JEE ADVANCED

ANSWER KEY

2021

CHEMISTRY

Paper-2

QUESTION WITH SOLUTION

हो चुकी है ऑफलाइन क्लासरूम की शुरुआत

अपने सपने को करो साकार, कोटा कोचिंग के साथ

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SECTION – A

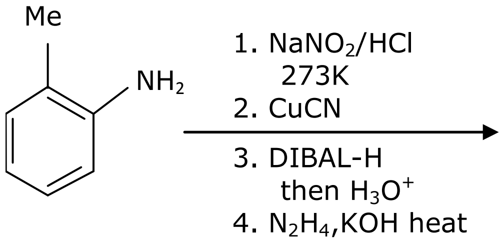
- This section contains SIX (06) questions.
- Each question has FOUR options (A), (B), (C) and (D). ONE OR MORE THAN ONE of these four option(s) is (are) correct answer(s).
- For each question, choose the option(s) corresponding to (all) the correct answer(s).
- Answer to each question will be evaluated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

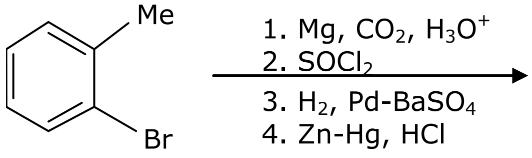
Full Marks : +4 If only (all) the correct option(s) is(are) chosen;
Partial Marks : +3 If all the four options are correct but ONLY three options are chosen;
Partial Marks : +2 If three or more options are correct but ONLY two options are chosen, both of which are correct;
Partial Marks : +1 If two or 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.

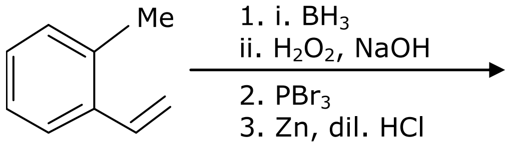
- For example, in a question, if (A), (B) and (D) are the ONLY three options corresponding to correct answers, then
choosing ONLY (A), (B) and (D) will get +4 marks;
choosing ONLY (A) and (B) will get +2 marks;
choosing ONLY (A) and (D) will get +2marks;
choosing ONLY (B) and (D) will get +2 marks;
choosing 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.

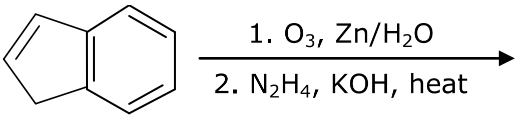
SECTION - 1

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

(A) 

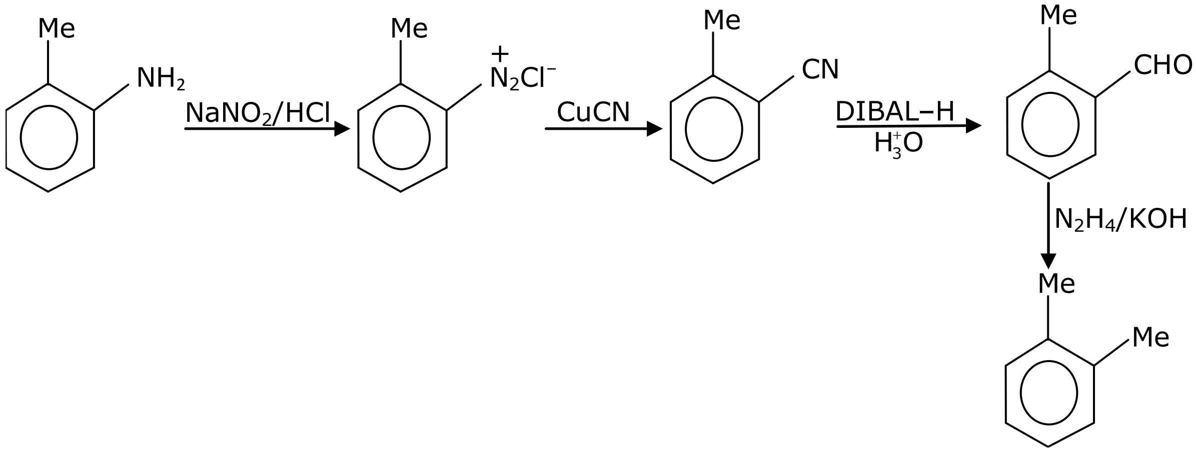
(B) 

(C) 

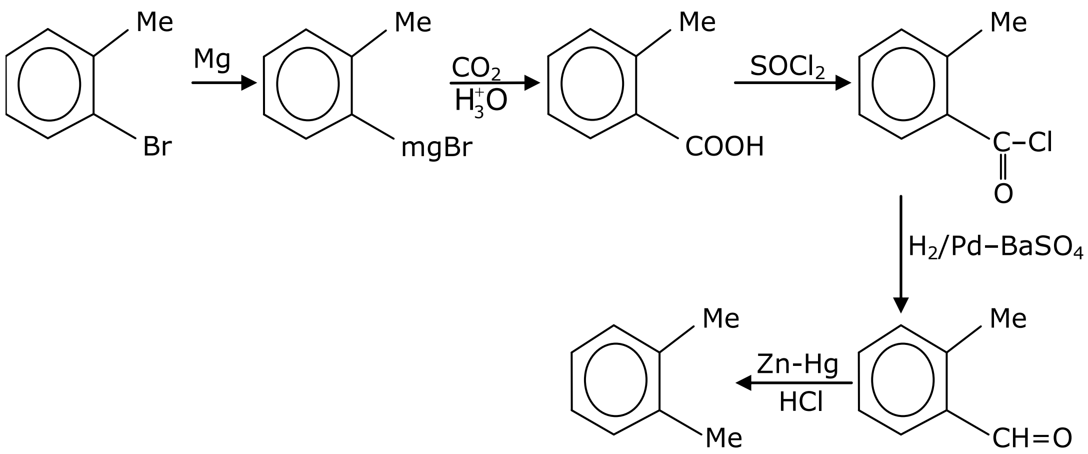
(D) 

Ans. AB

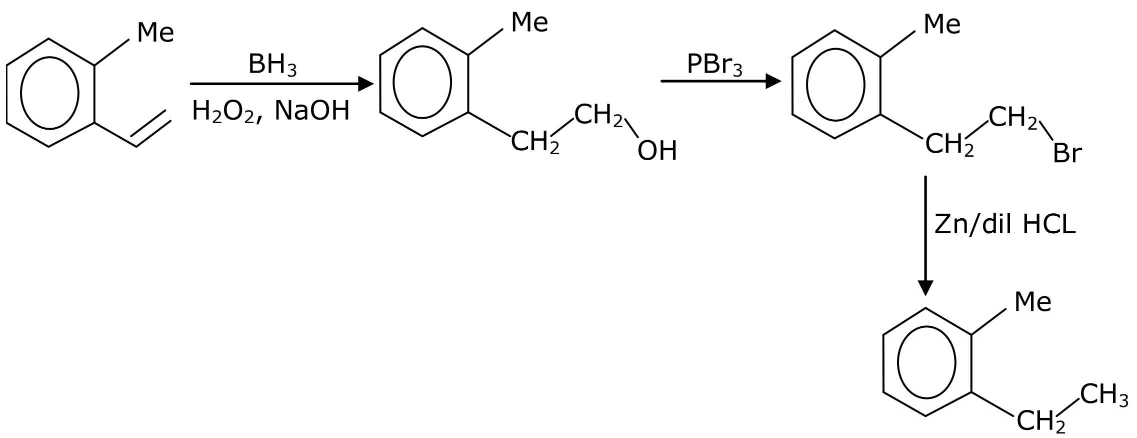
Sol. (A)



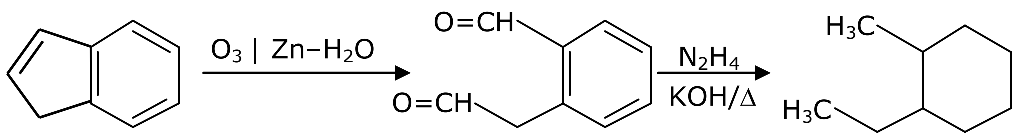
(B)



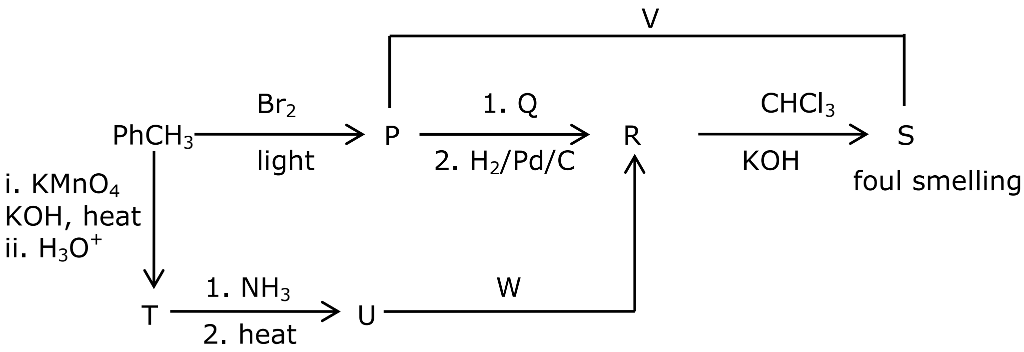
(C)



(D)



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



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

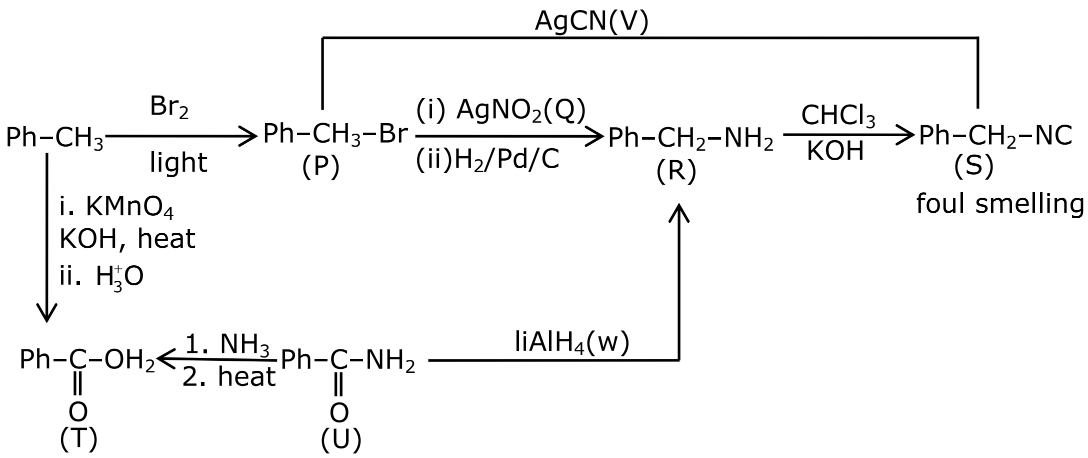
(B) R = benzenamine, **V** = KCN

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

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

Ans. CD

Sol.



P	:	$Ph-CH_2-Br$	T	:	$PH-C(=O)-OH$
Q	:	$AgNO_2$	U	:	$Ph-C(=O)-NH_2$
R	:	$Ph-CH_2-NH_2$	V	:	AgCN
S	:	$Ph-CH_2NC$	W	:	$LiAlH_4$

3. For the following reaction

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

the rate of reaction is $\frac{d[P]}{dt}$ $k[\mathbf{X}]$. 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 50 s.

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

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

Ans. **BCD**

Sol.

$$2X + Y \xrightarrow{k} P \qquad -\frac{1}{2}\frac{dX}{dt} = \frac{-dY}{dt} = \frac{dP}{dt} = k[X]$$

2 1

1 0.5

$$\frac{-dX}{dt} = 2[X] = kd[X]$$

$$t_{1/2}(A) = 50s = \frac{0.693}{k_d} \Rightarrow k_d = \frac{0.693}{50}$$

$$kd = 1.386 \times 10^{-2}$$

$$\frac{dX}{dt} = 1.386 \times 10^{-2} \times [X] \qquad [X] = \frac{1}{1} = 1$$

$$= 1.386 \times 10^{-2}$$

at 100 sec $\Rightarrow t_{3/4} = 100 \, sec$

$$[X] = \frac{Ao}{2^2} = \frac{2}{4} = 0.5$$

$$\frac{dY}{dt} = k \times [X] = \frac{1.386}{2} \times 0.5 = 3.46 \times 10^{-2}$$

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 X^{2+} and 0.1 M of 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 = 8.134 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. **ABC**

Sol. $Pb^{+2} + 2e^- \longrightarrow Pb(s)$ $E^o = -0.13v$

$\left[\begin{array}{l} Ni^{+2} + 2e^- \longrightarrow Ni(s) \\ Cd^{2+} + 2e^- \longrightarrow Cd(s) \end{array}\right.$ $\begin{array}{l} E^o = -0.24V \\ E^0 = -0.4V \end{array}$

$Fe^{+2} + 2e^- \longrightarrow Fe(s)$ $E^o = -0.44v$

$$E = E^o - \frac{0.0591}{2}\log Q$$

$$-0.4 = -0.24 - \frac{0.0591}{2}\log Q$$

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)

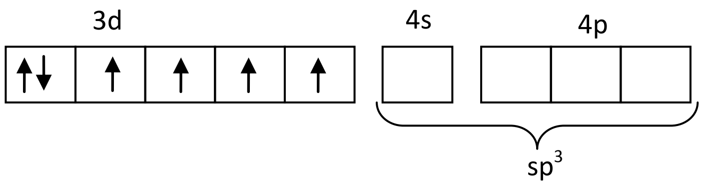
(A) $[FeCl_4]^-$ and $[Fe(CO)_4]^{2-}$ (B) $[CO(CO)_4]^-$ and $[COCl_4]^{2-}$

(C) $[Ni(CO)_4]$ and $[Ni(CN)_4]^{2-}$ (D) $[Cu(py)_4]^+$ and $[Cu(CN)_4]^{3-}$

Ans. **A, B, D**

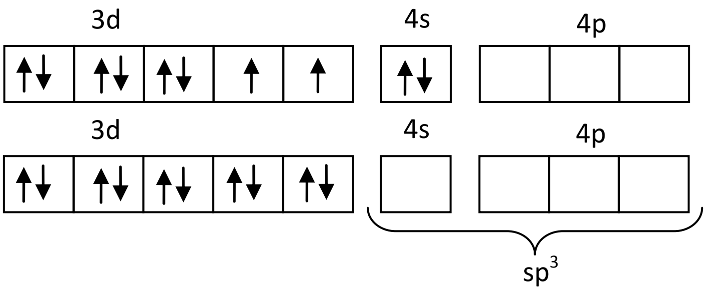
(1) $(FeCl_4)^- \longrightarrow$

Fe^{+3} =



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

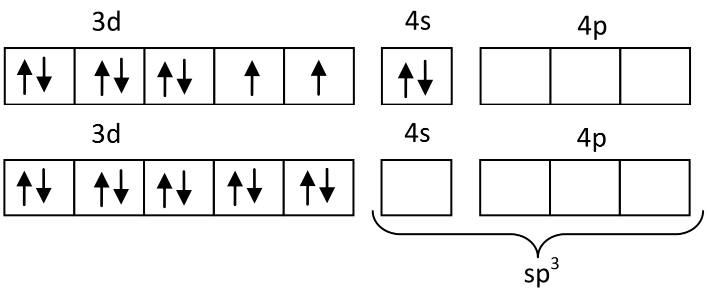
Fe^{-2} =



(3) $[Co(CO)_4]^- \longrightarrow$

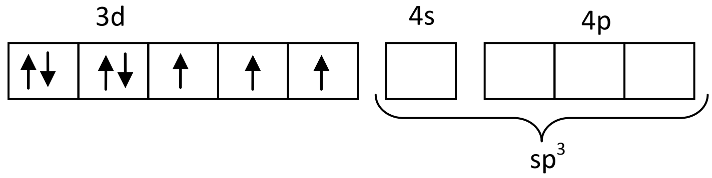
Co^- =

Co^- =



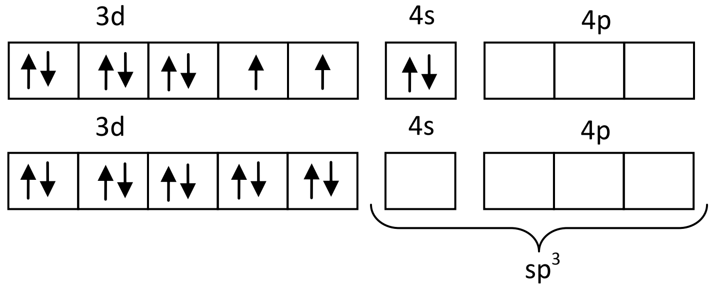
(4) $[CoCl_4]^{2-} \longrightarrow$

Co^{2+} =



(5) $Ni(CO)_4 \longrightarrow$

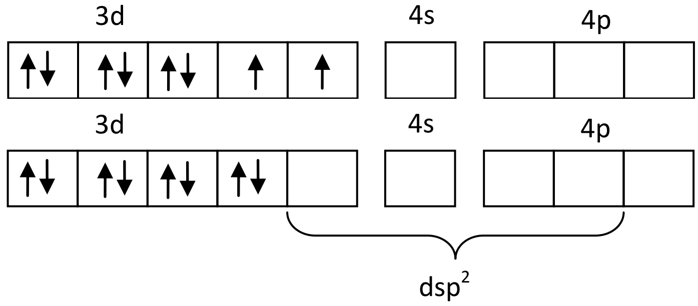
Ni =



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

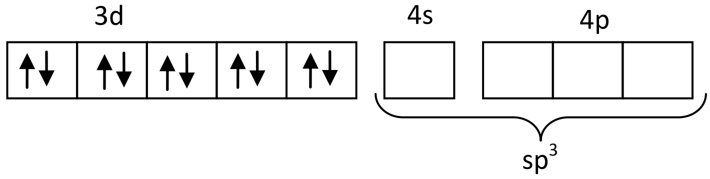
Ni^{+2} =

Ni^{+2} =



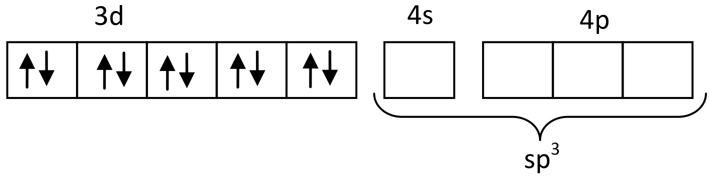
(7) $[Cu(Py)_4]^{+} \longrightarrow$

$Cu^{+}(3d^{10})$ =



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

$Cu^{+}(3d^{10})$ =



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**

(A) $H_3PO_3 \xrightarrow{\text{disproportionation}} H_3PO_4 + PH_3$
(B) H_3PO_3 is reducing agent due to presence of P – H bond
(C) H_3PO_3 is dibasic acid due to presence of two –OH group
(D) The H-atom of P–H bond is not Ionizable

Section – 2

- 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 is 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. **0.22**

8. The Value of y is _____.

Ans. **0.863**

Sol. $\Lambda^0{}_m(HA) = 4 \times 10^2\ Scm^2/mol$

$\Lambda^C\ HA = y \times 10^2\ Scm^2/mol$

$\alpha = \dfrac{\Lambda^C}{\Lambda^0}$

When solution is diluted 20 times with water $\alpha_2 = 3\alpha_1$

$$k_a = \frac{C\alpha^2}{1-\alpha} = \frac{C}{20} \times \frac{(3\alpha)^2}{1-3\alpha}$$

$$\frac{1}{1-\alpha} = \frac{1}{20} \times \frac{9}{1-3\alpha}$$

$$20 - 60\alpha = 9 - 9\alpha$$

$$11 = (60-9)\alpha$$

$$\frac{11}{51} = \alpha = 0.22$$

$$\alpha = 0.22$$

$$\alpha = \frac{\Lambda^C}{\Lambda^0} = \frac{y \times 10^2}{4 \times 10^2} = \frac{11}{51}$$

$$y = \frac{44}{51} = 0.863$$

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).

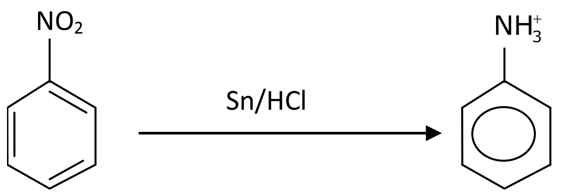
9. The value of x is____.

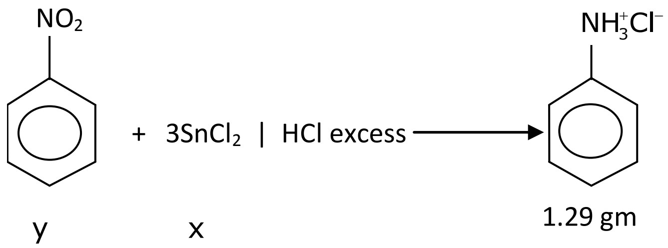
Ans. **3.57**

10. The value of y is _____.

Ans. **1.23**

Sol. $Sn + 2HCl \longrightarrow SnCl_2 \longrightarrow x/119 mol$





$$\frac{y}{123} \qquad \frac{x}{119}$$

$$\frac{y}{123} = \frac{1.29}{129} \Rightarrow 1.23 gm$$

$$\frac{y}{123} \times 6 = \frac{x}{119} \times 2 \Rightarrow x = \frac{y}{123} \times 3 \times 119$$

$$= 10^{-2} \times 3 \times 119$$

x = 3.57

y = 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 is 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. **1.875**

12. The value of y is _____.

Ans. **18.75**

Sol. $Fe + 2HCl \longrightarrow FeCl_2 + H_2$

meq of $KMnO_4$ = meq of Fe^{+2}

$12.5 \times 0.03 \times 5 = 1.875$ = meq of Fe^{+1} in 25ml

meq of Fe^{+2}= m.moles of Fe^{+1} in 250 ml

$= 18.75$

moles = $= 18.75 \times 10^{-3} = x \times 10^{-2}$

wt $= 18.75 \times 10^{-3} \times 56 = 1.05\,gm$

x = 1.875

% of Fe^{+2} = $\frac{1.05}{5.6} \times 100 = 18.75$

Section – 3

- 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 enrgy required to break a bond is same as the amount 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 formd. Shorter bonds are typically stronger bonds. BDEs for some bonds are given below:

$H_3C - H(g) \longrightarrow H_3\dot{C}(g) + \dot{H}(g) \quad \Delta H^o = 105\ kcal\ mol^{-1}$

$Cl - Cl(g) \longrightarrow \dot{Cl}(g) + \dot{Cl}(g) \quad \Delta H^o = 58\ kcal\ mol^{-1}$

$H_3C - Cl(g) \longrightarrow H_3\dot{C}(g) + \dot{Cl}(g) \quad \Delta H^o = 85\ kcal\ mol^{-1}$

$H - Cl(g) \longrightarrow \dot{H}(g) + \dot{Cl}(g) \quad \Delta H^o = 103\ kcal\ mol^{-1}$

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**–$CH(CH_3)_2$	(i) 132
(Q) **H**–CH_2Ph	(ii) 110
(R) **H**–$CH=CH_2$	(iii) 95
(S) **H**–$C\equiv CH$	(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. **D**

Sol. $CH_3-H \longrightarrow \dot{C}H_3 + \dot{H}$ $\quad \Delta H^\circ = 105\,K\,Cal$

(A)

$$\text{B.D.E} \; \alpha \; \frac{1}{\text{stability of free radical}}$$

$CH_4 \longrightarrow \dot{C}H_3 + \dot{H} \quad \Delta H^\circ = 105$

$HCl \longrightarrow \dot{H} + \dot{C}l \quad \Delta H^\circ = 103$

$Cl_2 + CH_4 \longrightarrow \dot{C}H_3$

$\dot{C}l + CH_4 \longrightarrow HCl + \dot{C}H_3 \quad \Delta H^\circ = 105 - 103$
$= 2$
endothermic

$\dot{C}H_3 + Cl_2 \longrightarrow CH_3Cl + \dot{C}l$

$\dot{C}H_3 + \dot{C}l \longrightarrow CH_3Cl \quad \Delta H^\circ = -85$

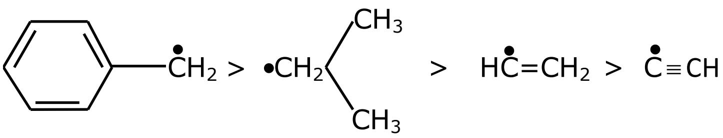
$Cl - Cl \longrightarrow 2\dot{C}l \quad \Delta H^\circ = 58$

$\dot{C}H_3 + Cl_2 \longrightarrow CH_3Cl + \dot{C}l \quad \Delta H^\circ = -27$
exothermic

final reaction

$CH_4 + Cl_2 \longrightarrow CH_3Cl + HCl$

$\Delta H^\circ = 105 + 58 - 85 - 103$
$= -25$



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 $\Delta H^\circ = -58 \text{ kcal mol}^{-1}$

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

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

(D) the recaiton is exothermic with $\Delta H^\circ = -25 \text{ kcal mol}^{-1}$

Ans. **D**

Sol.

$H_3C-H \rightarrow H_3\dot{C} + \dot{H}$, $\Delta H^\circ = 105$ kcal / mole

$Cl-Cl \rightarrow \dot{Cl} + \dot{Cl}$, $\Delta H^\circ = 58$ kcal / mole

$H_3C-Cl \rightarrow H_3\dot{C} + \dot{Cl}$, $\Delta H^\circ = 85$ kcal / mole

$H-Cl \rightarrow \dot{H} + \dot{Cl}$, $\Delta H^\circ = 103$ kcal / mole

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

Step-I Chain intiationstep

$Cl-Cl \rightarrow 2\dot{Cl}$

(+58)

Step-II Chain propogation step

$\underset{(+105)}{CH_3-H} + \dot{Cl} \rightarrow \underset{(-103)}{H-Cl} + \dot{C}H_3$

$\dot{C}H_3 + \underset{(+58)}{Cl-Cl} \rightarrow \underset{(-85)}{CH_3-Cl} + \dot{Cl}$

Total energy gain = 105 + 58 = 163 kcal mol^{-1}

Total energy released = 103 + 85 = 188 kcal mol^{-1}

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 $FeSO_4$ soluton in complete absence of air produces a white preipitate **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**

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**

(1) $K_3[Fe(CN)_6] + FeSO_4 \longrightarrow Fe_3[Fe(CN)_2]_2$
Turnbull's blue

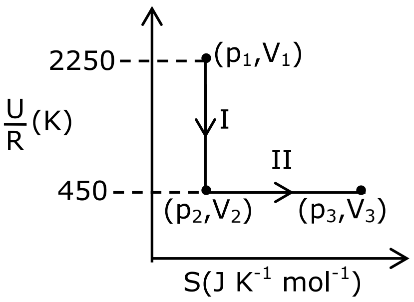
(2) $K_4[Fe(CN)_6] + FeSO_4 \longrightarrow K_3Fe[Fe(CN)_6]$
"X"
$\downarrow$ air
$Fe_4[Fe(CN)_6]_3$
Or K Fe $[Fe(CN)_6]$
Prussian blue

(3) $FeSO_4 + NaNO_3 + H_2SO_4 \longrightarrow [Fe(H_2O)_5NO]^{+2}$
Conc. (Brown ring)

SECTION 4

- 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.

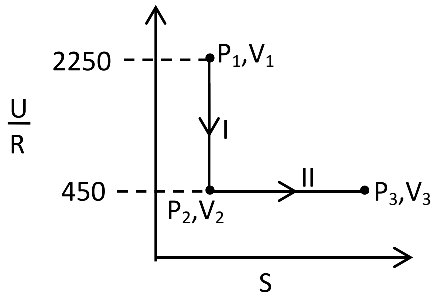
17. One mole of an ideal gas at 900 K, undergoes two reversible processes, **I** followed by **II**, as shown below. If the work done by the gas in the two processes are same, the value of ln $\frac{V_3}{V_2}$ is ______.



(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



In a reversible adiabatic exp.

$\frac{\Delta U}{R}(I) = 450 - 2250 = -1800$

$\Delta U = -1800R$

Process (II) is an Isothermal exp.

$W_{(I)} = W_{(II)}$

$nC_V(T_2 - T_1) = -nRT_2 \ln\frac{V_3}{V_2}$

$C_v(T_2 - T_1) = -RT_2 \ln\frac{V_3}{V_2}$

$W_{(I)} = \Delta U = -1800R$

$nC_v(T_2 - T_1) = -1800R$

$1 \times \frac{5}{3}R(T_2 - 900) = -1800R$

$\frac{-3600}{5} = T_2 - 900$

$T_2 = 180K$

$-1800R = -RT_2 \ln\frac{V_3}{V_2}$

$-1800 = -180 \ln\frac{V_3}{V_2}$

$\ln\frac{V_3}{V_2} = 10$

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 consant = 6.6×10^{-34} Js, Avogadro number = $6 \times 10^{23}\ mol^{-1}$, Molar mass of $He = 4 g\ mol^{-1}$)

Ans. **30**

Sol. $\lambda = \dfrac{h}{m(\Delta v)}$

$\Delta v = \dfrac{h}{m\lambda} = \dfrac{6.6 \times 10^{-34} N_A}{4 \times 10^{-3} \times 330 \times 10^{-9}}$

$= 0.3\,m/sec = 30\,Cm/sec$

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

Ans. **6**

Sol. ClO_2 contains an odd electron and is paramagnetic. It reacts with ozone to give O_2 and Cl_2O_6.

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

In Cl_2O_6, the average oxidation state of Cl is +6.