence,

$$\Delta S_{\text{universe}} = \Delta S_{\text{system}}$$

Step 3: Apply the second law of thermodynamics.
For a spontaneous process:

$$\Delta S_{\text{universe}} > 0$$

Therefore, in an isolated system, entropy always increases for a spontaneous process.

Final Answer: Positive

Answer: (B)

Go Back to Question 20

Q21.

Solution

Concept: Hybridization is the mixing of atomic orbitals to form new hybrid orbitals with different shapes and energies, which are then used for covalent bonding. The hybridization of an atom can be determined by counting the number of sigma bonds and lone pairs around it.

Solution: Step 1: Understand the structure of diamond.
Diamond is a crystalline allotrope of carbon. Its structure is a three-dimensional network where each carbon atom is covalently bonded to four other carbon atoms. This arrangement forms a giant tetrahedral structure.

Step 2: Determine the number of sigma bonds and lone pairs around a carbon atom in diamond.
Each carbon atom in diamond forms four single covalent bonds with its neighboring carbon atoms. Each single covalent bond is a sigma (σ) bond.
A carbon atom has 4 valence electrons. In diamond, all 4 valence electrons are used to form these four σ bonds. There are no lone pairs of electrons on the carbon atoms.

Step 3: Determine the hybridization.
The number of hybrid orbitals required is equal to the sum of sigma bonds and lone pairs.
Number of sigma bonds = 4
Number of lone pairs = 0
Total electron domains = 4 + 0 = 4

To accommodate 4 electron domains, the carbon atom undergoes hybridization involving one s orbital and three p orbitals, forming four sp^3 hybrid orbitals. These sp^3 hybrid orbitals are arranged tetrahedrally around the carbon atom, leading to the tetrahedral geometry of the carbon framework in diamond.

Step 4: Evaluate the options.
A. sp: This hybridization leads to a linear geometry (2 electron domains).
B. sp^2: This hybridization leads to a trigonal planar geometry (3 electron domains).
C. sp^3: This hybridization leads to a tetrahedral geometry (4 electron domains). This matches the structure of carbon in diamond.
D. dsp^2: This hybridization leads to a square planar geometry (4 electron domains, often seen in transition metal complexes).

Final Answer: $\boxed{sp^3}$

Answer: (C)

Go Back to Question 21

Q22.

Solution

Concept: The boiling point of a substance is influenced by the strength of intermolecular forces between its molecules. For hydrides of Group 15 elements (N, P, As, Sb), boiling points generally increase down the group due to increasing molecular size and van der Waals forces. However, ammonia (NH_3) exhibits an anomalous boiling point due to the presence of strong hydrogen bonding.

Solution: Step 1: Consider the trend in molecular weight and van der Waals forces.
As we move down Group 15, the molecular weight of the hydrides increases:
$NH_3 < PH_3 < AsH_3 < SbH_3$
Consequently, the van der Waals forces (London dispersion forces) also increase down the group. This generally leads to an increase in boiling points.

Step 2: Consider the effect of hydrogen bonding.
Nitrogen is highly electronegative, and ammonia (NH_3) is a small molecule. The nitrogen atom in ammonia can form strong hydrogen bonds with hydrogen atoms of adjacent ammonia molecules. Hydrogen bonding is a much stronger intermolecular force than dipole-dipole interactions or London dispersion forces.

Step 3: Analyze the boiling points of the hydrides.
- NH_3: Due to strong hydrogen bonding, NH_3 has a significantly higher boiling point than would be expected based on its molecular weight alone. Boiling point of NH_3 is -33°C.
- PH_3 (Phosphine): Molecules are larger than NH_3, but lacks significant hydrogen bonding. It has dipole-dipole interactions and London dispersion forces. Boiling point of PH_3 is -87.8°C.
- AsH_3 (Arsine): Larger molecule than PH_3, so stronger London dispersion forces. Boiling point of AsH_3 is -55°C.
- SbH_3 (Stibine): Largest molecule, so strongest London dispersion forces. Boiling point of SbH_3 is -17°C.

Step 4: Compare the boiling points.
The order of boiling points is:
$PH_3(-87.8°C) < AsH_3(-55°C) < NH_3(-33°C) < SbH_3(-17°C)$

This means SbH_3 has the highest boiling point among the given options.

Final Answer: $\boxed{SbH_3}$

Answer: (D)

Go Back to Question 22

Q23.

Solution

Concept: The Arrhenius equation relates the rate constant (k) of a chemical reaction to temperature (T), activation energy (E_a), and the pre-exponential factor (A). The logarithmic form of the Arrhenius equation can be linearized to plot $\log k$ versus $1/T$, which yields a straight line.

Solution: The Arrhenius equation is:

$$k = Ae^{-E_a/RT}$$

Taking logarithm on both sides,

$$\log k = \log A - \frac{E_a}{2.303R}\left(\frac{1}{T}\right)$$

This equation is in the form of a straight line:

$$y = mx + c$$

where,

$$y = \log k, \qquad x = \frac{1}{T}$$

Hence, the slope of the graph between $\log k$ and $1/T$ is:

$$m = -\frac{E_a}{2.303R}$$

Thus, the graph is a straight line with negative slope.

Final Answer: $\boxed{-\frac{E_a}{2.303R}}$

Answer: (A)

Go Back to Question 23

Q24.

Solution

Concept: Acidity is determined by the stability of the conjugate base formed after the donation of a proton. A more stable conjugate base leads to a stronger acid.

Solution: Phenol and ethanol ionise as:

$$C_6H_5OH \rightleftharpoons C_6H_5O^- + H^+$$

$$C_2H_5OH \rightleftharpoons C_2H_5O^- + H^+$$

The acidity of a compound depends on the stability of its conjugate base.
In phenoxide ion ($C_6H_5O^-$), the negative charge on oxygen is delocalised over the benzene ring through resonance. This resonance stabilisation makes the phenoxide ion more stable.

$$\text{Phenoxide ion} \leftrightarrow \text{Resonance structures}$$

On the other hand, the ethoxide ion ($C_2H_5O^-$) does not show resonance. The negative charge remains localized on the oxygen atom, making it less stable.
Since the phenoxide ion is more stable than the ethoxide ion, phenol can lose a proton more easily. Therefore, phenol is more acidic than ethanol.

Final Answer: Phenoxide ion is resonance stabilised

Answer: (B)

Go Back to Question 24

Q25.

Solution

Concept: Packing efficiency (or packing fraction) is the ratio of the volume occupied by atoms in a unit cell to the total volume of the unit cell. It is usually expressed as a percentage. Different crystal lattice structures have different packing efficiencies.

Solution: In a Face-Centred Cubic (FCC) lattice, atoms are present at all eight corners and at the centre of each face.
Number of atoms in one FCC unit cell:

$$8 \times \frac{1}{8} + 6 \times \frac{1}{2} = 1 + 3 = 4$$

In FCC, atoms touch along the face diagonal.

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

Hence,

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

Volume occupied by 4 atoms:

$$4 \times \frac{4}{3}\pi r^3 = \frac{16}{3}\pi r^3$$

Volume of the unit cell:

$$a^3 = (2\sqrt{2}r)^3 = 16\sqrt{2}r^3$$

Therefore, packing efficiency is:

$$\text{Packing Efficiency} = \frac{\text{Volume occupied by atoms}}{\text{Volume of unit cell}} \times 100$$

$$= \frac{\frac{16}{3}\pi r^3}{16\sqrt{2}r^3} \times 100$$

$$= \frac{\pi}{3\sqrt{2}} \times 100 \approx 74\%$$

Thus, the packing efficiency of an FCC lattice is 74%.

Final Answer: $\boxed{74\%}$

Answer: (C)

Go Back to Question 25

Q26.

Solution

Concept: Ambidentate ligands are ligands that can coordinate to a central metal atom through two or more different atoms. This means the ligand has at least two potential donor atoms, and the bonding can occur through either of them.

Solution: Step 1: Define an ambidentate ligand.
An ambidentate ligand is a ligand that can bind to a central metal ion through different donor atoms, resulting in different coordination complexes.

Step 2: Analyze the given ligands.
A. NH_3 (Ammonia): The only donor atom is Nitrogen (N). It is a monodentate ligand.
B. H_2O (Water): The only donor atom is Oxygen (O). It is a monodentate ligand.
C. SCN^- (Thiocyanate ion): This ion has two possible donor atoms: Sulfur (S) and Nitrogen (N).
- If it binds through Nitrogen, it is called thiocyanato-N: $[M - SCN]$.
- If it binds through Sulfur, it is called thiocyanato-S: $[M - NCS]$.
Therefore, SCN^- is an ambidentate ligand.
D. EDTA (Ethylenediaminetetraacetic acid): EDTA is a hexadentate ligand, meaning it can bind to a metal ion through six donor atoms (four oxygen atoms and two nitrogen atoms). It is not ambidentate as it binds in a specific chelating manner using multiple atoms simultaneously, not by choosing between different donor atoms for a single binding site.

Step 3: Identify the ambidentate ligand.
Based on the analysis, SCN^- is the ambidentate ligand among the given options because it can coordinate to the metal ion through either the nitrogen atom or the sulfur atom.

Final Answer: $\boxed{SCN^-}$

Answer: (C)

Go Back to Question 26

Q27.

Solution

Concept: The relationship between Gibbs free energy change (ΔG) and the electromotive force (emf) or standard emf (E°) of an electrochemical cell is a fundamental thermodynamic equation. It relates the spontaneity of a redox reaction to the electrical work it can perform.

Solution: Step 1: Recall the relationship between Gibbs free energy and maximum non-expansion work.
The Gibbs free energy change (ΔG) for a process represents the maximum amount of non-expansion work that can be extracted from the system at constant temperature and pressure. For an electrochemical cell, the electrical work done is equal to the charge transferred multiplied by the potential difference.

Step 2: Define the terms.
- ΔG: Gibbs free energy change.
- n: Number of moles of electrons transferred in the balanced redox reaction.
- F: Faraday's constant (96485 C/mol), which represents the charge of one mole of electrons.
- E: Electromotive force (emf) of the cell, which is the potential difference driving the electron flow.

Step 3: Relate electrical work to emf.
The electrical work done by the cell is given by $W_{elec} = q \times E$, where q is the total charge transferred.
The total charge transferred is nF (moles of electrons transferred multiplied by the charge per mole of electrons).
So, $W_{elec} = nFE$.

Step 4: Connect Gibbs free energy to electrical work.
The maximum non-expansion work (which is electrical work in this case) that can be obtained from a spontaneous process is equal to the decrease in Gibbs free energy. Thus, $\Delta G = -W_{elec}$.
The negative sign indicates that if the cell performs work (spontaneous process, $\Delta G < 0$), the work done is positive.

Step 5: Substitute the expressions.
$\Delta G = -(nFE)$
$\Delta G = -nFE$

This equation holds for the standard conditions as well, where $\Delta G^\circ = -nFE^\circ$.

Step 6: Choose the correct option. The relation between Gibbs free energy and emf is $\Delta G = -nFE$.

Final Answer: $\boxed{\Delta G = -nFE}$

Answer: (B)

Go Back to Question 27

Q28.

Solution

Concept: Aldol condensation is a reaction between two carbonyl compounds (aldehydes or ketones) that have at least one alpha-hydrogen atom. The reaction involves the formation of a carbon-carbon bond between the alpha-carbon of one molecule and the carbonyl carbon of another, leading to the formation of a β-hydroxy aldehyde or ketone, which then often dehydrates to form an α, β-unsaturated aldehyde or ketone.

Solution: Step 1: Understand the requirements for aldol condensation.
Aldol condensation requires the presence of α-hydrogens. The α-hydrogens are the hydrogen atoms attached to the carbon atom adjacent to the carbonyl group. These hydrogens are acidic and can be removed by a base to form an enolate ion, which is the nucleophile in the aldol condensation.

Step 2: Analyze each compound for the presence of α-hydrogens.
A. Acetaldehyde (CH_3CHO): The carbon atom adjacent to the carbonyl group (the α-carbon) has three hydrogen atoms (α-hydrogens). Thus, it can undergo aldol condensation.
$CH_3\underline{H}_2CHO \rightarrow [CH_3\underline{C}HO^-]$ (enolate)

B. Benzaldehyde (C_6H_5CHO): The carbon atom adjacent to the carbonyl group is the carbon atom of the benzene ring. Benzene ring carbons do not have hydrogen atoms attached that are considered α-hydrogens in the context of aldol condensation for aldehydes. While the phenyl group itself has hydrogens, they are not acidic enough to be removed by typical bases used in aldol condensation. Therefore, benzaldehyde does not have α-hydrogens directly attached to the carbon adjacent to the carbonyl group and cannot undergo aldol condensation. It can undergo a related reaction called the Cannizzaro reaction if it lacks α-hydrogens and is treated with a strong base.

C. Propanal (CH_3CH_2CHO): The α-carbon has two hydrogen atoms (α-hydrogens). Thus, it can undergo aldol condensation. $CH_3\underline{H}_2CHO \rightarrow [CH_3\underline{C}HO^-]$ (enolate)

D. Acetone (CH_3COCH_3): The carbon atoms adjacent to the carbonyl group (both are α-carbons) have three hydrogen atoms each (α-hydrogens). Thus, it can undergo aldol condensation.
$CH_3\underline{H}_2COCH_3 \rightarrow [CH_3\underline{C}HOCH_3^-]$ (enolate)

Step 3: Identify the compound that does not undergo aldol condensation.
Benzaldehyde is the only compound among the given options that lacks α-hydrogens on the carbon directly attached to the carbonyl group and therefore cannot undergo aldol condensation.

Final Answer: Benzaldehyde

Answer: (B)

Go Back to Question 28

Q29.

Solution

Concept: Covalent bonds are formed by the overlap of atomic orbitals. The type of overlap (head-on or sideways) and the types of orbitals involved determine the nature of the bond formed (σ or π).

Solution: Step 1: Analyze the orbital overlap shown in the diagram.
The diagram shows:
- A spherical orbital on the left, representing an s orbital.
- Two lobed orbitals on the right, representing a p orbital.
- The s orbital and one lobe of the p orbital are overlapping in a head-on manner along the internuclear axis.
- The overlap region is depicted as a bond.

Step 2: Understand the types of covalent bonds formed by orbital overlap.
- σ (sigma) bond: Formed by the head-on overlap of atomic orbitals (s-s, s-p, p-p head-on). σ bonds are stronger and occur along the internuclear axis.
- π (pi) bond: Formed by the sideways overlap of atomic orbitals (usually p-p or p-d). π bonds occur above and below the internuclear axis and are generally weaker than σ bonds.

Step 3: Determine the type of bond formed based on the overlap.
The diagram clearly shows head-on overlap between an s orbital and a p orbital. This type of head-on overlap along the internuclear axis results in the formation of a sigma (σ) bond.

Step 4: Evaluate the options.
A. $p\pi - p\pi$: This would involve the sideways overlap of two p orbitals, forming a π bond. This is not what is shown.
B. $s - s\,\sigma$: This involves the head-on overlap of two s orbitals, forming a σ bond. The diagram shows an s and a p orbital.
C. $s - p\,\sigma$: This involves the head-on overlap of an s orbital and a p orbital, forming a σ bond. This perfectly matches the diagram.
D. Ionic bond: This is formed by the transfer of electrons, not by the overlap of orbitals.

Final Answer: $\boxed{s - p\,\sigma}$

Answer: (C)

Go Back to Question 29

Q30.

Solution

Concept: The number of moles of a substance can be calculated using its mass and molar mass. The molar mass of a compound is the sum of the atomic masses of all atoms in its chemical formula.

Solution: Step 1: Determine the molar mass of CO_2.
The chemical formula for carbon dioxide is CO_2.
- Atomic mass of Carbon (C) $\approx$ 12 g/mol
- Atomic mass of Oxygen (O) $\approx$ 16 g/mol

Molar mass of CO_2 = (Atomic mass of C) + 2 $\times$ (Atomic mass of O)
Molar mass of $CO_2 = 12 + 2 \times 16 = 12 + 32 = 44$ g/mol.

Step 2: Use the formula to calculate the number of moles.
Number of moles $(n) = \frac{\text{Mass of substance}}{\text{Molar mass of substance}}$

Given mass of CO_2 = 22 g.
Molar mass of CO_2 = 44 g/mol.

$n = \frac{22\text{ g}}{44\text{ g/mol}}$

Step 3: Calculate the result.
$n = 0.5$ moles.

Step 4: Choose the correct option.
The number of moles present in 22 g of CO_2 is 0.5.

Final Answer: $\boxed{0.5}$

Answer: (B)

Go Back to Question 30

Q31.

Solution

Concept: A catalyst is a substance that increases the rate of a chemical reaction without itself undergoing any permanent chemical change. It achieves this by altering the reaction pathway.

Solution: Step 1: Understand the role of a catalyst.
Catalysts do not change the thermodynamics of a reaction (like the overall enthalpy change or equilibrium position). Instead, they affect the kinetics, i.e., the rate at which the reaction proceeds.

Step 2: Recall how catalysts affect reaction rates.
Catalysts work by providing an alternative reaction pathway with a lower activation energy. Activation energy is the minimum amount of energy required for reactant molecules to overcome the energy barrier and form products. By lowering this barrier, more molecules have sufficient energy to react at a given temperature, thus increasing the reaction rate.

Step 3: Analyze the given options:
A. Increasing collision frequency: While increased collision frequency can increase reaction rate, a catalyst doesn't fundamentally change the frequency of collisions; it changes the *effectiveness* of those collisions.
B. Lowering activation energy: This is the primary mechanism by which catalysts increase reaction rates. They provide an alternative mechanism with a lower energy barrier.
C. Increasing enthalpy change: Enthalpy change (ΔH) is a thermodynamic property of the reaction and is not affected by a catalyst.
D. Shifting equilibrium: Catalysts do not shift the equilibrium position of a reversible reaction. They only help the reaction reach equilibrium faster by increasing the rates of both the forward and reverse reactions equally.

Step 4: Conclude the mechanism.
A catalyst increases the rate of reaction by providing an alternative reaction pathway with a lower activation energy.

Final Answer: $\boxed{Loweringactivationenergy}$

Answer: (B)

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Q32.

Solution

Concept: Aryl halides, such as chlorobenzene, are generally unreactive towards nucleophilic substitution under normal conditions. This is due to the strong C-X bond (strengthened by resonance with the aromatic ring) and the difficulty in forming a stable aryl carbocation. However, under drastic conditions, nucleophilic aromatic substitution can occur.

Solution: Step 1: Understand the reactivity of chlorobenzene.
Chlorobenzene has a chlorine atom attached to a benzene ring. The carbon atom of the benzene ring attached to chlorine is sp^2 hybridized, making the C-Cl bond stronger than in alkyl halides. Also, the lone pairs on chlorine can participate in resonance with the benzene ring, further strengthening the C-Cl bond and making it resistant to nucleophilic attack.

Step 2: Consider the conditions required for nucleophilic aromatic substitution.
Nucleophilic aromatic substitution typically requires harsh conditions, such as:
- High temperatures.
- High pressures.
- Strong nucleophiles.

Step 3: Evaluate the given reagents and conditions.
A. Dilute NaOH: At room temperature or mild conditions, NaOH will not react with chlorobenzene.
B. Fused NaOH at high temperature and pressure: This combination provides the drastic conditions necessary for nucleophilic aromatic substitution. The hydroxide ion (OH^-) acts as a strong nucleophile, and the high temperature and pressure overcome the activation energy barrier. This reaction proceeds via a benzyne intermediate or nucleophilic addition-elimination mechanism.
$C_6H_5Cl + 2NaOH \xrightarrow{HighT,P} C_6H_5ONa + NaCl + H_2O$
Acidification of C_6H_5ONa yields phenol.
C. Aqueous KOH at room temperature: Similar to dilute NaOH, this is not drastic enough for a significant reaction.
D. $NaHCO_3$: Sodium bicarbonate is a weak base and will not react with chlorobenzene.

Step 4: Identify the correct reagent and conditions.
Fused NaOH at high temperature and pressure are the drastic conditions required to convert chlorobenzene to phenol.

Final Answer: Fused NaOH at high temperature and pressure

Answer: (B)

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Q33.

Solution

Concept: Raoult's law describes the vapor pressure of a solution. It states that the partial vapor pressure of each component in an ideal solution is directly proportional to its mole fraction in the solution and its vapor pressure in the pure state.

Solution: Step 1: Understand Raoult's Law.
Raoult's law is mathematically expressed as $P_i = x_i P_i^\circ$, where:
- P_i is the partial vapor pressure of component i in the solution.
- x_i is the mole fraction of component i in the solution.
- P_i° is the vapor pressure of pure component i.

Step 2: Identify the conditions under which Raoult's law is applicable.
Raoult's law is strictly applicable to ideal solutions. An ideal solution is one where the solute-solvent interactions are similar in strength to the solute-solute and solvent-solvent interactions. This means that the components do not interact strongly with each other, and the volume change upon mixing is zero.

Step 3: Evaluate the given options.
A. Ideal solutions: Raoult's law is fundamentally defined for ideal solutions.
B. Non-ideal solutions only: This is incorrect. For non-ideal solutions, deviations from Raoult's law occur.
C. Electrolytic solutions only: Electrolytic solutions involve ions and often exhibit non-ideal behavior due to strong interionic interactions. Raoult's law is not directly applicable without considering the van't Hoff factor, and even then, it's an approximation for non-ideal behavior.
D. Colloidal solutions: Colloidal solutions are heterogeneous mixtures with large dispersed particles, and Raoult's law, which deals with the vapor pressure of components based on mole fraction, is not applicable here.

Step 4: Conclude the applicability of Raoult's law.
Raoult's law is precisely applicable to ideal solutions. Real solutions approximate ideal behavior at very low concentrations or when the components are chemically similar.

Final Answer: Ideal solutions

Answer: (A)

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Q34.

Solution

Concept: Crystal systems describe the arrangement of atoms in a crystal lattice. The body-centred cubic (BCC) structure is characterized by atoms at the corners of the cube and one atom at the very center of the cube.

Solution: Step 1: Analyze the provided crystal structure diagram.
The diagram shows a cube.
- Atoms are located at each of the eight corners of the cube.
- There is an additional atom located precisely at the center of the cube.

Step 2: Recall the definitions of different crystal systems.
- Simple cubic (SC): Atoms are located only at the eight corners of the cube.
- Face-centred cubic (FCC): Atoms are located at the eight corners and at the center of each of the six faces of the cube.
- Body-centred cubic (BCC): Atoms are located at the eight corners and one atom is at the exact center of the body of the cube.
- Hexagonal close packed (HCP): This is a different type of packing arrangement, not based on a cubic unit cell.

Step 3: Match the diagram to the crystal system definition.
The diagram shows atoms at the corners and one atom in the center of the body of the cube. This description precisely matches the definition of a body-centred cubic (BCC) crystal system.

Final Answer: Body-centred cubic

Answer: (C)

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Q35.

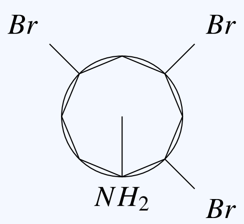
Solution

Concept: Aniline ($C_6H_5NH_2$) is an aromatic amine. The amino group (NH_2) is an activating group and an ortho, para-director for electrophilic aromatic substitution. Bromine water (Br_2 in H_2O) is a potent brominating agent.

Solution: Step 1: Understand the structure and reactivity of aniline.
Aniline has an amino group (NH_2) attached to a benzene ring. The lone pair of electrons on the nitrogen atom of the amino group is delocalized into the benzene ring, activating it towards electrophilic aromatic substitution. The amino group directs incoming electrophiles to the ortho and para positions.

Step 2: Consider the reaction of aniline with bromine water.
Bromine water is a very reactive brominating agent. Due to the strong activating effect of the amino group, aniline reacts readily and rapidly with bromine water to undergo substitution at all available ortho and para positions.

Step 3: Identify the products of the reaction.
The ortho positions (positions 2 and 6 relative to the amino group) and the para position (position 4) are activated. In bromine water, all these positions are substituted by bromine atoms.
Therefore, the reaction of aniline with bromine water yields 2,4,6-tribromoaniline.



Step 4: Evaluate the options.
A. Bromobenzene: This would be the product of brominating benzene, not aniline.
B. *o*-bromoaniline: This is a product of partial bromination, but bromine water leads to complete substitution at activated positions.
C. 2,4,6-tribromoaniline: This is the correct product formed by rapid substitution at all ortho and para positions.
D. Nitrobenzene: This is the product of nitration, not bromination.

Final Answer: 2,4,6-tribromoaniline

Answer: (C)

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Q36.

Solution

Concept: Linearity of a molecule is determined by its molecular geometry, which can be predicted using Valence Shell Electron Pair Repulsion (VSEPR) theory. A molecule is linear if its central atom is bonded to two other atoms with no lone pairs, resulting in a 180° bond angle.

Solution: Using VSEPR theory:

A. CO_2 Carbon has two electron domains and no lone pairs.

$$O = C = O$$

Hence, the geometry is linear with bond angle 180°.

B. $BeCl_2$ Beryllium forms two bonds and has no lone pairs.

$$Cl - Be - Cl$$

So, the molecule is linear with bond angle 180°.

C. SO_2 Sulfur has two bonding pairs and one lone pair.

$$O = S = O$$

Due to the lone pair, the shape becomes bent (V-shaped), not linear.

D. HCN

$$H - C \equiv N$$

Carbon has two electron domains, so the molecule is linear.

Thus, the linear molecules are:

$$CO_2, \ BeCl_2, \ HCN$$

Final Answer: $\boxed{CO_2, \ BeCl_2, \ HCN}$

Answer: (A, B, D)

Go Back to Question 36

Q37.

Solution

Concept: Unpaired electrons in a molecule contribute to its paramagnetism. The presence of unpaired electrons can be determined by analyzing the molecular orbital electronic configuration, particularly for diatomic and triatomic species.

Solution: Step 1: Determine the total number of valence electrons for each species.
A. O_2 (Oxygen molecule): 2 oxygen atoms * 6 valence electrons/atom = 12 valence electrons.
B. NO (Nitric oxide): 5 valence electrons (N) + 6 valence electrons (O) = 11 valence electrons.
C. N_2 (Nitrogen molecule): 2 nitrogen atoms * 5 valence electrons/atom = 10 valence electrons.
D. NO_2 (Nitrogen dioxide): 5 valence electrons (N) + 2 oxygen atoms * 6 valence electrons/atom = 17 valence electrons.

Step 2: Construct the molecular orbital (MO) diagram or Lewis structure and determine electron pairing.

A. O_2: The MO diagram for O_2 shows that there are two unpaired electrons in the degenerate π^* antibonding orbitals. Thus, O_2 is paramagnetic.
Lewis structure: O=O (double bond, with resonance and unpaired electrons on each O). A more accurate MO description shows unpaired electrons.

B. NO: This molecule has an odd number of valence electrons (11), so it must have at least one unpaired electron. In its MO diagram, there is one unpaired electron in an antibonding orbital. Thus, NO is paramagnetic.

C. N_2: This molecule has 10 valence electrons. Its MO diagram shows all electrons paired. It has a triple bond ($N \equiv N$). Thus, N_2 is diamagnetic.

D. NO_2: This molecule has 17 valence electrons. In its Lewis structure, there is typically one unpaired electron on the nitrogen atom, making it paramagnetic.

Step 3: Identify species with unpaired electrons.
O_2, NO, and NO_2 all contain unpaired electrons and are paramagnetic. N_2 is diamagnetic.

Final Answer: $\boxed{O_2, NO, NO_2}$

Answer: (A, B, D)

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Q38.

Solution

Concept: Fehling's test is a qualitative test used to detect the presence of aldehydes or alpha-hydroxy ketones. It is a mild oxidizing agent that oxidizes the aldehyde group while being reduced itself to a brick-red precipitate of copper(I) oxide (Cu_2O). Ketones generally do not give this test unless they have an α-hydroxy group. Aromatic aldehydes like benzaldehyde do not give Fehling's test.

Solution: Step 1: Understand Fehling's test.
Fehling's solution contains two parts: Fehling's solution A (aqueous copper(II) sulfate) and Fehling's solution B (alkaline sodium potassium tartrate). When mixed, they form a complex of Cu^{2+} ions. In the presence of a reducing agent (like an aldehyde), Cu^{2+} is reduced to Cu^{+} in an alkaline medium, forming a characteristic brick-red precipitate of Cu_2O.

Step 2: Identify the functional groups that give a positive Fehling's test.
- Aldehydes (except aromatic aldehydes like benzaldehyde)
- α-hydroxy ketones

Step 3: Analyze each given compound.
A. Methanal ($HCHO$): This is an aldehyde and has α-hydrogens. It readily gives a positive Fehling's test.
B. Ethanal (CH_3CHO): This is an aldehyde and has α-hydrogens. It readily gives a positive Fehling's test.
C. Benzaldehyde (C_6H_5CHO): This is an aromatic aldehyde. The carbonyl carbon is directly attached to the phenyl group. Aromatic aldehydes do not typically give Fehling's test because the phenyl group does not activate the carbonyl carbon in the same way as alkyl groups, and the resonance stabilization makes it less reactive towards mild oxidation. It undergoes the Cannizzaro reaction under strong alkaline conditions.
D. Glucose ($C_6H_{12}O_6$): Glucose is a monosaccharide. In solution, it exists in equilibrium between its cyclic hemiacetal form and an open-chain aldehyde form. The open-chain form is an aldehyde (specifically, an aldohexose), which readily gives a positive Fehling's test.

Step 4: Identify the compounds that give a positive Fehling's test.
Methanal, ethanal, and glucose will give a positive Fehling's test. Benzaldehyde will not.

Final Answer: Methanal, Ethanal, Glucose

Answer: (A, B, D)

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Q39.

Solution

Concept: Colloids are heterogeneous mixtures in which one substance is dispersed as very fine particles throughout another substance. They exhibit specific properties related to their particle size and interaction with light and the dispersion medium.

Solution: Step 1: Analyze each statement about colloids.

A. Colloidal particles show Brownian motion.
- Correct. Colloidal particles are constantly bombarded by the molecules of the dispersion medium, which are in random thermal motion. This results in the irregular, zigzag movement of colloidal particles known as Brownian motion.

B. Colloids pass through parchment paper.
- Correct. Parchment paper (or a semipermeable membrane) allows small molecules and ions to pass through but retains larger colloidal particles. This property is utilized in dialysis to purify colloidal solutions.

C. Tyndall effect is shown by colloids.
- Correct. The Tyndall effect is the scattering of a beam of light by colloidal particles, making the path of the light visible. This is due to the size of colloidal particles (typically in the range of 1 nm to 1000 nm), which is large enough to scatter light. True solutions, with much smaller solute particles, do not exhibit the Tyndall effect.

D. Colloids are homogeneous systems.
- Incorrect. Colloids are heterogeneous systems. Although they appear uniform to the naked eye, microscopic examination reveals that they consist of dispersed particles separate from the dispersion medium. True solutions are homogeneous.

Step 2: Identify the correct statements. Statements A, B, and C are correct descriptions of colloidal systems.

Final Answer:

Colloidal particles show Brownian motion,
Colloids pass through parchment paper,
Tyndall effect is shown by colloids

Answer: (A, B, C)

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Q40.

Solution

Concept: Geometrical isomerism (cis-trans isomerism) occurs in compounds where rotation around a bond is restricted, and there are different groups attached to the atoms involved in the restricted rotation. This typically happens in alkenes with different substituents on each carbon of the double bond or in coordination complexes with different ligands arranged around a central metal atom.

Solution: Geometrical isomerism is possible when rotation is restricted and the attached groups are different.

A. But-2-ene

$$CH_3 - CH = CH - CH_3$$

Each carbon of the double bond has two different groups (H and CH_3), so it shows cis-trans isomerism.

B. $[Pt(NH_3)_2Cl_2]$

This square planar complex can exist in:

$$\text{cis-}[Pt(NH_3)_2Cl_2] \quad \text{and} \quad \text{trans-}[Pt(NH_3)_2Cl_2]$$

Hence, it shows geometrical isomerism.

C. Hex-3-ene

$$CH_3CH_2 - CH = CH - CH_2CH_3$$

Both double-bonded carbons have different groups attached, so cis-trans isomerism is possible.

D. 1,2-dichloroethene

$$CHCl = CHCl$$

Each carbon has H and Cl attached, so it also exhibits geometrical isomerism.

Thus, all the given compounds show geometrical isomerism.

Final Answer:

$$\boxed{\text{But-2-ene, } [Pt(NH_3)_2Cl_2], \text{ Hex-3-ene, 1, 2-dichloroethene}}$$

Answer: (A, B, C, D)

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Answer Key

Q	Ans	Q	Ans	Q	Ans	Q	Ans	Q	Ans
1	A	2	B	3	A	4	C	5	B
6	C	7	B	8	D	9	B	10	C
11	B	12	B	13	A	14	A	15	B
16	A	17	B	18	C	19	B	20	B
21	C	22	D	23	A	24	B	25	C
26	C	27	B	28	B	29	C	30	B
31	B	32	B	33	A	34	C	35	C
36	A, B, D	37	A, B, D	38	A, B, D	39	A, B, C	40	A, B, C, D