JEE (ADVANCED) 2018
CHEMISTRY PAPER 2
SECTION 1

- This section contains **SIX (06)** questions.
- Each question has **FOUR** options for correct answer(s). **ONE OR MORE THAN ONE** of these four option(s) is (are) correct option(s).

1. The correct option(s) regarding the complex $[Co(en)(NH_3)_3(H_2O)]^{3+}$

$$(en = H_2NCH_2CH_2NH_2) \text{ is (are)}$$

(A) It has two geometrical isomers.

(B) It will have three geometrical isomers if bidentate 'en' is replaced by two cyanide ligands.

(C) It is paramagnetic.

(D) It absorbs light at longer wavelength as compared to $[Co(en)(NH_3)_4]^{3+}$.

Solution

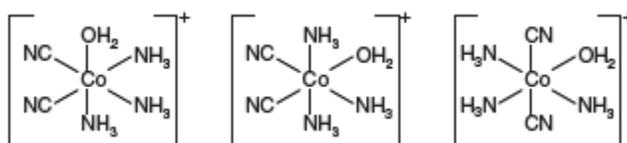**(A), (B), (D)**

Option (A): Correct. The complex $[Co(en)(NH_3)_3(H_2O)]^{3+}$ has two following isomers:
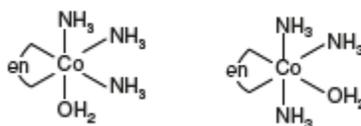
Option (B): Correct. When bidentate 'en' is replaced by two cyanide ligands complex $[Co(CN)_2(NH_3)_3(H_2O)]^+$ will have three following isomers:

Option (C): Incorrect. In complex $[Co(en)(NH_3)_3(H_2O)]^{3+}$, Co is in +3 oxidation, that is, $[Ar]d^6$. In the presence given ligands the complex will have low spin.

Option (D): Correct. Complex $[Co(en)(NH_3)_4]^{3+}$ has larger gap between t_{2g} and e_g than $[Co(en)(NH_3)_3(H_2O)]^{3+}$. Hence $[Co(en)(NH_3)_3(H_2O)]^{3+}$ will absorb light at longer wavelength as compared to $[Co(en)(NH_3)_4]^{3+}$.

2. The correct option(s) to distinguish nitrate salts of Mn^{2+} and Cu^{2+} taken separately is (are)

(A) Mn^{2+} shows the characteristic green color in the flame test.

(B) Only Cu^{2+} shows the formation of precipitate by passing H_2S in acidic medium.

(C) Only Mn^{2+} shows the formation of precipitate by passing H_2S in faintly basic medium.

(D) Cu^{2+}/Cu has higher reduction potential than Mn^{2+}/Mn (measured under similar conditions).

Solution

**(B), (D)** Option (A): Incorrect. Mn^{2+} shows purple color in the flame test.

Option (B): Correct. When H_2S gas is passed through a solution containing Cu^{2+} in the acidic medium, black ppt. is obtained.

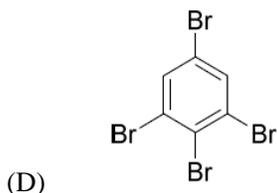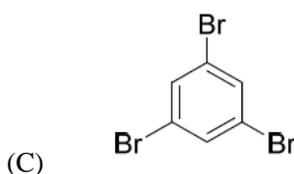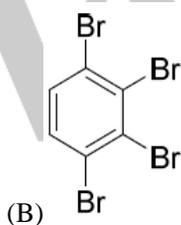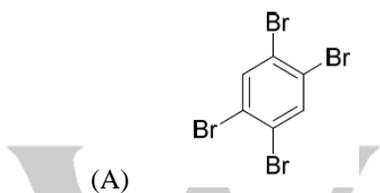$$Cu^{2+} \xrightarrow[\text{HCl}]{H_2S} \underset{\text{(Black ppt.)}}{CuS}$$
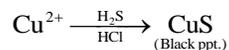
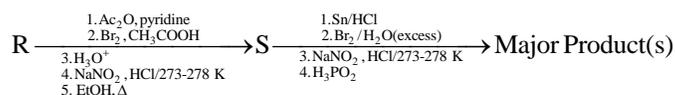Option (C): Incorrect. Both Mn^{2+} and Cu^{2+}can form precipitate by passing H_2S in faintly basic medium.

Option (D): Correct. Higher reduction potential indicates higher tendency to gain the electrons.

$$Cu^{2+} \rightarrow Cu \qquad Mn^{2+} \rightarrow Mn$$
$$(d^9 s^0) \quad (d^{10} s^1) \qquad (d^5 s^0) \quad (d^5 s^2)$$
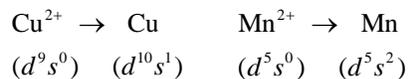
3. Aniline reacts with mixed acid (conc. HNO_3 and conc. H_2SO_4) at 288 K to give **P** (51 %), **Q** (47%) and **R** (2%). The major product(s) of the following reaction sequence is (are)

$$R \xrightarrow[\substack{3.\,H_3O^+ \\ 4.\,NaNO_2\,,HCl/273\text{-}278\ K \\ 5.\,EtOH,\Delta}]{\substack{1.\,Ac_2O,\,pyridine \\ 2.\,Br_2,\,CH_3COOH}} S \xrightarrow[\substack{3.\,NaNO_2\,,HCl/273\text{-}278\ K \\ 4.\,H_3PO_2}]{\substack{1.\,Sn/HCl \\ 2.\,Br_2\,/H_2O(excess)}} \text{Major Product(s)}$$

(A)

(B)

(C)

(D)

Solution

(D)
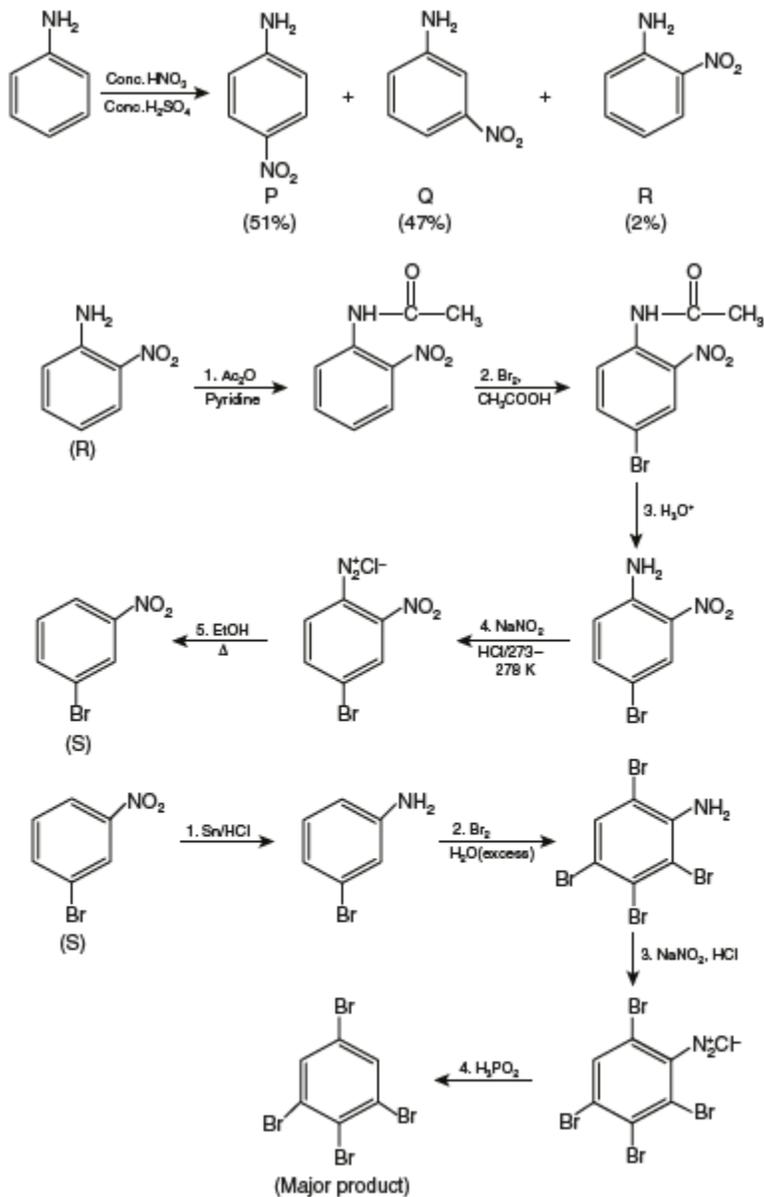
4. The Fischer presentation of D-glucose is given below.
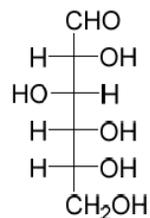
D-glucose

The correct structure(s) of β-L-glucopyranose is (are)

(A)

(B)

(C)

(D)
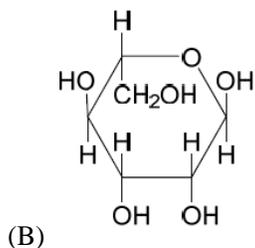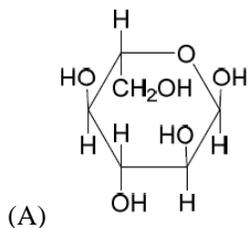
Solution

(D) The structure of β-L-glucopyranose is as follows:
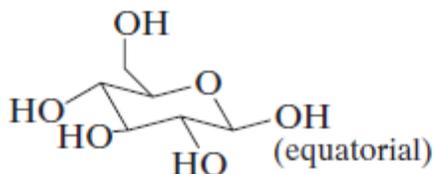
β-D-(+)-Glucopyranose

5. For a first order reaction A(g) → 2B(g) + C(g) at constant volume and 300 K, the total pressure at the beginning (t = 0) and at time t are P_0 and 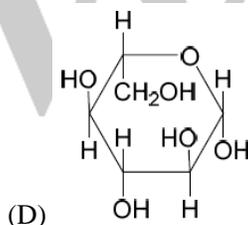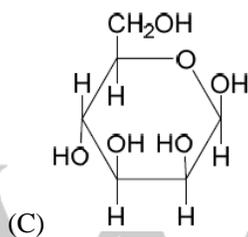P_t, respectively. Initially, only A is present with concentration $[A]_0$, and $t_{1/3}$ is the time required for the partial pressure of A to reach $1/3^{rd}$ of its initial value. The correct option(s) is (are)

(Assume that all these gases behave as ideal gases)

(A)

(B)

(C)

(D)
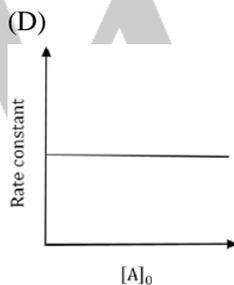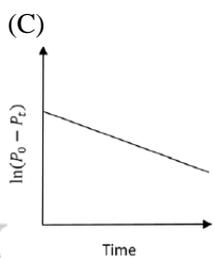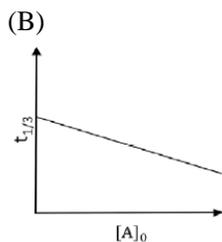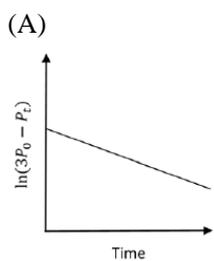
Solution

(A), (D) The reaction can be represented as

$$A(g) \longrightarrow 2B(g) + C(g)$$

At $t = 0$	P_0	0	0
At $t = t_{1/3}$	$P_0 - \dfrac{2P_0}{3}$	0	0
At $t = t$	$P_0 - x$	$2x$	x
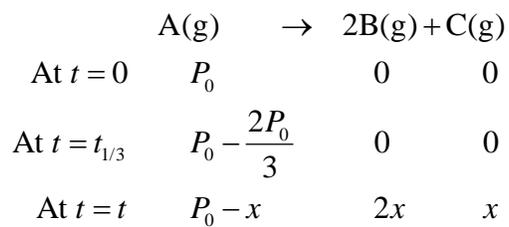
Now,

$$P_t = P_0 - x + 2x + x \Rightarrow x = \frac{P_t - P_0}{2}$$

Substituting in the expression $t = \dfrac{1}{k}\ln\left(\dfrac{P_0}{P_0 - x}\right)$, we get

$$t = \frac{1}{k}\ln\left(\frac{P_0}{P_0 - \dfrac{P_t - P_0}{2}}\right) = \frac{1}{k}\ln\left(\frac{2P_0}{3P_0 - P_t}\right)$$

which can be rearranged as

$$\ln(3P_0 - P_t) = -kt + \ln 2P_0$$

Thus, the graph of $\ln(3P_0 - P_t)$ vs. t is a straight line having negative slope $-k$ and intercept $\ln 2P_0$ as shown in (A).

Also, as rate is independent of initial concentration, so the plot in option (D) is also correct.

6. For a reaction, $A \rightleftharpoons P$, the plots of [A] and [P] with time at temperatures T_1 and T_2 are given below.

If $T_2 > T_1$, the correct statement(s) is (are)

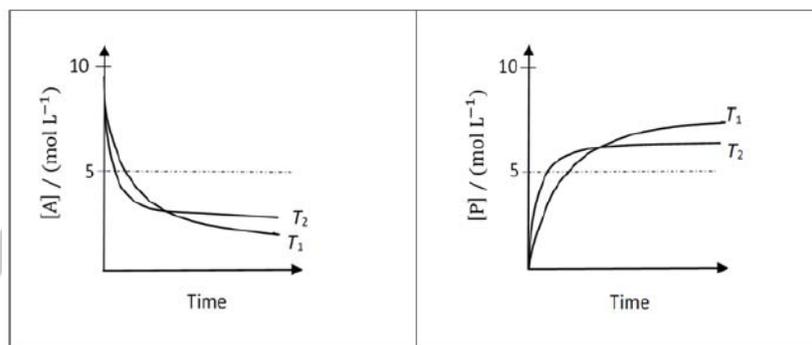(Assume ΔH^θ and ΔS^θ are independent of temperature and ratio of $\ln K$ at T_1 to $\ln K$ at T_2 is greater than T_2/T_1 Here H, S, G and K are enthalpy, entropy, Gibbs energy and equilibrium constant, respectively)

(A) $\Delta H^\theta < 0$, $\Delta S^\theta < 0$

(B) $\Delta G^\theta < 0$, $\Delta H^\theta > 0$

(C) $\Delta G^\theta < 0$, $\Delta S^\theta < 0$

(D) $\Delta G^\theta < 0$, $\Delta S^\theta > 0$

Solution

(A), (C) As we increase the temperature, the concentration of the product reduces. This implies that the reaction is exothermic, and $\Delta H^\theta < 0$.

$$\frac{\ln K_{T_1}}{\ln K_{T_2}} > 1 \Rightarrow \ln K_{T_1} > \ln K_{T_2} \Rightarrow K_{T_1} > K_{T_2}$$

But

$$\frac{\ln K_{T_1}}{\ln K_{T_2}} > \frac{T_2}{T_1}$$

As $\Delta G = -RT \ln K$, $\Delta G^\theta_{T_1} < \Delta G^\theta_{T_2} \Rightarrow \Delta H^\theta_{T_1} - T\Delta S^\theta_{T_1} < \Delta H^\theta_{T_2} - T\Delta S^\theta_{T_2}$

This is only possible if $\Delta S^\theta < 0$

- This section contains **EIGHT (08)** questions. The answer to each question is a **NUMERICAL VALUE**.
- For each question, enter the correct numerical value (in decimal notation, truncated/rounded–off to the **second decimal place**; e.g. 6.25, 7.00, –0.33, –.30, 30.27, –127.30) using the mouse and the onscreen virtual numeric keypad in the place designated to enter the answer.

7. The total number of compounds having at least one bridging oxo group among the molecules given below is_____.

$$N_2O_3, N_2O_5, P_4O_6, P_4O_7, H_4P_2O_5, H_5P_3O_{10}, H_2S_2O_3, H_2S_2O_5$$
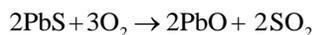
Solution

(5)
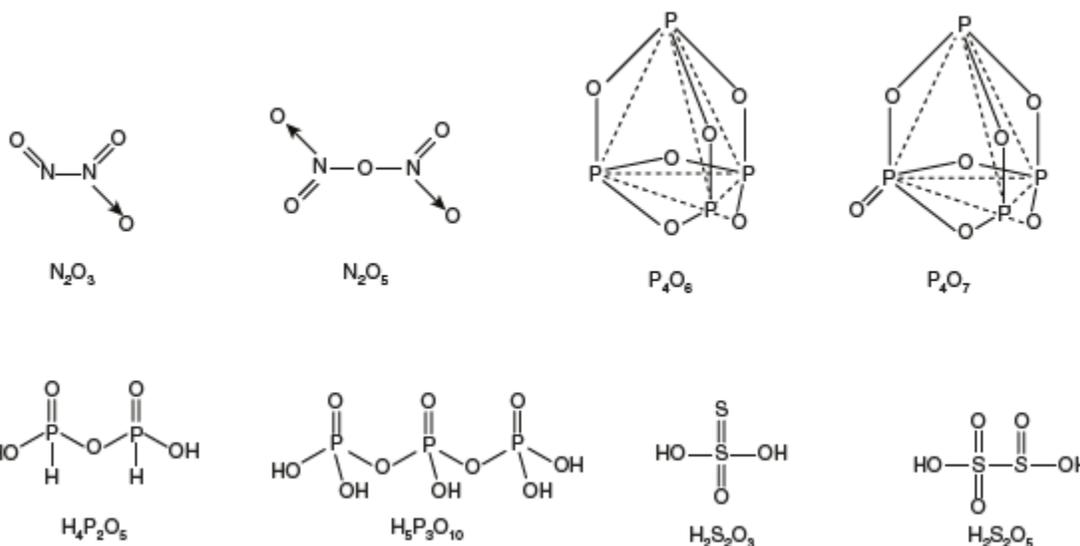
8. Galena (an ore) is partially oxidized by passing air through it at high temperature. After some time, the passage of air is stopped, but the heating is continued in a closed furnace such that the contents undergo self-reduction. The weight (in kg) of Pb produced per kg of O_2 consumed is____.

(Atomic weights in g mol^{-1}: O = 16, S = 32, Pb = 207)

Solution

The steps involved in the oxidation of galena (PbS) are as follows:

$$2PbS + 3O_2 \rightarrow 2PbO + 2SO_2$$
$$2PbO + PbS \rightarrow 3Pb + SO_2$$

As per the above reactions, we can conclude that

3 mol of O_2 produces 3 mol of lead

96 kg of O_2 produces 621 kg of lead

Therefore, 1 kg of O_2 will produce $\dfrac{621}{96} \times 1 = 6.47\,\text{kg}$ of Pb.

9. To measure the quantity of $MnCl_2$ dissolved in an aqueous solution, it was completely converted to $KMnO_4$ using the reaction,

$MnCl_2 + K_2S_2O_8 + H_2O \rightarrow KMnO_4 + H_2SO_4 + HCl$ (equation not balanced).
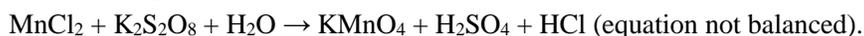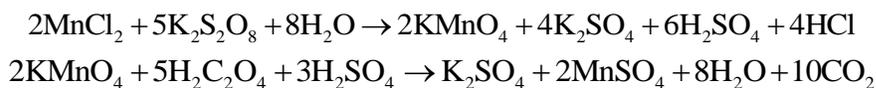
Few drops of concentrated HCl were added to this solution and gently warmed. Further, oxalic acid (225 mg) was added in portions till the color of the permanganate ion disappeared. The quantity of $MnCl_2$ (in mg) present in the initial solution is_____.

(Atomic weights in g mol^{-1}: Mn = 55, Cl = 35.5)

Solution

The balanced equation can be written as

$$2MnCl_2 + 5K_2S_2O_8 + 8H_2O \rightarrow 2KMnO_4 + 4K_2SO_4 + 6H_2SO_4 + 4HCl$$

$$2KMnO_4 + 5H_2C_2O_4 + 3H_2SO_4 \rightarrow K_2SO_4 + 2MnSO_4 + 8H_2O + 10CO_2$$

Millimoles of $KMnO_4$ = Millimoles of $H_2C_2O_4$

$$\text{Millimole } MnCl_2 \times 5 = \left(\frac{225}{90}\right) \times 2$$

So, millimole of $MnCl_2$ = 1 = 126 mg.

10.   For the given compound **X**, the total number of optically active stereoisomers is_____.
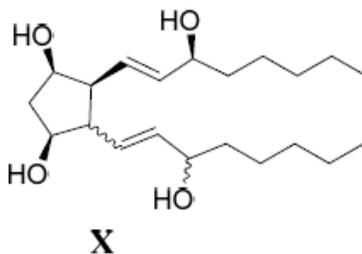
X

——   This type of bond indicates that the configuration at the specific carbon and the geometry of the double bond is fixed.

᠆᠆᠆   This type of bond indicates that the configuration at the specific carbon and the geometry of the double bond is not fixed.

Solution

There are total 7 optically active stereoisomers. Their structures are as follows:

OH
OH
(optically active)

OH
OH
(optically active)

ŌH   HO
ŌH   ŌH

OH
OH
(optically active)

OH
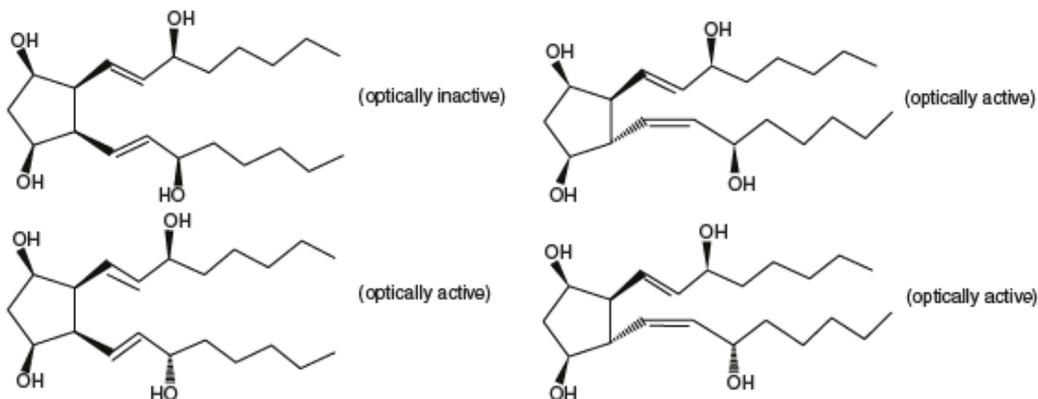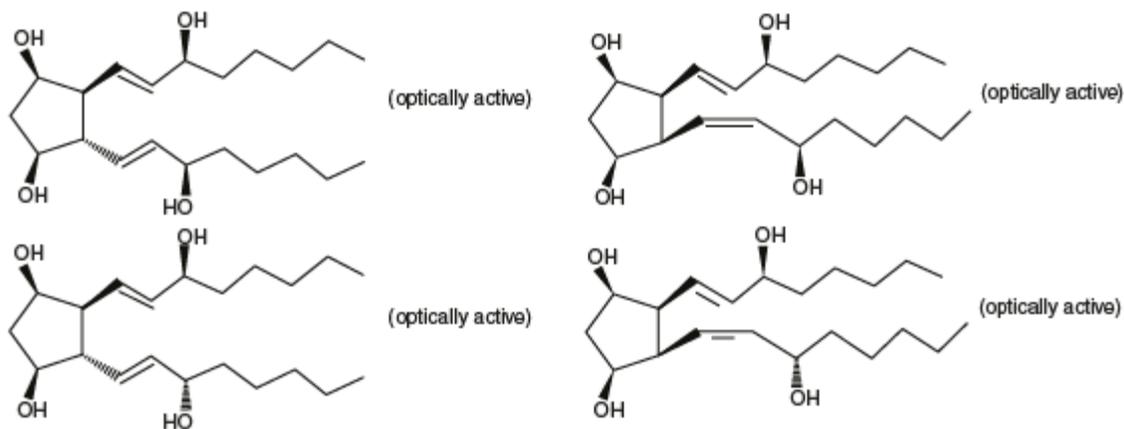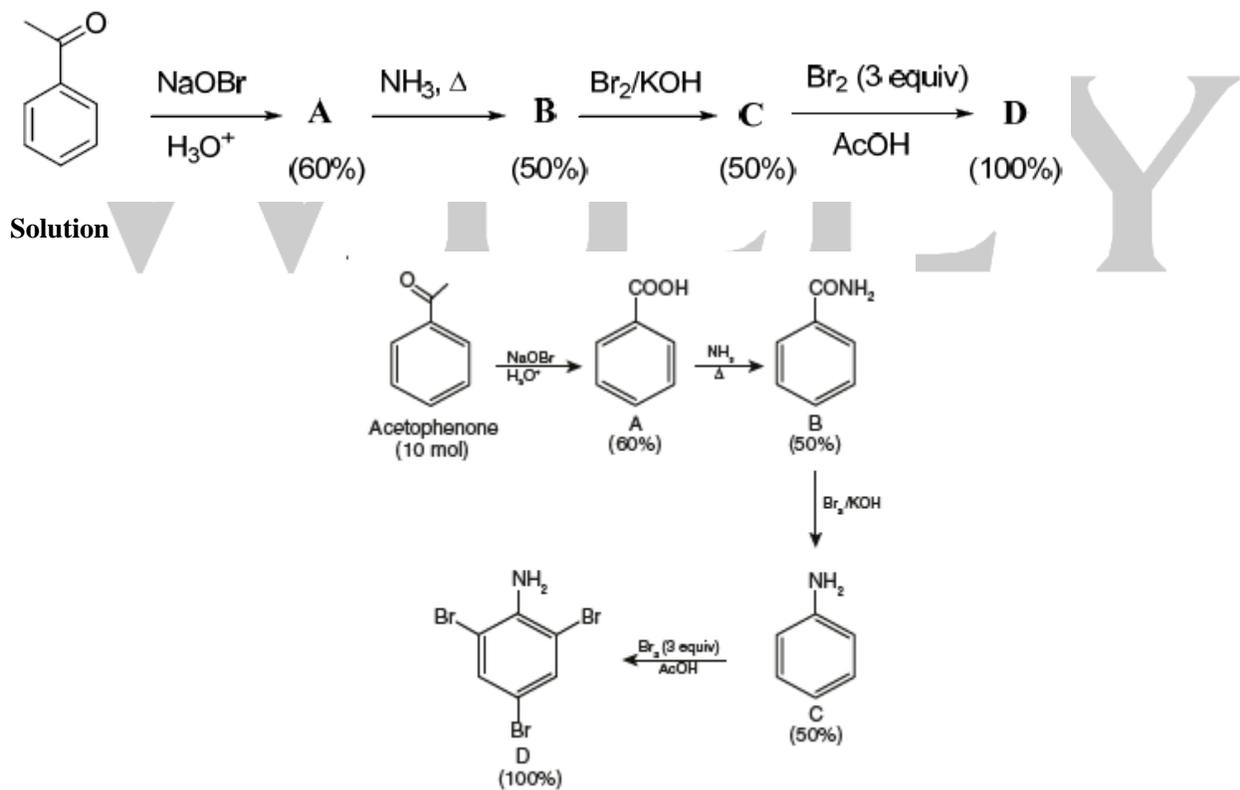OH
(optically active)

ŌH   HO
ŌH   ŌH

11. In the following reaction sequence, the amount of **D** (in g) formed from 10 mol of acetophenone is____.

(Atomic weights in g mol^{-1}: H = 1, C = 12, N = 14, O = 16, Br = 80. The yield (%) corresponding to the product in each step is given in the parenthesis)

$$\underset{\text{(60\%)}}{\overset{\text{NaOBr}}{\underset{H_3O^+}{\longrightarrow}} \mathbf{A}} \quad \underset{\text{(50\%)}}{\overset{NH_3,\,\Delta}{\longrightarrow} \mathbf{B}} \quad \underset{\text{(50\%)}}{\overset{Br_2/KOH}{\longrightarrow} \mathbf{C}} \quad \underset{\text{(100\%)}}{\overset{Br_2\,(3\,equiv)}{\underset{AcOH}{\longrightarrow}} \mathbf{D}}$$

Solution

Acetophenone (10 mol) $\xrightarrow[\text{H}_2\text{O}^+]{\text{NaOBr}}$ COOH **A** (60%) $\xrightarrow[\Delta]{NH_3}$ CONH$_2$ **B** (50%)

B $\xrightarrow{Br_2/KOH}$ NH$_2$ **C** (50%)

NH$_2$ **C** (50%) $\xleftarrow[\text{AcOH}]{Br_2\,(3\,equiv)}$ Br, NH$_2$, Br, Br **D** (100%)

The amount of D formed in mol is $\dfrac{60}{100} \times \dfrac{50}{100} \times \dfrac{50}{100} \times 10 = 1.5\,\text{mol}$

Amount of D in grams is $= 1.5 \times 330\,\text{g} = 495\,\text{g}$

12. The surface of copper gets tarnished by the formation of copper oxide. N_2 gas was passed to prevent the oxide formation during heating of copper at 1250 *K*. However, the N_2 gas contains 1 mole % of

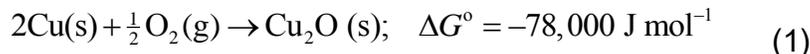water vapour as impurity. The water vapor oxidizes copper as per the reaction given below:

$$2Cu(s) + H_2O(g) \rightarrow Cu_2O(s) + H_2(g)$$
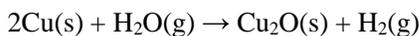
p_{H2} is the minimum partial pressure of H_2 (in bar) needed to prevent the oxidation at 1250 K. The value of $\ln(p_{H2})$ is___.

(Given: total pressure = 1 bar, R (universal gas constant) = 8 J K^{-1} mol^{-1}, $\ln(10)$ = 2.3. Cu(s) and $Cu_2O(s)$ are mutually immiscible.

At 1250 K: $2Cu(s) + {}^1\!/_2 O_2(g) \rightarrow Cu_2O(s)$; $\Delta G^\ominus = -78,000$ J mol^{-1}

$\quad\quad\quad H_2(g) + {}^1\!/_2 O_2(g) \rightarrow H_2O(g)$; $\Delta G^\ominus = -1,78,000$ J mol^{-1}; G is the Gibbs energy)

Solution

$$2Cu(s) + \tfrac{1}{2}O_2(g) \rightarrow Cu_2O\ (s); \quad \Delta G^\circ = -78,000 \text{ J mol}^{-1} \tag{1}$$

$$H_2(g) + \tfrac{1}{2}O_2(g) \rightarrow H_2O(g); \quad \Delta G^\circ = -178000 \text{ J mol}^{-1} \tag{2}$$

Subtracting Eq. (1) –Eq. (2), we get

$$2Cu(s) + H_2O(g) \rightarrow Cu_2O(s) + H_2(g); \quad \Delta G^\circ = +100000 \text{ J mol}^{-1} \tag{3}$$
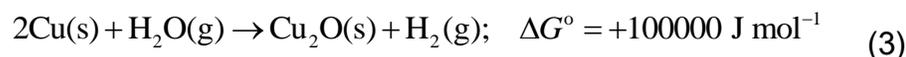
Now, $$\Delta G = \Delta G^\circ + RT \ln \left(\frac{p_{H_2}}{p_{H_2O}} \right)$$

For the reaction (3) to not occur,

$$\Delta G > 0 \text{ or } \Delta G^\circ + RT \ln \left(\frac{p_{H_2}}{p_{H_2O}} \right) > 0$$

$$\Rightarrow 100000 + 8 \times 1250 \ln \left(\frac{p_{H_2}}{p_{H_2O}} \right) > 0$$

$$\Rightarrow 100000 + 8 \times 1250 \ln \left(\frac{p_{H_2}}{p_{H_2O}} \right) > \frac{-100000}{8 \times 1250}$$

$$\Rightarrow \ln \left(\frac{p_{H_2}}{p_{H_2O}} \right) > -10$$
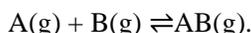
$$\ln p_{H_2} > -10 + \ln p_{H_2O}$$

Now, $$p_{H_2O} = x_{H_2O} \times p_T = 0.01 \times 1 = 10^{-2}$$

So, $$\ln p_{H_2} > -10 - 2\ln 10 \Rightarrow p_{H_2} > -14.6 \text{ bar}$$

13. Consider the following reversible reaction,

$$A(g) + B(g) \rightleftharpoons AB(g).$$

The activation energy of the backward reaction exceeds that of the forward reaction by $2RT$ (in J mol^{-1}). If the pre-exponential factor of the forward reaction is 4 times that of the reverse reaction, the absolute

value of $\Delta G^{\ominus}$ (in J mol^{-1}) for the reaction at 300 K is_____.

(Given; $\ln(2) = 0.7$, $RT = 2500$ J mol^{-1} at 300 K and G is the Gibbs energy)

Solution

$$\Delta G^{\Theta} = -RT \ln K$$

where

$$K = \frac{K_f}{K_b} = \frac{A_f e^{-E_{a_f}/RT}}{A_b e^{-E_{a_b}/RT}}$$

Now, given that $A_f = 4A_b$ and $E_{a_b} - E_{a_f} = 2RT$. Substituting, we get

$$K = \frac{K_f}{K_b} = 4e^{(E_{a_b} - E_{a_f})/RT} = 4e^2$$

Therefore, $\Delta G^{\Theta} = -RT \ln(4e^2) = -2500 \times [\ln(4) + 2] = 8466 \text{ J mol}^{-1}$

14. Consider an electrochemical cell: A(s) | A^{n+} (aq, 2 M) || B^{2n+} (aq, 1 M) | B(s). The value of $\Delta H^{\ominus}$ for the cell reaction is twice that of $\Delta G^{\ominus}$ at 300 K. If the emf of the cell is zero, the $\Delta S^{\ominus}$ (in J K^{-1} mol^{-1}) of the cell reaction per mole of B formed at 300 K is_____.

(Given: $\ln(2) = 0.7$, R (universal gas constant) = 8.3 J K^{-1} mol^{-1}. H, S and G are enthalpy, entropy and Gibbs energy, respectively)
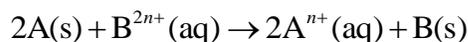
WILEY

Solution

The half-cell reactions are

$$A(s) \rightarrow A^{n+}(aq) + ne^- \qquad (1)$$

$$B^{2n+}(aq) + 2ne^- \rightarrow B(s) \qquad (2)$$
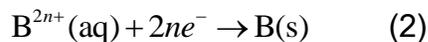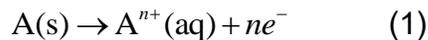
Adding Eq. (1) and Eq. (2), we get

$$2A(s) + B^{2n+}(aq) \rightarrow 2A^{n+}(aq) + B(s)$$

Given that $\Delta H^{\ominus} = 2\Delta G^{\ominus}$ and $E_{cell} = 0$, so

$$\Delta G^{\ominus} = \Delta H^{\ominus} - T\Delta S^{\ominus} \Rightarrow \Delta S^{\ominus} = \frac{\Delta G^{\ominus}}{T} = \frac{-RT \ln K}{T}$$

$$\Rightarrow \Delta S^{\ominus} = -R \ln \frac{[A^{n+}]^2}{[B^{2n+}]} = -8.3 \times \ln 4 = -11.5 \text{ J K}^{-1} \text{ mol}^{-1}$$

SECTION 3

- This section contains **FOUR (04)** questions.
- Each question has **TWO (02)** matching lists: **LIST-I** and **LIST-II**.
- FOUR options are given representing matching of elements from **LIST-I** and **LIST-II. ONLY ONE** of these four options corresponds to a correct matching.

15. Match each set of hybrid orbitals from LIST-I with complex(es) given in LIST-II.

LIST–I	LIST–II
P. dsp^2	1. $[FeF_6]^{4-}$
Q. sp^3	2. $[Ti(H_2O)_3Cl_3]$
R. sp^3d^2	3. $[Cr(NH_3)_6]^{3+}$
S. d^2sp^3	4. $[FeCl_4]^{2-}$
	5. $[Ni(CO)]_4$
	6. $[Ni(CN)_4]^{2-}$

The correct option is

(A) P → 5; Q → 4,6; R → 2,3; S → 1

(B) P → 5,6; Q → 4; R → 3; S → 1,2

(C) P → 6; Q → 4,5; R → 1; S → 2,3

(D) P → 4,6; Q → 5,6; R → 1,2; S → 3

Solution

(C) $[FeF_6]^{4-}$: The arrangement of electrons in Fe^{2+} ($3d^6$) will be
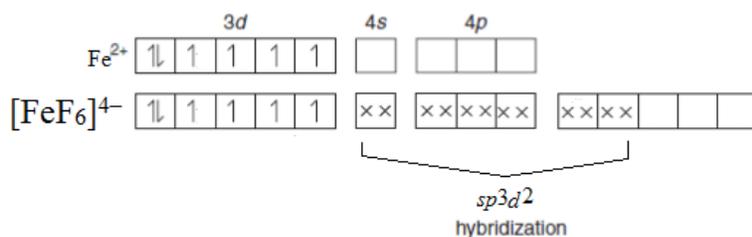
$[Ti(H_2O)_3Cl_3]$: The arrangement of electrons in Ti^{3+} ($3d^1$) will be
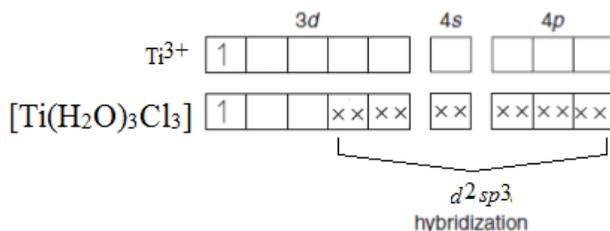
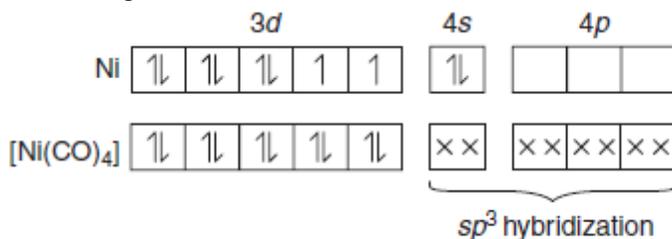**$[Cr(NH_3)_6]^{3+}$:** The arrangement of electrons in Cr^{3+} ($3d^3$) will be
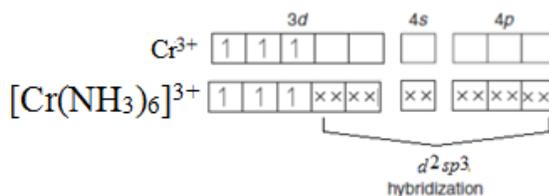
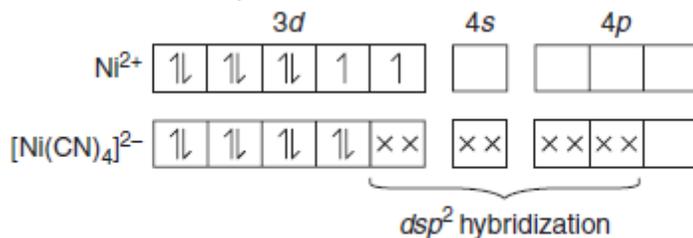**$[FeCl_4]^{2-}$:** The arrangement of electrons in Fe^{2+} ($3d^6$) will be
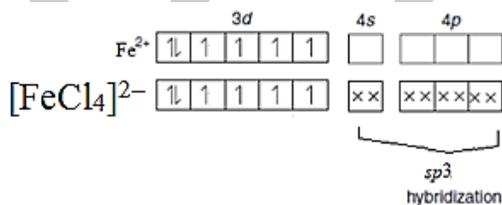
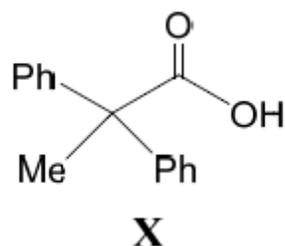**$[Ni(CO)_4]$:** The arrangement of electrons in Ni^0 ($3d^8 4s^2$) will be

$[Ni(CN)_4]^{2-}$: The arrangement of electrons in Ni^{2+} ($3d^8$) will be

16. The desired product **X** can be prepared by reacting the major product of the reactions in LIST-I with

one or more appropriate reagents in LIST-II.

(Given, order of migratory aptitude: aryl > alkyl > hydrogen)

X

LIST-I	LIST-II

P.
  $+$ H_2SO_4

1. I_2, NaOH

Q.
  $+$ HNO_2
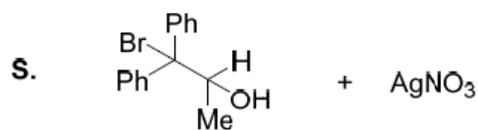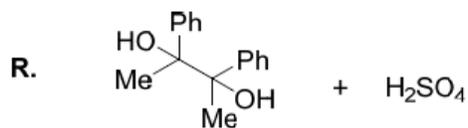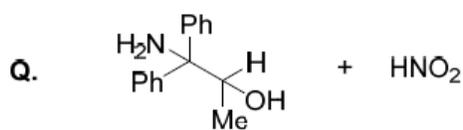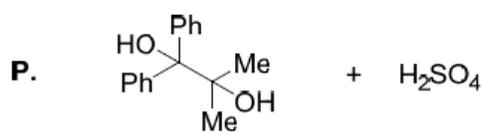
2. $[Ag(NH_3)_2]OH$

3. Fehling solution

R.
  $+$ H_2SO_4

4. HCHO, NaOH

S.
  $+$ $AgNO_3$

5. NaOBr

The correct option is

(A) P → 1; Q → 2,3; R → 1,4; S → 2,4

(B) P → 1,5; Q → 3,4; R → 4,5; S → 3

(C) P → 1,5; Q → 3,4; R → 5;   S → 2,4

(D) P → 1,5; Q → 2,3; R → 1,5; S → 2,3

Solution

(D) The reactions are as follows:

17. LIST-I contains reactions and LIST-II contains major products.

P. $\underset{ONa}{\diagup}$ + $\underset{Br}{\diagup}$ ⟶   **1** $\underset{OH}{\diagup}$

Q. $\underset{OMe}{\diagup}$ + HBr ⟶   **2** $\underset{Br}{\diagup}$

R. $\underset{Br}{\diagup}$ + NaOMe ⟶   **3** $\underset{OMe}{\diagup}$

S. $\underset{ONa}{\diagup}$ + MeBr ⟶   **4** (isobutylene structure)
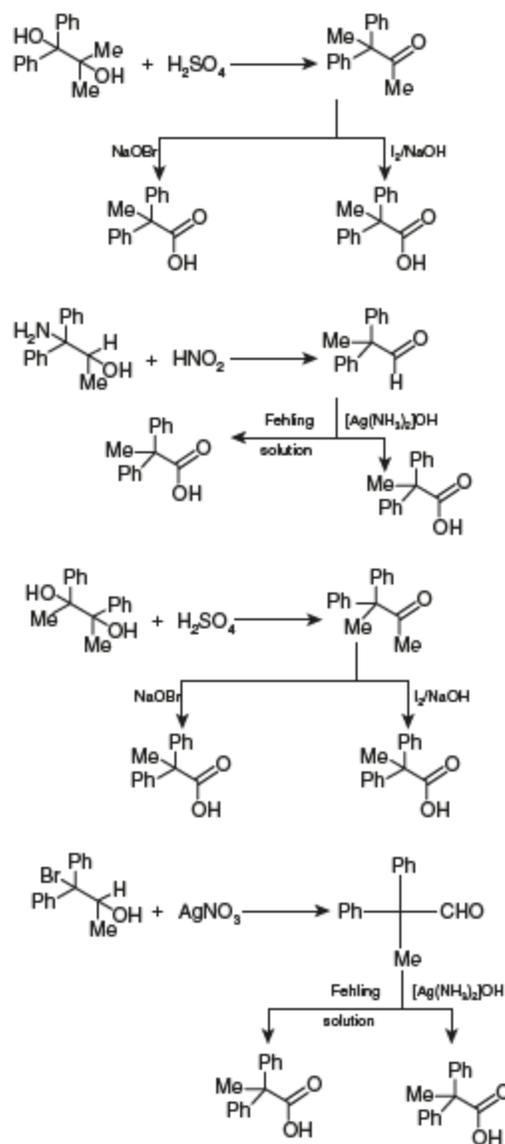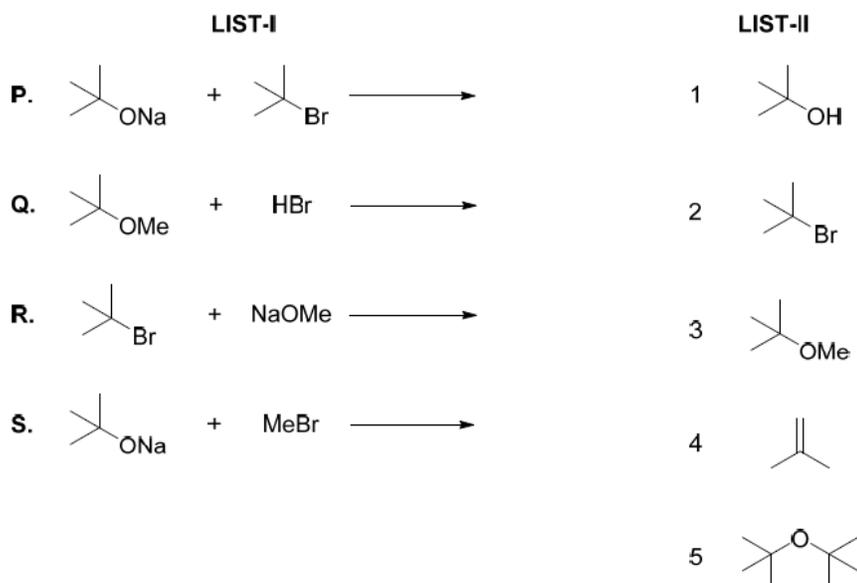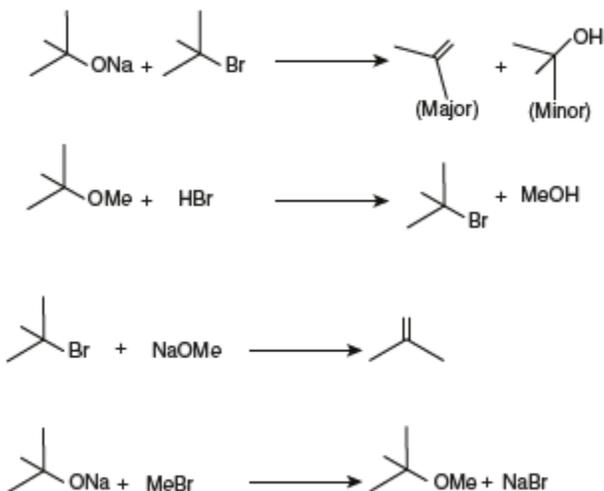
                     5 (di-tert-butyl ether structure)

Match each reaction in LIST-I with one or more products in LIST-II and choose the correct option.

(A) P → 1,5; Q → 2; R → 3;   S → 4
(B) P → 1,4; Q → 2; R → 4;   S → 3
(C) P → 1,4; Q → 1,: 2; R → 3,4; S → 4
(D) P → 4,5; Q → 4; R → 4;   S → 3,4

Solution

(B) With *tertiary* halides, steric hindrance in the substrate is severe, thus, elimination is highly favored, especially when the reaction is carried out at higher temperatures.

$\underset{ONa}{\diagup}$ + $\underset{Br}{\diagup}$ ⟶ (Major) + $\underset{OH}{\diagup}$ (Minor)

$\underset{OMe}{\diagup}$ + HBr ⟶ $\underset{Br}{\diagup}$ + MeOH

$\underset{Br}{\diagup}$ + NaOMe ⟶ (isobutylene)

$\underset{ONa}{\diagup}$ + MeBr ⟶ $\underset{OMe}{\diagup}$ + NaBr

18. Dilution processes of different aqueous solutions, with water, are given in LIST-I. The effects of dilution of the solutions on [H⁺] are given in

(**Note:** Degree of dissociation (α) of weak acid and weak base is $\ll 1$; degree of hydrolysis of salt $\ll 1$; [H⁺] represents the concentration of H⁺ ions)
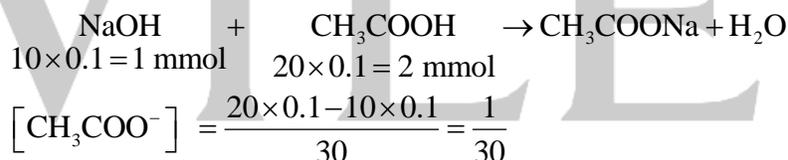
LIST-I

P. (10 mL of 0.1 M NaOH + 20 mL of 0.1 M acetic acid) diluted to 60 mL

Q. (20 mL of 0.1 M NaOH + 20 mL of 0.1 M acetic acid) diluted to 80 mL

R. (20 mL of 0.1 M HCl + 20 mL of 0.1 M ammonia solution) diluted to 80 mL

S. 10 mL saturated solution of $Ni(OH)_2$ in equilibrium with excess solid $Ni(OH)_2$ is diluted to 20 mL (solid $Ni(OH)_2$ is still present after dilution).
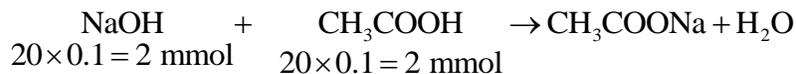
LIST-II

1. the value of $[H^+]$ does not change on dilution

2. the value of $[H^+]$ changes to half of its initial value on dilution

3. the value of $[H^+]$ changes to two times of its initial value on dilution

4. the value of $[H^+]$ changes to $\dfrac{1}{\sqrt{2}}$ times of its initial value on dilution

5. the value of $[H^+]$ changes to $\sqrt{2}$ times of its initial value on dilution

Match each process given in LIST-I with one or more effect(s) in LIST-II. The correct option is

(A) P → 4; Q → 2; R → 3; S →1

(B) P → 4; Q → 3; R → 2; S →3

(C) P → 1; Q → 4; R → 5; S →3

(D) P → 1; Q → 5; R → 4; S →1

Solution

(D)
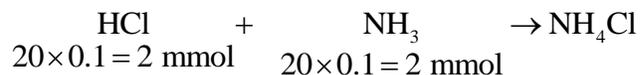
$$\underset{10\times 0.1 = 1 \text{ mmol}}{\text{NaOH}} + \underset{20\times 0.1 = 2 \text{ mmol}}{\text{CH}_3\text{COOH}} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$$

$$\left[\text{CH}_3\text{COO}^-\right] = \frac{20\times 0.1 - 10\times 0.1}{30} = \frac{1}{30}$$

Since it is a buffer solution, with 1 mmol of CH_3COOH and 1 mmol of CH_3COONa in solution. So, (P) → (1).

$$\underset{20\times 0.1 = 2 \text{ mmol}}{\text{NaOH}} + \underset{20\times 0.1 = 2 \text{ mmol}}{\text{CH}_3\text{COOH}} \rightarrow \text{CH}_3\text{COONa} + \text{H}_2\text{O}$$

Since the solution contains 2 mmol of CH_3COONa in 40 ml solution. So, for a salt of weak acid and strong base, we have
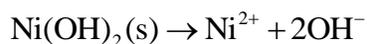
$$[H^+]_{\text{initial}} = \sqrt{\frac{K_w K_a}{C}}$$

On dilution to 80 ml, C becomes $C/2$, so $[H^+]_{\text{new}} = \sqrt{\dfrac{K_w K_a}{C/2}} = [H^+]_{\text{initial}} \times \sqrt{2}$. So, (Q) → (5)

$$\underset{20\times0.1=2\text{ mmol}}{\text{HCl}} \quad + \quad \underset{20\times0.1=2\text{ mmol}}{\text{NH}_3} \quad \rightarrow \text{NH}_4\text{Cl}$$

Since the solution contains 2 mmol of CH_3COONa in 40 mL solution. So, for a salt of strong acid and weak base, we have

$$[H^+]_{initial} = \sqrt{\frac{K_w C}{K_b}}$$

On dilution to 80 mL, C becomes C/2, so $[H^+]_{new} = \sqrt{\dfrac{K_w C}{2K_b}} = [H^+]_{initial}/\sqrt{2}$. So, (R) → (4)

$$\text{Ni(OH)}_2(s) \rightarrow \text{Ni}^{2+} + 2\text{OH}^-$$

As it is a sparingly soluble salt, there is no change in [OH⁻] on dilution. So, (S) → (1)

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