FINAL JEE(Advanced) EXAMINATION - 2021

(Held On Sunday 03rd OCTOBER, 2021)

PAPER-2 | **TEST PAPER WITH SOLUTION**

PART-2 : CHEMISTRY

SECTION-1 : (Maximum Marks : 24)

- This section contains **SIX (06)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONE OR MORE THAN ONE** of these four option(s) is (are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 If only (all) the correct option(s) is(are) chosen;
Partial Marks : +3 If all the four options are correct but ONLY three options are chosen;
Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;
Partial Marks : +1 If two or more options are correct but ONLY one option is chosen and it is a correct option;
Zero Marks : 0 If unanswered;
Negative Marks : −2 In all other cases.

- For example, in a question, if (A), (B) and (D) are the ONLY three options corresponding to correct answers, then
choosing ONLY (A), (B) and (D) will get +4 marks;
choosing ONLY (A) and (B) will get +2 marks;
choosing ONLY (A) and (D) will get +2 marks;
choosing ONLY (B) and (D) will get +2 marks;
choosing ONLY (A) will get +1 mark;
choosing ONLY (B) will get +1 mark;
choosing ONLY (D) will get +1 mark;
choosing no option(s) (i.e. the question is unanswered) will get 0 marks and
choosing any other option(s) will get −2 marks.

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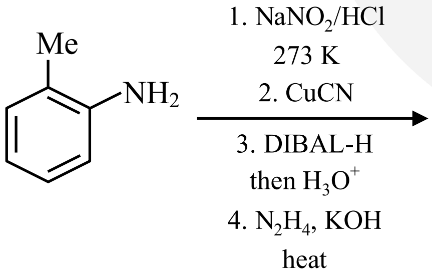
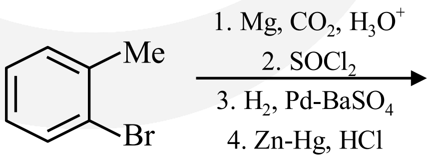
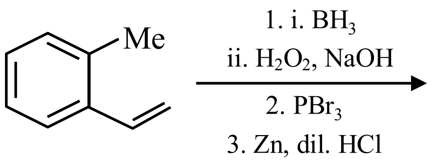
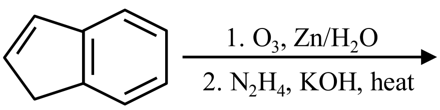
1. The reaction sequence(s) that would lead to *o*-xylene as the major product is (are)

(A) 

(B) 

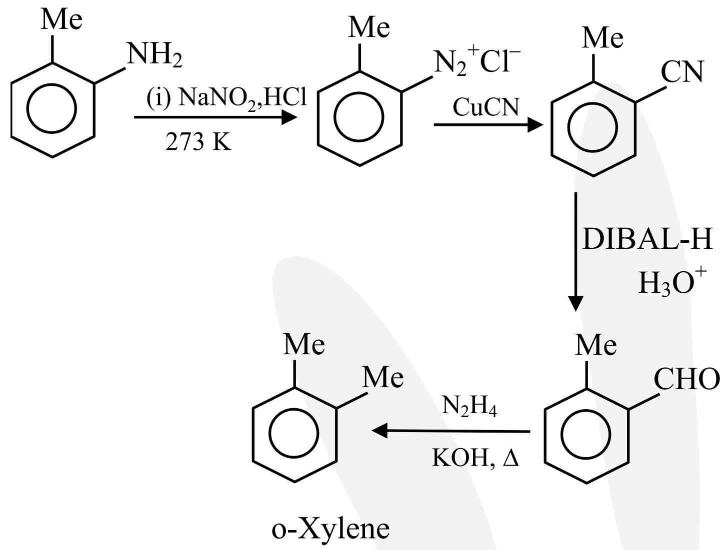
(C) 

(D) 

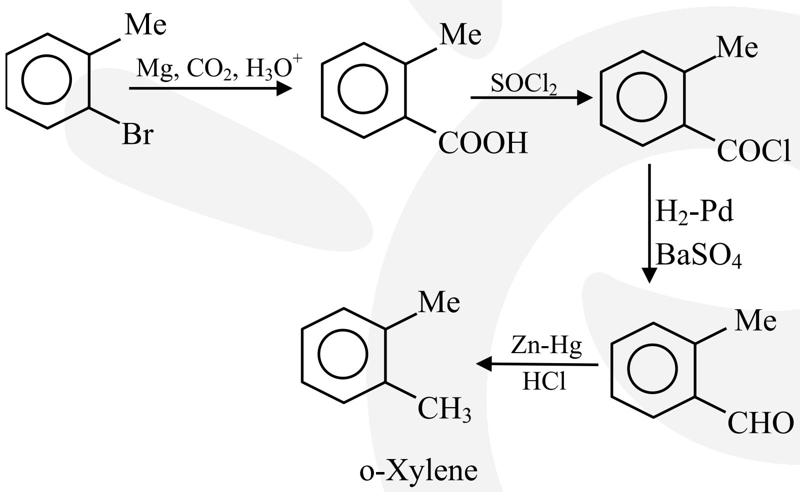
Ans. (A,B)

Sol.

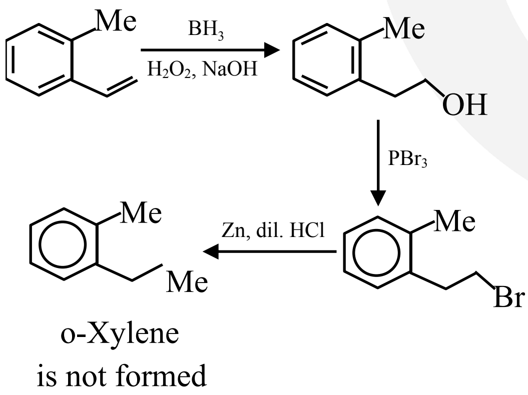
(A)


Me
NH2
(i) NaNO2,HCl
273 K
Me
N2+Cl−
CuCN
Me
CN
DIBAL-H
H3O+
Me
CHO
N2H4
KOH, Δ
Me
Me
o-Xylene

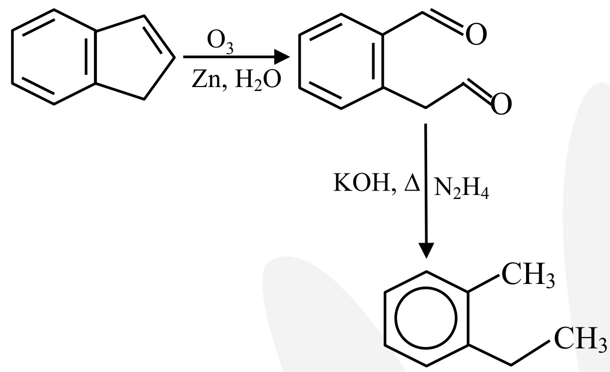
(B)


Me
Br
Mg, CO2, H3O+
Me
COOH
SOCl2
Me
COCl
H2-Pd
BaSO4
Me
CHO
Zn-Hg
HCl
Me
CH3
o-Xylene

(C)

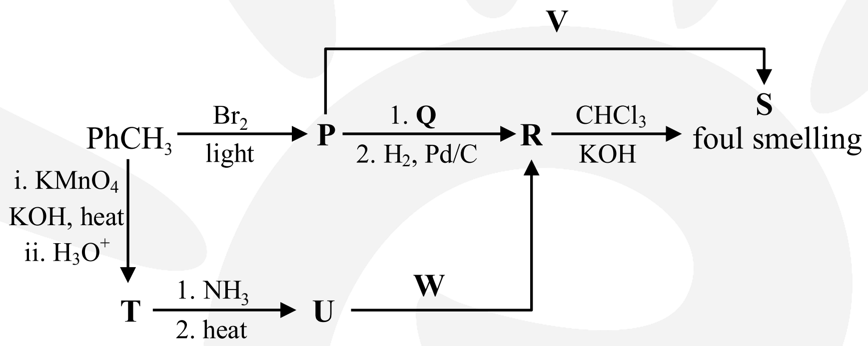

Me
BH3
H2O2, NaOH
Me
OH
PBr3
Me
Br
Zn, dil. HCl
Me
Me
o-Xylene
is not formed

(D)



o-Xylene is not formed

2. Correct option(s) for the following sequence of reactions is(are)



(A) **Q** = KNO_2, **W** = $LiAlH_4$

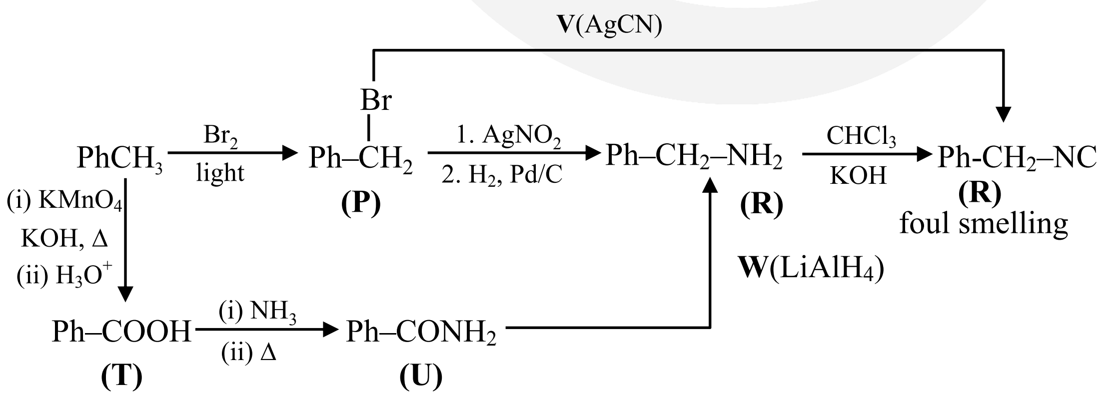
(B) **R** = benzenamine, **V** = KCN

(C) **Q** = $AgNO_2$, **R** = phenylmethanamine

(D) **W** = $LiAlH_4$, **V** = AgCN

Ans. (C,D)

Sol.



3. For the following reaction

$$2\mathbf{X}+\mathbf{Y}\xrightarrow{k}\mathbf{P}$$

the rate of reaction is $\frac{d[\mathbf{P}]}{dt}=k[\mathbf{X}]$. Two moles of **X** are mixed with one mole of **Y** to make 1.0 L of solution. At 50 s, 0.5 mole of **Y** is left in the reaction mixture. The correct statement(s) about the reaction is(are)

(Use: ln 2 = 0.693)

(A) The rate constant, k, of the reaction is $13.86 \times 10^{-4}\ s^{-1}$.

(B) Half–life of **X** is 50s.

(C) At 50 s, $-\frac{d[\mathbf{X}]}{dt} = 13.86 \times 10^{-3}$ mol $L^{-1}\ s^{-1}$.

(D) At 100 s, $-\frac{d[\mathbf{Y}]}{dt} = 3.46 \times 10^{-3}$ mol $L^{-1}\ s^{-1}$.

Ans. (B,C,D)

Sol. $\frac{dp}{dt}=k[x]^1$

	2x	+ y	→ p
t = 0	2	1	
t = 50 s	(2–1)	(1–0.5)	0.5

$$-\frac{1}{2}\frac{dx}{dt}=\frac{dp}{dt}=k[x]^1$$

$$-\frac{dx}{dt}=2k[x]^1$$

$$2k=\frac{\ln 2}{50} \Rightarrow k=\frac{\ln 2}{100}$$

At 50 sec $\frac{-dx}{dt}=2k\times(1)^1=\frac{\ln 2}{50}$

At 100 sec $-\frac{1}{2}\frac{dx}{dt}=\frac{-dy}{dt} \Rightarrow -\frac{dy}{dt}=\frac{\ln 2}{100}\times\frac{1}{2}\quad\left\{\frac{-dy}{dt}=k[x]^1\right\}$

4. Some standard electrode potentials at 298 K are given below:

Pb^{2+}/Pb	–0.13 V
Ni^{2+}/Ni	–0.24 V
Cd^{2+}/Cd	–0.40 V
Fe^{2+}/Fe	–0.44 V

To a solution containing 0.001 M of $\mathbf{X}^{2+}$ and 0.1 M of $\mathbf{Y}^{2+}$, the metal rods **X** and **Y** are inserted (at 298 K) and connected by a conducting wire. This resulted in dissolution of **X**. The correct combination(s) of **X** and **Y**, respectively, is (are)

(Given: Gas constant, R = 8.314 J K^{-1} mol^{-1},

Faraday constant, F = 96500 C mol^{-1})

(A) Cd and Ni (B) Cd and Fe (C) Ni and Pb (D) Ni and Fe

Ans. (A,B,C)

Sol. $x(s) \longrightarrow x^{+2}$ (0.001 M) + $2e^-$ (anode)

y^{+2} (0.1 M) + $2e^- \longrightarrow$ y (s) (cathode)

$$E_{cell} = E^\circ_{cell} - \frac{0.06}{2} \log \frac{x^{+2}}{y^{+2}}$$

$E_{cell} = E^\circ_{cell} + 0.06$

(A) Cd and Ni E°_{cell} = + 0.4 – 0.24 ; E_{cell} = 0.22

(B) Cd and Fe E°_{cell} = – 0.04 ; E_{cell} = 0.02

(C) Ni and Pb E°_{cell} = 0.11 ; E_{cell} = 0.17

(D) Ni and Fe E°_{cell} = – 0.2 ; E_{cell} = –0.14

since in (A) (B) (C) E_{cell} is positive hence answer is (A) (B) (C).

5. The pair(s) of complexes wherein both exhibit tetrahedral geometry is(are)

(Note: py = pyridine

Given: Atomic numbers of Fe, Co, Ni and Cu are 26, 27, 28 and 29, respectively)

(A) $[FeCl_4]^-$ and $[Fe(CO)_4]^{2-}$

(B) $[Co(CO)_4]^-$ and $[CoCl_4]^{2-}$

(C) $[Ni(CO)_4]$ and $[Ni(CN)_4]^{2-}$

(D) $[Cu(py)_4]^+$ and $[Cu(CN)_4]^{3-}$

Ans. (A,B,D)

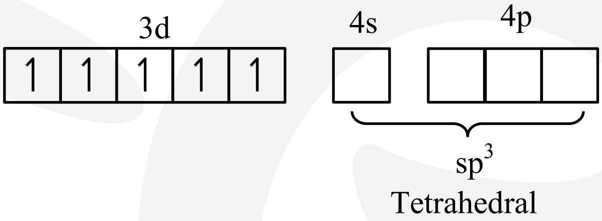
Sol.(A)

$[FeCl_4]^-$

Fe $\longrightarrow$ [Ar] $3d^6 4s^2$

$Fe^{+3} \longrightarrow$ [Ar] $3d^5 4s^0$

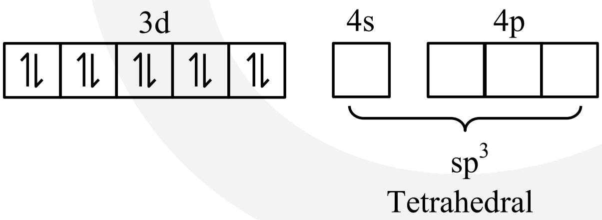
Cl^- is W.F.L. and does not pair up the unpaired electron of central metal atom.

$\therefore Fe^{3+} (d^5)$ in$[FeCl_4]^-$ 

$[Fe(CO)_4]^{2-}$

Fe $\longrightarrow$ [Ar] $3d^6 4s^2$

$Fe^{2-} \longrightarrow$ [Ar] $3d^8 4s^2$

$\therefore Fe^{2-} (d^{10})$ in $[Fe(CO)_4]^{2-}$ 

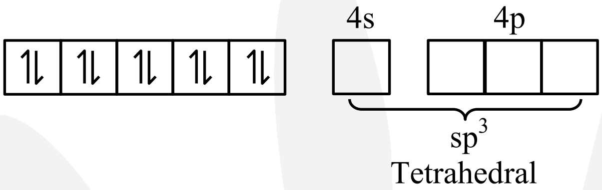
(B)

$[Co(CO)_4]^-$

$Co \longrightarrow [Ar]\ 3d^7 4s^2$

$Co^{-1} \longrightarrow [Ar]\ 3d^8 4s^2$

$\therefore Co^-\ (d^{10})$ in $[Co(CO)_4]^-$



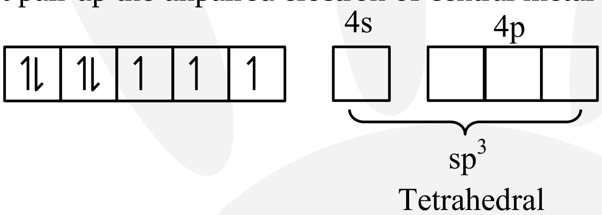
$[CoCl_4]^{2-}$

$Co \longrightarrow [Ar]\ 3d^7 4s^2$

$Co^{+2} \longrightarrow [Ar]\ 3d^7 4s^0$

Cl^- is W.F.L. and does not pair up the unpaired electron of central metal atom.

$\therefore Co^{2+}\ (d^7)$ in $[CoCl_4]^{2-}$



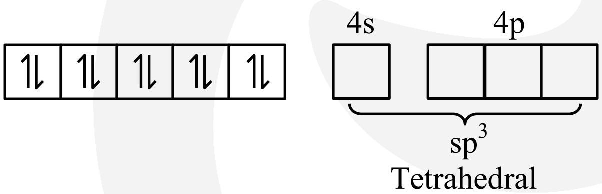
(C)

$[Ni(CO)_4]$

$Ni \longrightarrow [Ar]\ 3d^8 4s^2$

$Ni^0 \longrightarrow [Ar]\ 3d^8 4s^2$

$\therefore Ni\ (d^{10})$ in $[Ni(CO)_4]$



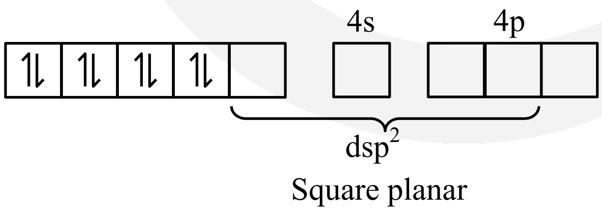
$[Ni(CN)_4]^{2-}$

$Ni \longrightarrow [Ar]\ 3d^8 4s^2$

$Ni^{+2} \longrightarrow [Ar]\ 3d^8 4s^0$

CN^- is S.F.L. and pair up the unpaired electron of central metal atom.

$\therefore Ni\ (d^8)$ in $[Ni(CN)_4]^{2-}$

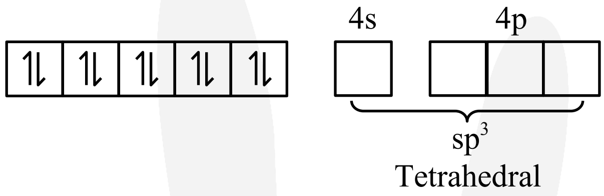


(D) $[Cu(py)_4]^+$

$Cu \rightarrow [Ar]\ 3d^{10}4s^1$

$Cu^{+1} \rightarrow [Ar]\ 3d^{10}4s^0$

$\therefore Cu^{+1}(d^{10})$ in $[Cu(py)_4]^+$



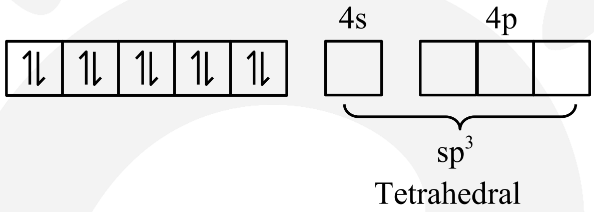
$[Cu(CN)_4]^{3-}$

$Cu \rightarrow [Ar]\ 3d^{10}4s^1$

$Cu^{+1} \rightarrow [Ar]\ 3d^{10}4s^0$

CN^- is S.F.L. and pair up the unpaired electron of central metal atom.

$\therefore Cu^{+1}\ (d^{10})$ in $[Cu(CN)_4]^{3-}$



6. The correct statement(s) related to oxoacids of phosphorous is(are)

(A) Upon heating, H_3PO_3 undergoes disproportionation reaction to produce H_3PO_4 and PH_3.

(B) While H_3PO_3 can act as reducing agent, H_3PO_4 cannot.

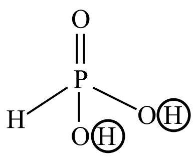
(C) H_3PO_3 is a monobasic acid.

(D) The H atom of P–H bond in H_3PO_3 is not ionizable in water.

Ans. (A,B,D)

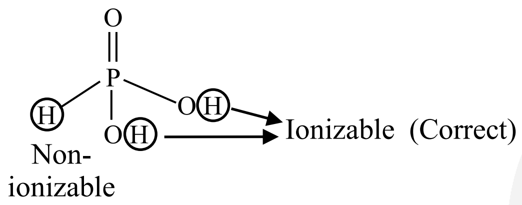
Sol. (A) $4H_3PO_3 \xrightarrow{\Delta} 3H_3PO_4 + PH_3$ (correct)

(B) H_3PO_4 has "P" in its highest oxidation state, hence cannot act as a reducing agent (correct)

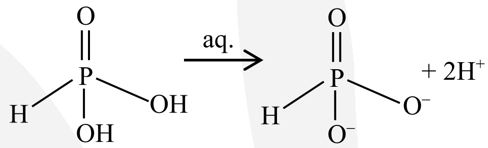
(C) 

Dibasic acid (incorrect)

Two OH group present in H_3PO_3

(D) 

The hydrogen which is directly attached to phosphorous does not ionized in water.



SECTION-2 : (Maximum Marks : 12)

- This section contains **THREE (03)** question stems.
- There are **TWO (02)** questions corresponding to each question stem.
- The answer to each question is a **NUMERICAL VALUE**.
- For each question, enter the correct numerical value corresponding to the answer in the designated place using the mouse and the on-screen virtual numeric keypad.
- If the numerical value has more than two decimal places, **truncate/round-off** the value to **TWO** decimal places.
- Answer to each question will be evaluated according to the following marking scheme:

  Full Marks : +2 If ONLY the correct numerical value is entered at the designated place;

  Zero Marks : 0 In all other cases.

Question Stem for Question Nos. 7 and 8

Question Stem

At 298 K, the limiting molar conductivity of a weak monobasic acid is 4×10^2 S cm^2 mol^{-1}. At 298 K, for an aqueous solution of the acid the degree of dissociation of α and the molar conductivity is $\mathbf{y} \times 10^2$ S cm^2 mol^{-1}. At 298 K, upon 20 times dilution with water, the molar conductivity of the solution becomes $3\mathbf{y} \times 10^2$ S cm^2 mol^{-1}.

7. The value of α is ______.

Ans. (0.21 or 0.22)

Solution for Q.7 & Q.8

Sol. $$K_a = \frac{\Lambda_m^2 C}{\Lambda_m^{\circ}\left(\Lambda_m^{\circ} - \Lambda_m\right)}$$

$$K_a = \frac{(y \times 10^2)^2 \times C}{4 \times 10^2 (4 \times 10^2 - y \times 10^2)} = \frac{(3y \times 10^2)^2 \times \frac{C}{20}}{4 \times 10^2 (4 \times 10^2 - 3y \times 10^2)}$$

$$\Rightarrow \frac{1}{(4-y)} = \frac{9}{20(4-3y)} \Rightarrow y = \frac{44}{51}$$

$$\alpha = \frac{\frac{44}{51}\times 10}{4\times 10^2}$$

$\alpha = 0.2156$ ($\alpha = 0.22$ or 0.21)

$y = 0.86$

8. The value of **y** is ______.

Ans. (0.86)

Question Stem for Question Nos. 9 and 10

Question Stem

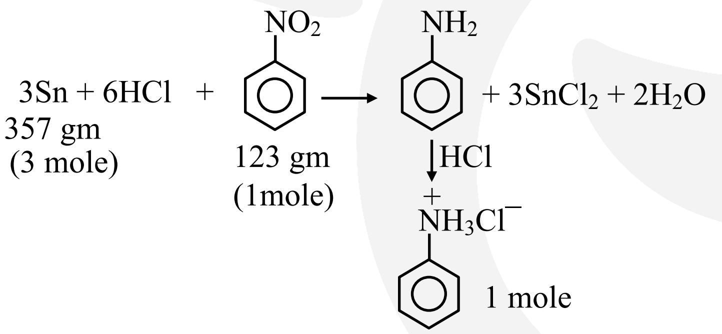
Reaction of **x** g of Sn with HCl quantitatively produced a salt. Entire amount of the salt reacted with **y** g of nitrobenzene in the presence of required amount of HCl to produce 1.29 g of an organic salt (quantitatively).

(Use Molar masses (in g mol^{-1}) of H, C, N, O, Cl and Sn as 1, 12, 14, 16, 35 and 119, respectively).

9. The value of **x** is ______.

Ans. (3.57)

Sol. The value of **x** is



(72 + 8 + 35) + 14

= 129gm (molecular weight of organic salt)

So to get 1.29 gm organic salt.

We have to form 0.01 mole salt.

So 0.01 mole nitrobenzene is required.

0.03 mole Sn is required.

So the amount of nitrobenzene = 0.01 × 123 = 1.23 gm

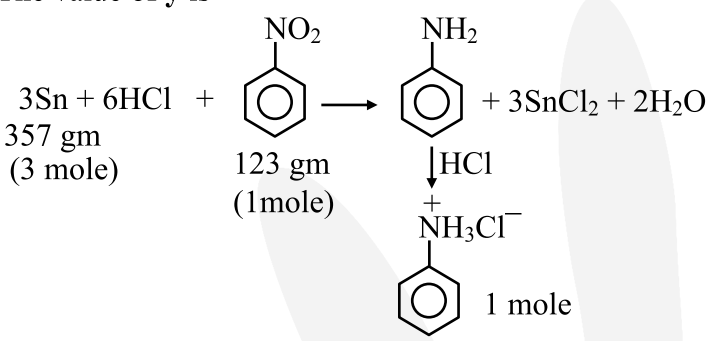
the amount of Sn required = 0.01 × 357 = 3.57 gm

Ans. 3.57 & 1.23

10. The value of **y** is ______.

Ans. (1.23)

Sol. The value of **y** is



(72 + 8 + 35) + 14

= 129gm (molecular weight of organic salt)

So to get 1.29 gm organic salt.
We have to form 0.01 mole salt.
So 0.01 mole nitrobenzene is required.
0.03 mole Sn is required.
So the amount of nitrobenzene = 0.01 × 123 = 1.23 gm
the amount of Sn required = 0.01 × 357 = 3.57 gm
Ans. 3.57 & 1.23

Question Stem for Question Nos. 11 and 12

Question Stem

A sample (5.6 g) containing iron is completely dissolved in cold dilute HCl to prepare a 250 mL of solution. Titration of 25.0 mL of this solution requires 12.5 mL of 0.03 M $KMnO_4$ solution to reach the end point. Number of moles of Fe^{2+} present in 250 mL solution is **x** × 10^{-2} (consider complete dissolution of $FeCl_2$). The amount of iron present in the sample of **y%** by weight.
(Assume : $KMnO_4$ reacts only with Fe^{2+} in the solution
Use : Molar mass of iron as 56 g mol^{-1})

11. The value of **x** is ______.

Ans. (1.87 or 1.88)

Solution for Q.11 & Q.12

$$\underset{x \text{ mole}}{Fe} + 2HCl \longrightarrow \underset{x \text{ mole}}{FeCl_2} + H_2$$

$$Fe^{+2} + MnO4^{-}$$

$\frac{x}{10}$ mole   12.5 ml

0.03 M

$n_f = 1$ $n_f = 5$

$$\frac{x}{10} = \frac{12.5 \times 0.03 \times 5}{1000}$$

x = 0.01875 (x = 1.88 or 1.87)

wt of Fe = 1.05g

$$\% \text{ Fe} = \frac{1.05}{5.6} \times 100 = 18.75$$

12. The value of **y** is ______.

Ans. (18.75)

SECTION-3 : (Maximum Marks : 12)

- This section contains **TWO (02) paragraphs**. Based on each paragraph, there are **TWO (02)** questions.
- Each question has **FOUR** options (A), (B), (C) and (D). **ONLY ONE** of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +3 If ONLY the correct option is chosen;
Zero Marks : 0 If none of the options is chosen (i.e. the question is unanswered);
Negative Marks : −1 In all other cases.

Paragraph

The amount of energy required to break a bond is same as the amount of energy released when the same bond is formed. In gaseous state, the energy required for *homolytic cleavage* of a bond is called Bond Dissociation Energy (BDE) or Bond Strength. BDE is affected by *s*-character of the bond and the stability of the radicals formed. Shorter bonds are typically stronger bonds. BDEs for some bonds are given below :

$$H_3C-H(g) \longrightarrow H_3C^{\bullet}(g) + H^{\bullet}(g) \quad \Delta H^{\circ} = 105\ \text{kcal mol}^{-1}$$
$$Cl-Cl(g) \longrightarrow Cl^{\bullet}(g) + Cl^{\bullet}(g) \quad \Delta H^{\circ} = 58\ \text{kcal mol}^{-1}$$
$$H_3C-Cl(g) \longrightarrow H_3C^{\bullet}(g) + Cl^{\bullet}(g) \quad \Delta H^{\circ} = 85\ \text{kcal mol}^{-1}$$
$$H-Cl(g) \longrightarrow H^{\bullet}(g) + Cl^{\bullet}(g) \quad \Delta H^{\circ} = 103\ \text{kcal mol}^{-1}$$

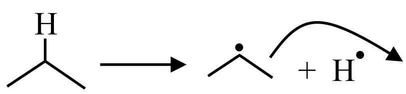
13. Correct match of the **C–H** bonds (shown in bold) in Column **J** with their BDE in Column **K** is

Column **J** Molecule	Column **K** BDE (kcal mol^{-1})
(P) **H–C**H$(CH_3)_2$	(i) 132
(Q) H–CH_2Ph	(ii) 110
(R) **H–C**H=CH_2	(iii) 95
(S) H–**C**≡CH	(iv) 88

(A) P – iii, Q – iv, R – ii, S – i
(B) P – i, Q – ii, R – iii, S – iv
(C) P – iii, Q – ii, R –i, S – iv
(D) P – ii, Q – i, R – iv, S – iii

Ans. (A)

Sol. Most stability of radical, less is the bond energy

(P)  2° Carbon Free radical

(Q) Ph–CH_2–H ⟶ Ph–$\dot{C}H_2$ + $H^{\bullet}$ Most stable due to resonance

(R) CH_2=CH–H ⟶ CH_2=$\dot{C}H$ + $H^{\bullet}$ (less stable)

(S) CH≡C–H ⟶ CH≡$C^{\bullet}$ + $H^{\bullet}$ More % S-Character decreases stability of free radical

Q require least BDE and S Required maximum BDE
Max BDE
So, Order of BDE Q < P < R < S

14. For the following reaction

$CH_4(g) + Cl_2(g) \xrightarrow{\text{light}} CH_3Cl(g) + HCl\ (g)$

the correct statement is

(A) Initiation step is exothermic with $\Delta H° = -58$ kcal mol^{-1}

(B) Propagation step involving $^{\bullet}CH_3$ formation is exothermic with $\Delta H° = -2$ kcal mol^{-1}.

(C) Propagation step involving CH_3Cl formation is endothermic with $\Delta H° = +27$ kcal mol^{-1}.

(D) The reaction is exothermic with $\Delta H° = -25$ kcal mol^{-1}.

Ans. **(D)**

Sol. Initiation step is endothermic hence option (A) is wrong.

Propagation step involving $^{\bullet}CH_3$ formation is endothermic hence option (B) is wrong.

Propagation step involving CH_3Cl formation is exothermic hence option (C) is wrong.

Reaction

$$CH_4 + Cl_2 \longrightarrow CH_3 - Cl + HCl$$

$$CH_4 \longrightarrow CH_3^{\bullet} + H^{\bullet} \qquad \Delta H = 105\,KCal/mol$$
$$Cl_2 \longrightarrow Cl^{\bullet} + Cl^{\bullet} \qquad \Delta H = 58\,KCal/mol$$
$$Cl^{\bullet} + CH_3^{\bullet} \longrightarrow CH_3 - Cl \qquad \Delta H = -85\,KCal/mol$$
$$Cl^{\bullet} + H^{\bullet} \longrightarrow HCl \qquad \Delta H = -103\,KCal/mol$$
$$CH_4 + Cl_2 \longrightarrow CH_3 - Cl + HCl \quad \Delta H = -25\,KCal/mol$$

Overall reaction is exothermic with $\Delta H° = -25$ KCal/mol, hence option (D) is correct.

Paragraph

The reaction of $K_3[Fe(CN)_6]$ with freshly prepared $FeSO_4$ solution produces a dark blue precipitate called Turnbull's blue. Reaction of $K_4[Fe(CN)_6]$ with the $FeSO_4$ solution in complete absence of air produces a white precipitate **X**, which turns blue in air. Mixing the $FeSO_4$ solution with $NaNO_3$, followed by a slow addition of concentrated H_2SO_4 through the side of the test tube produces a brown ring.

15. Precipitate **X** is

(A) $Fe_4[Fe(CN)_6]_3$ (B) $Fe[Fe(CN)_6]$ (C) $K_2Fe[Fe(CN)_6]$ (D) $KFe[Fe(CN)_6]$

Ans. (C)

Sol. $K_4[Fe(CN)_6] \xrightarrow[\text{absence of air}]{FeSO_4} K_2Fe[Fe(CN)_6]$

White precipitate

$\downarrow$ air

$Fe_4[Fe(CN)_6]_3$

(Prussian Blue)

16. Among the following, the brown ring is due to the formation of

(A) $[Fe(NO)_2(SO_4)_2]^{2-}$ (B) $[Fe(NO)_2(H_2O)_4]^{3+}$ (C) $[Fe(NO)_4(SO_4)_2]$ (D) $[Fe(NO)(H_2O)_5]^{2+}$

Ans. (D)

Sol. $FeSO_4 \xrightarrow[\text{slow addition of conc. } H_2SO_4]{NaNO_3} \left[Fe(H_2O)_5 NO\right]SO_4$

(Brown Ring Complex)

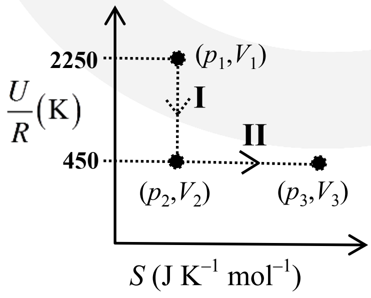
SECTION-4 : (Maximum Marks : 12)

- This section contains **THREE (03)** questions.
- The answer to each question is a **NON-NEGATIVE INTEGER.**
- For each question, enter the correct integer corresponding to the answer using the mouse and the on-screen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:

Full Marks : +4 If ONLY the correct integer is entered;

Zero Marks : 0 In all other cases.

17. One mole of an ideal gas at 900 K, undergoes two reversible processes, **I** followed by **II**, as shown below. If the work done by the gas in the two processes are same, the value of ln $\frac{V_3}{V_2}$ is ____.



(U: internal energy, S: entropy, p: pressure, V: volume, R: gas constant)

(Given: molar heat capacity at constant volume, $C_{V,m}$ of the gas is $\frac{5}{2}R$)

Ans. (10)

Sol. $\Delta U_I = nC_{v,m}\,\Delta T = W_I\ \{q_I = 0\}$

$$-1800\ R = 1 \times \frac{5R}{2} \times \Delta T = \Delta T = -720\ K$$

$T_2 = 180$ K

$$W_{II} = W_I = -1800\ R = -1 \times R \times 180\ \ln\left(\frac{V_3}{V_2}\right)$$

$$ln\left(\frac{V_3}{V_2}\right) = 10 \Rightarrow 10$$

18. Consider a helium (He) atom that absorbs a photon of wavelength 330 nm. The change in the velocity (in cm s^{-1}) of He atom after the photon absorption is ___.
(Assume: Momentum is conserved when photon is absorbed.
Use: Planck constant = 6.6×10^{-34} J s, Avogadro number = 6×10^{23} mol^{-1}, Molar mass of He = 4 g mol^{-1})

Ans. **(30)**

Sol. $\lambda = \frac{h}{p} \Rightarrow p = \frac{6.6\times10^{-34}}{330\times10^{-9}} = \frac{4\times10^{-3}}{6\times10^{23}}\times v\ \ (p = m \times v)$

$v = 0.3$ m/s = 30 cm/s

19. Ozonolysis of ClO_2 produces an oxide of chlorine. The average oxidation state of chlorine in this oxide is ___.

Ans. **(6)**

Sol. $2ClO_2 + 2O_3 \longrightarrow Cl_2O_6 + 2O_2$

Cl_2O_6

$2x + 6(-2) = 0$

$x = +6$

Average oxidation state of Cl in Cl_2O_6 is 6.