JEE (ADVANCED) 2023 PAPER-1

[PAPER WITH SOLUTION]

HELD ON SUNDAY 04TH JUNE 2023

CHEMISTRY

SECTION 1 (Maximum Marks : 12)

- This section contains THREE (03) 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 ONLY if (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 none of the options is chosen (i.e. the question is 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 (i.e. the question is unanswered) will get 0 marks; and

  choosing any other combination of options will get −2 marks.

[:Q.1] The correct statement(s) related to processes involved in the extraction of metals is(are)

[:A] Roasting of Malachite produces Cuprite.

[:B] Calcination of Calamine produces Zincite.

[:C] Copper pyrites is heated with silica in a reverberatory furnace to remove iron.

[:D] Impure silver is treated with aqueous KCN in the presence of oxygen followed by reduction with zinc metal.

[:ANS] B,C,D

[:SOLN] [A] $CuCO_3{\cdot}Cu(OH)_2 \xrightarrow{\text{Roasting}} 2CuO + CO_2 + H_2O$

[B] $ZnCO_3 \xrightarrow{\text{Calcination}} ZnO + CO_2$

[C] $2CuFeS_2 + O_2 \xrightarrow{\Delta} Cu_2S + FeS + SO_2$

$FeS + \frac{3}{2}O_2 \longrightarrow FeO + SO_2$

$FeO + SiO_2 \longrightarrow FeSiO_3$ (Slag)

[D] $4\,Ag + 8\,KCN + O_2 + 2H_2O \longrightarrow 4K[Ag(CN)_2] + 4\,NaOH$

$4K[Ag(CN)_2] + 2Zn \longrightarrow 2K_2[Zn(CN)_4] + 4Ag$

[:Q.2] In the following reactions, P, Q, R, and S are the major products.

$$CH_3CH_2CH(CH_3)CH_2CN \xrightarrow[\text{(ii) PhMgBr, then } H_2O]{\text{(i) PhMgBr, then } H_3O^{\oplus}} \mathbf{P}$$

$$Ph\text{-}H + CH_3\overset{O}{\overset{\|}{C}}Cl \xrightarrow[\text{(ii) PhMgBr, then } H_2O]{\text{(i) anhyd. } AlCl_3} \mathbf{Q}$$

$$CH_3CH_2\overset{O}{\overset{\|}{C}}Cl \xrightarrow[\text{(ii) PhMgBr, then } H_2O]{\text{(i) } \frac{1}{2}\,(PhCH_2)_2Cd} \mathbf{R}$$

$$PhCH_2CHO \xrightarrow[\text{(iii) HCN}]{\substack{\text{(i) PhMgBr, then } H_2O \\ \text{(ii) } CrO_3\text{, dil. } H_2SO_4}} \mathbf{S}$$
$$\text{(iv) } H_2SO_4, \Delta$$

The correct statement(s) about **P, Q, R**, and **S** is(are)

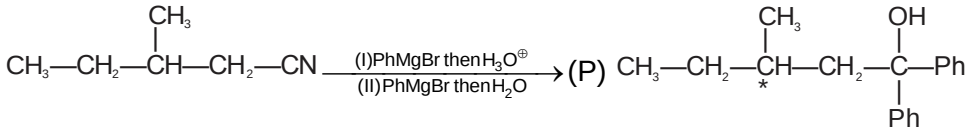
[:A] Both **P** and **Q** have asymmetric carbon(s).

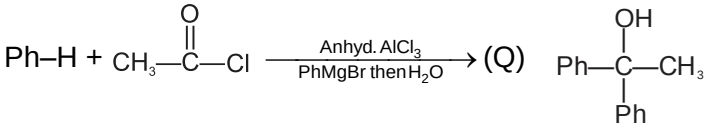
[:B] Both **Q** and **R** have asymmetric carbon(s).

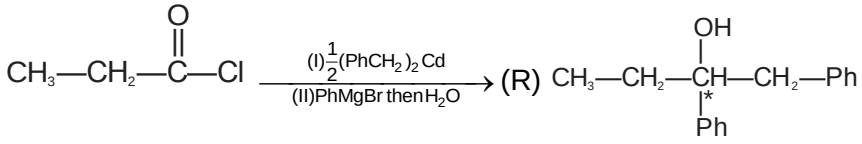
[:C] Both **P** and **R** have asymmetric carbon(s).

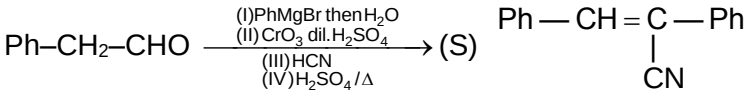
[:D] **P** has asymmetric carbon(s), **S** does not have any asymmetric carbon

[:ANS] C,D

[:SOLN] 





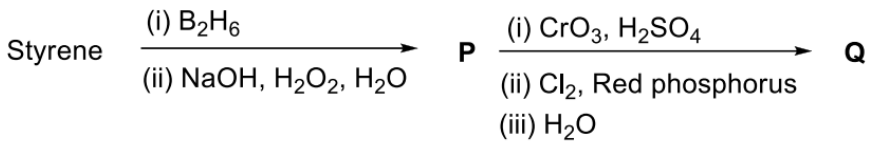


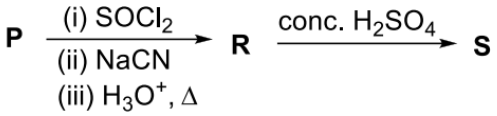
(C) P and R have asymmetrical carbon(s)

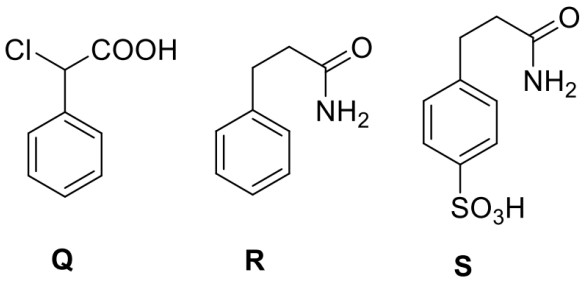
(D) P has asymmetrical carbon(s)

S doesn't have any asymmetrical carbon.

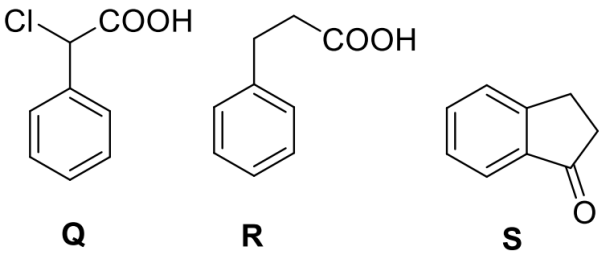
[:Q.3] Consider the following reaction scheme and choose the correct option(s) for the major products Q, R and S



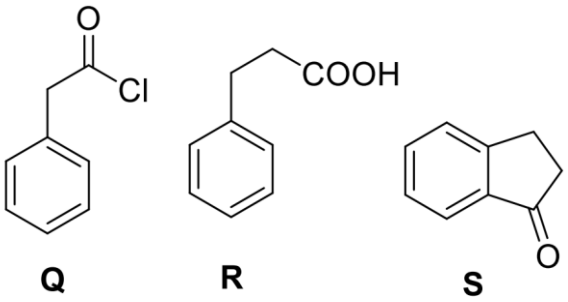


[A] 

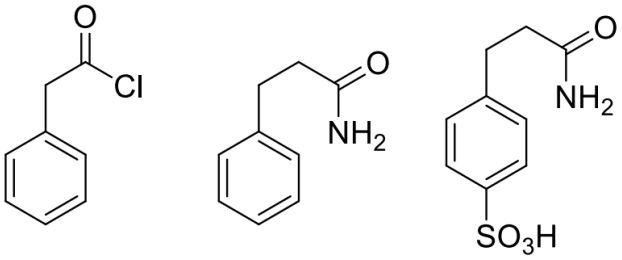
Q **R** **S**

[B] 

Q R S

[C] 

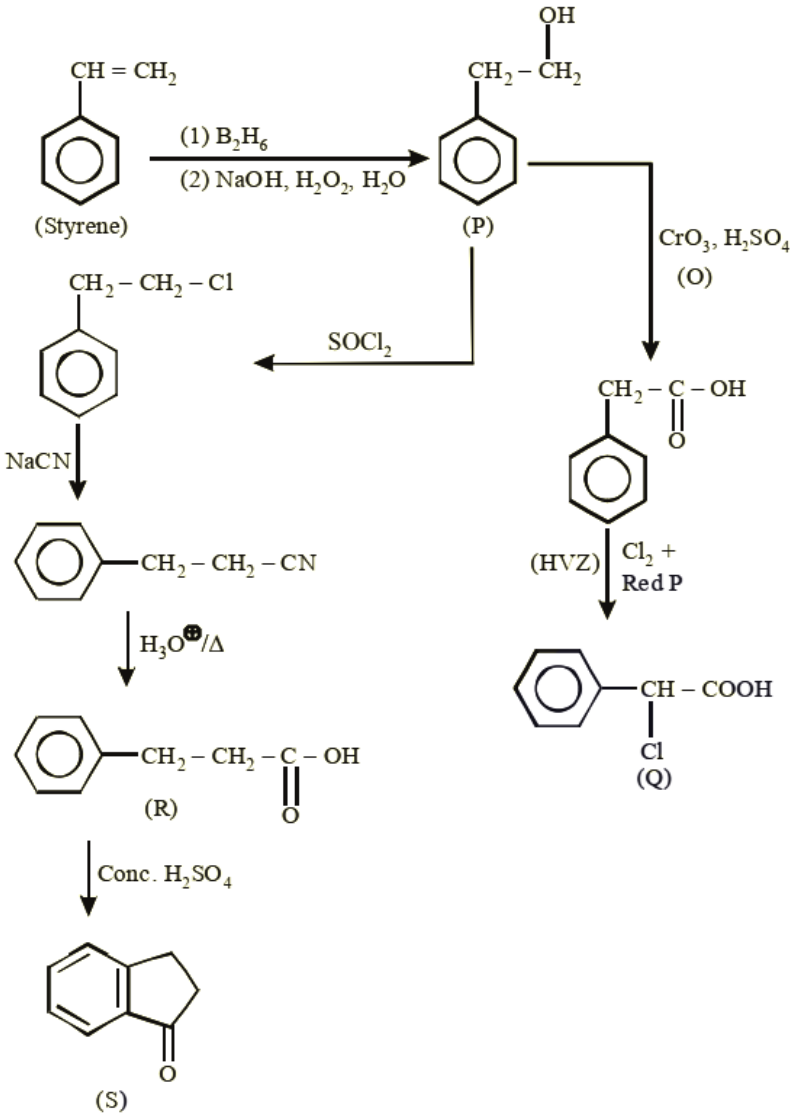
Q R S

[D] 

Q R S

[:ANS] B

[:SOLN]



SECTION 2 (Maximum Marks : 12)

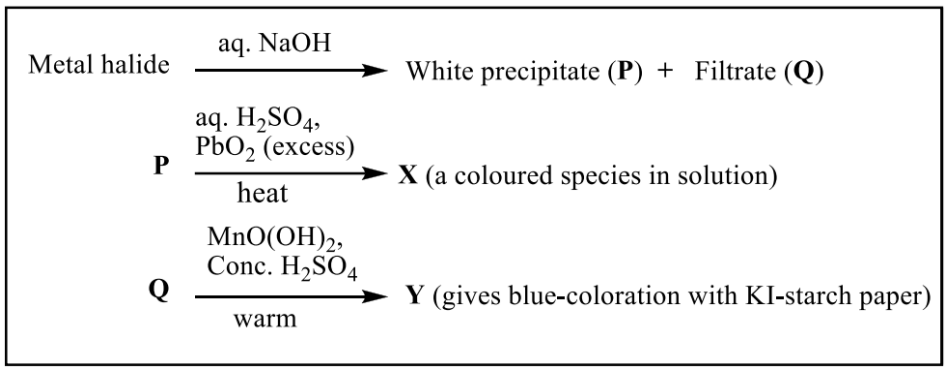
- This section contains FOUR (04) questions.
- Each question has FOUR options (A), (B), (C) and (D). ONLY ONE of these four options is the correct answer.
- For each question, choose the option corresponding to the correct answer.
- Answer to each question will be evaluated according to the following 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.

[:Q.4] In the scheme given below, **X** and **Y**, respectively, are



[:A] CrO_4^{2-} and Br_2

[:B] MnO_4^{2-} and Cl_2

[:C] MnO_4^- and Cl_2

[:D] $MnSO_4$ and HOCl

[:ANS] C

[:SOLN] $MnCl_2 + NaOH(Aq.) \longrightarrow \underset{\text{White ppt}}{\overset{(P)}{Mn(OH)_2}} + \underset{\text{filterate}}{\overset{(Q)}{NaCl}}$

In forth group (qualitative analysis), white precipitate of $Mn(OH)_2$ on heating with PbO_2 and aq. H_2SO_4 gives red violet (Purple) colour due to formation of $HMnO_4$

$$5PbO_2 + 2\underset{(P)}{Mn(OH)_2} + 5H_2SO_4 \longrightarrow 2HMnO_4 + 5PbSO_4 + 6H_2O$$

$$2\underset{(Q)}{NaCl} + H_2SO_4 \rightarrow 2HCl + Na_2SO_4$$

$$HCl \xrightarrow[KI-Starch\,Paper]{Conc.H_2SO_4} Blue\,colouration$$

[:Q.5] Plotting $1/\Lambda_m$ against $C\Lambda_m$ for aqueous solutions of a monobasic weak acid (HX) resulted in a straight line with y-axis intercept of P and slope of S. The ratio P/S is

[Λ_m = molar conductivity

Λ_m^0 = limiting molar conductivity

C = molar concentration

K_a = dissociation constant of HX]

[:A] $K_a\ \Lambda_m^0$

[:B] $K_a\ \Lambda_m^0/2$

[:C] $2\ K_a\ \Lambda_m^0/2$

[:D] $1 / (K_a \Lambda_m^0)$

[:ANS] A

[:SOLN] $HX \rightleftharpoons H^+ + X^-$

$C(1-\alpha) \quad C\alpha \quad C\alpha$

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

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

$$1-\frac{\lambda_m}{\lambda_m^o} = \frac{C\lambda_m^2}{(\lambda_m^0)^2 K_a}$$

$$\frac{1}{\lambda_m} = \frac{1}{\left(\lambda_m^0\right)^2 K_a} \times C\lambda_m + \frac{1}{\lambda_m^0}$$

$$P = \frac{1}{\lambda_m^0} \qquad S = \frac{1}{\left(\lambda_m^0\right)^2 K_a}$$

$$P/S = \frac{\left(\lambda_m^0\right)^2 K_a}{\lambda_m^0} = \lambda_m^0 K_a$$

[:Q.6] On decreasing the pH from 7 to 2, the solubility of a sparingly soluble salt (MX) of a weak acid (HX) increased from 10^{-4} mol L^{-1} to 10^{-3} mol L^{-1}. The pKa of HX is

[:A] 3

[:B] 4

[:C] 5

[:D] 2

[:ANS] B

[:SOLN] $MX \rightleftharpoons M^+ + X^-$

$H^+ + X^- \rightleftharpoons HX$

$$S = [X^-] + HX$$

$$S = [X^-] + \frac{[H^+] \times [X^-]}{K_a}$$

$$S = [X^-]\left[1 + \frac{H^+}{K_a}\right]$$

$$S = \frac{K_{sp}}{M^+}\left[1 + \frac{H^+}{K_a}\right]$$

$$S^2 = K_{sp}\left[1+\frac{H^+}{K_a}\right]$$

$$\left(10^{-4}\right)^2 = K_{sp}\left[1+\frac{10^{-7}}{K_a}\right]$$

$$\left(10^{-3}\right)^2 = K_{sp}\left[1+\frac{10^{-2}}{K_a}\right]$$

$$10^{-2} = \frac{1+\frac{10^{-7}}{K_a}}{1+\frac{10^{-2}}{K_a}}$$

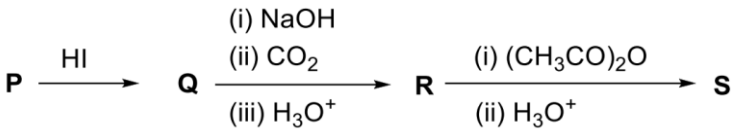
$$1+\frac{10^{-2}}{K_a} = 100+\frac{10^{-5}}{K_a}$$

$$\frac{10^{-2}-10^{-5}}{K_a} = 99$$

$$K_a = \frac{10^{-2}}{99} \approx 10^{-4}$$

$P_{Ka} = 4$

[:Q.7] In the given reaction scheme, P is a phenyl alkyl ether, Q is an aromatic compound; R and S are the major products.



The correct statement about S is

[:A] It primarily inhibits noradrenaline degrading enzymes.

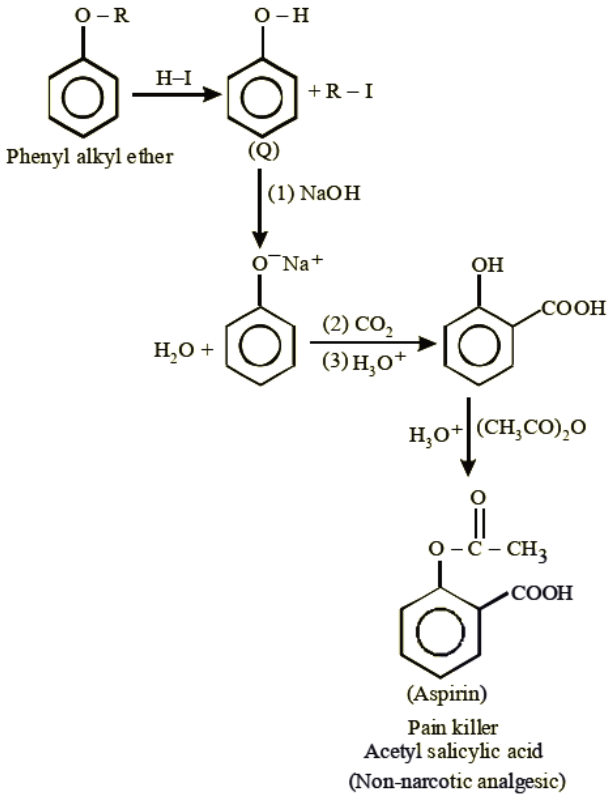
[:B] It inhibits the synthesis of prostaglandin.

[:C] It is a narcotic drug.

[:D] It is ortho-acetylbenzoic acid.

[:ANS] B

[:SOLN]



SECTION 3 (Maximum Marks : 24)

- This section contains SIX (06) 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 onscreen virtual numeric keypad in the place designated to enter the answer.
- Answer to each question will be evaluated according to the following marking scheme:

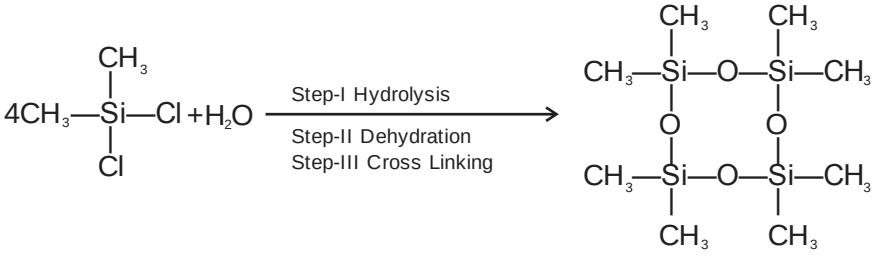
  Full Marks : +4 If ONLY the correct integer is entered;

  Zero Marks : 0 In all other cases.

[:Q.8] The stoichiometric reaction of 516 g of dimethyldichlorosilane with water results in a tetrameric cyclic product **X** in 75% yield. The weight (in g) of **X** obtained is___.
[Use, molar mass (g mol−1): H = 1, C = 12, O = 16, Si = 28, Cl = 35.5]

[:ANS] 222g

[:SOLN]



Given Wt. = 516g

Molar mass = 129 g/mol $n = \frac{516}{129} = 4$

$$\frac{n Si(CH_3)_2Cl_2}{4} = (n\,\text{Tetrameric Cyclic Product}) \times \frac{100}{75}$$

$$n \text{ Tetrameric Cyclic Product} = 4 \times \frac{1}{4} \times \frac{75}{100}\text{mole} = \frac{3}{4}\text{mole}$$

$$\text{wt. of Tetrameric Cyclic Product} = \frac{3}{4} \times 296\text{g} = 222\text{ g}$$

[:Q.9] A gas has a compressibility factor of 0.5 and a molar volume of 0.4 dm3 mol−1 at a temperature of 800 K and pressure x atm. If it shows ideal gas behaviour at the same temperature and pressure, the molar volume will be y dm^3 mol^{-1}. The value of **x/y** is ___. [Use: Gas constant, R = 8 × 10^{-2} L atm K^{-1} mol^{-1}]

[:ANS] 100

[:SOLN] Z = 0.5 V_m = 0.4 800K x atm

$x \times 0.4 = 0.5R \times 800$

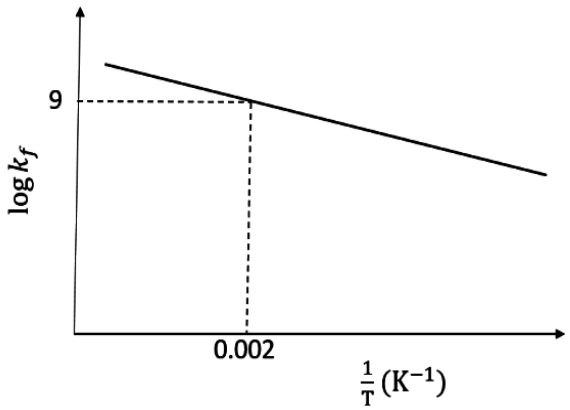
$$x = \frac{0.5 \times 8 \times 10^{-2} \times 800}{0.4} = 80$$

$x \times y = R \times 800$

$$\frac{0.4}{y} = 0.5 \quad \Rightarrow \quad y = 0.8$$

$$\frac{x}{y} = \frac{80}{0.80} = 100$$

[:Q.10] The plot of log k_f versus $1/T$ for a reversible reaction A(g)⇌P(g) is shown.



Pre-exponential factors for the forward and backward reactions are 10^{15} s−1 and 10^{11} s−1, respectively. If the value of log K for the reaction at 500 K is 6, the value of |log k_b | at 250 K is ___.

[K = equilibrium constant of the reaction

k_f = rate constant of forward reaction

k_b = rate constant of backward reaction]

[:ANS] 5

[:SOLN] $K_f = A_f e^{-\frac{E_f}{RT}}$

$$\log K_f = \log A_f - \frac{E_f}{2.303RT}$$

$$\text{at } 500K \quad 9 = 15 - \frac{E_f}{2.303 \times R \times 500} \Rightarrow \frac{E_f}{2.303 \times R \times 500} = 6$$

$$\text{at } 250K \quad \log K_{f_{250}} = 15 - \frac{E_f}{2.303 \times 250}$$

$$= 15 - 12 = 3$$

$$\log K_f = \log A_f - \frac{E_f}{2.303RT}$$

$$\log K_b = \log A_b - \frac{E_b}{2.303RT}$$

$$\log K = \log \frac{K_f}{K_b} - \frac{\Delta H}{2.303RT}$$

$$\text{at } 500K \quad 6 = 4 - \frac{\Delta H}{2.303 \times R \times 500}$$

$$\frac{\Delta H}{2.303 \times R \times 500} = -2$$

$$\text{at } 250K \quad \log K_{250} = 4 - \frac{\Delta H}{2.303 \times 250} = 4 - (-4) = 8$$

$$K_{250} = 10^8$$

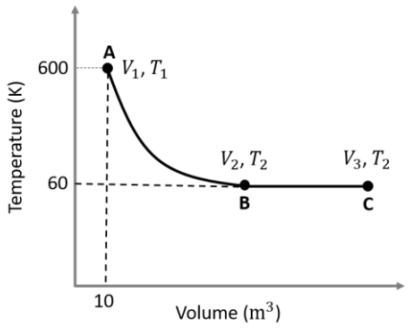
$$K_{f_{250}} = 10^3$$

$$K_{b_{250}} = 10^{-5}$$

$$\log K_{b_{(250)}} = -5$$

$$\left|\log K_{b_{(250)}}\right| = 5$$

[:Q.11] One mole of an ideal monoatomic gas undergoes two reversible processes (A $\rightarrow$ B) and B $\rightarrow$ C) as shown in the given figure:



A $\rightarrow$ B is an adiabatic process. If the total heat absorbed in the entire process (A $\rightarrow$ B and B $\rightarrow$ C) is RT2 ln 10, the value of 2 log V_3 is ___.

[Use, molar heat capacity of the gas at constant pressure, $C_{p,m} = 5/2\,R$]

[:ANS] 7

[:SOLN] A $\rightarrow$ B adiabatic = $q_{AB} = 0$

B $\rightarrow$ C $q_{BC} = -W_{BC}$

$$W_{BC} = -RT\ln\frac{V_3}{V_2}$$

$$q_{BC} = RT\ln\frac{V_3}{V_2}$$

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

$$T_1V_1^{\gamma-1} = T_2V_2^{\gamma-1}$$

$$600\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 60$$

$$\left(\frac{V_1}{V_2}\right)^{\gamma-1} = 0.1$$

$$\left(\frac{V_1}{V_2}\right)^{\frac{5}{3}-1} = 0.1$$

$$\left(\frac{10}{V_2}\right)^2 = 10^{-3}$$

$$V_2 = 10^{5/2}$$

$V_3 = 10 \times V_2 = 10 \times 10^{5/2} = 10^{7/2}$

$$\log V_3 = \frac{7}{2}$$

$2 \log V_3 = 7$

[:Q.12] In a one-litre flask, 6 moles of A undergoes the reaction A (g) ⇌ P (g). The progress of product formation at two temperatures (in Kelvin), T_1 and T_2, is shown in the figure: If $T_1 = 2T_2$ and $(\Delta G_2^{\ominus} - \Delta G_1^{\ominus}) = RT2 \ln x$, then the value of x is ___.

[$\Delta G_1^{\ominus}$ and $\Delta G_2^{\ominus}$ are standard Gibb's free energy change for the reaction at temperatures T_1 and T_2, respectively

[:ANS] 8

[:SOLN] $A \rightleftharpoons P$

AT	T_1	2	4	$K_{eq} = 2$
AT	T_2	4	2	$K_{eq} = ½$

$$\Delta G_1^0 = -RT_1 \ln K_{eq} = -RT_1 \ln 2$$

$$\Delta G_2^0 = -RT_2 \ln K_{eq} = -RT_2 \ln \frac{1}{2}$$

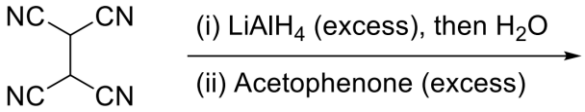
$$\Delta G_2^0 - \Delta G_1^0 = RT_2 \ln 2 - [-R2T_2 \ln 2]$$

$= RT_2 \ln 2 + RT_2 \ln 4$

$= RT_2 \ln 8$

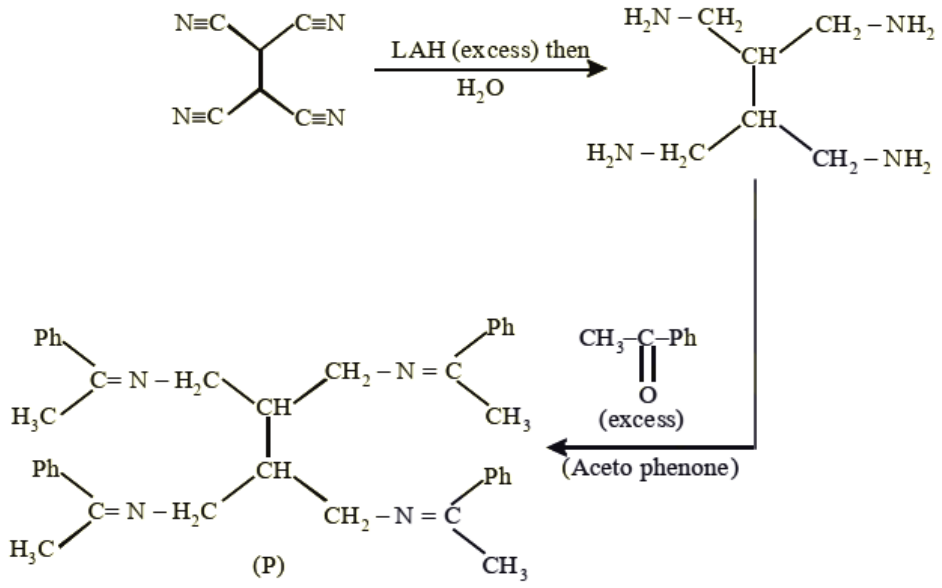
$X = 8$

[:Q.13] The total number of sp^2 hybridised carbon atoms in the major product P (a non-heterocyclic compound) of the following reaction is ___.



[:ANS] 28

[:SOLN]



In Phenyl 6 sp^2 hybridised C = 6× 4 =24

Sp^2C in open structure = 1×4 =4

Total sp^2 hybridised carbon = 24+4=28

SECTION 4 (Maximum Marks : 12)

- This section contains **FOUR (04)** Matching List Sets.
- Each set has ONE Multiple Choice Question.
- Each set has TWO lists: List-I and List-II.
- List-I has Four entries (P), (Q), (R) and (S) and List-II has Five entries (1), (2), (3), (4) and (5).
- FOUR options are given in each Multiple Choice Question based on List-I and List-II and ONLY ONE of these four options satisfies the condition asked in the Multiple Choice Question.
- Answer to each question will be evaluated according to the following marking scheme:

  Full Marks : +3 ONLY if the option corresponding to the correct combination 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

[:Q.14] Match the reactions (in the given stoichiometry of the reactants) in List-I with one of their products given in List-II and choose the correct option.

	List-I		**List-II**
(P)	$P_2O_3 + 3H_2O \rightarrow$	(1)	$P(O)(OCH3)Cl_2$
(Q)	$P_4 + 3NaOH + 3H2O \rightarrow$	(2)	H_3PO_3
(R)	$PCl_5 + CH3COOH \rightarrow$	(3)	PH_3
(S)	$H_3PO_2 + 2H_2O + 4AgNO_3 \rightarrow$	(4)	$POCl_3$
		(5)	H_3PO_4

Codes :

[:A] P $\rightarrow$ 2; Q $\rightarrow$ 3; R $\rightarrow$ 1; S $\rightarrow$ 5

[:B] P $\rightarrow$ 3; Q $\rightarrow$ 5; R $\rightarrow$ 4; S $\rightarrow$ 2

[:C] P $\rightarrow$ 5; Q $\rightarrow$ 2; R $\rightarrow$ 1; S $\rightarrow$ 3

[:D] P $\rightarrow$ 2; Q $\rightarrow$ 3; R $\rightarrow$ 4; S $\rightarrow$ 5

[:ANS] C

[:SOLN] $P_2O_3 + 3H_2O \longrightarrow 2H_3PO_3$

$P_4 + 3NaOH + 3H_2O \longrightarrow PH_3 + \underset{\text{sodium hypophosphite}}{3NaH_2PO_2}$

$PCl_5 + CH_3COOH \longrightarrow CH_3COCl + POCl_3 + HCl$

$H_3PO_2 + 2H_2O + 4AgNO_3 \rightarrow 4Ag + 4HNO_3 + H_3PO_4$

[:Q.15] Match the column:

	List-I		List-II
(P)	$t_{2g}^6\ e_g^0$	(1)	$[Fe(H_2O)_6]^{+2}$
(Q)	$t_{2g}^3\ e_g^2$	(2)	$[Mn(H_2O)_6]^{+3}$
(R)	$e^2\ t_2^3$	(3)	$[Co(NH_3)_6]^{+2}$
(S)	$t_{2g}^4\ e_g^2$	(4)	$[FeCl_4]^-$
		(5)	$[CoCl_4]^{2-}$

Codes :

[:A] P $\rightarrow$ 1; Q $\rightarrow$ 4; R $\rightarrow$ 2; S $\rightarrow$ 3

[:B] P $\rightarrow$ 1; Q $\rightarrow$ 2; R $\rightarrow$ 4; S $\rightarrow$ 5

[:C] P $\rightarrow$ 3; Q $\rightarrow$ 2; R $\rightarrow$ 5; S $\rightarrow$ 1

[:D] P $\rightarrow$ 3; Q $\rightarrow$ 2; R $\rightarrow$ 4; S $\rightarrow$ 1

[:ANS] D

[:SOLN] $[Fe(H_2O)_6]^{+2}$

H_2O is WFL

Fe^{+2} = [Ar] $3d^6$

Now d^6 system in presence of WFL is $t_{2g}^4 eg^2$

$[Mn(H_2O)_6]^{+3}$
H_2O is WFL

Mn^{+2} = [Ar] $3d^5$

Now d^5 system in presence of WFL is $t_{2g}^3 eg^2$

$[Co(NH_3)_6]^{+3}$
NH_3 is SFL
Co^{+3} = [Ar] $3d^6$

Now d^6 system in presence of SFL is $t_{2g}^6 eg^0$

$[FeCl_4]^-$

Cl^- is WFL

Fe^{+3} = [Ar] $3d^5$

For co-ordination number 4,d^5 system in presence of WFL is $t_2^3 e^2$

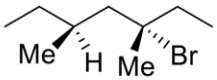
$[CoCl_4]^{2-}$

Cl^- is WFL

Co^{+2} = [Ar] $3d^7$

For co-ordination number 4,d^7 system in presence of WFL is $e^4 t_2^3$

[:Q.16] Match the reactions in List-I with the features of their products in List-II and choose the correct option.

List-I		List-II	
(P)	(-)-1-Bromo-2-ethylpentane (single enantiomer) $\xrightarrow[S_N2 \text{ reaction}]{\text{aq. NaOH}}$	(1)	Inversion of configuration
(Q)	(-)-2-Bromopentane (single enantiomer) $\xrightarrow[S_N2 \text{ reaction}]{\text{aq. NaOH}}$	(2)	Retention of configuration
(R)	(-)-3-Bromo-3-methylhexane (single enantiomer) $\xrightarrow[S_N1 \text{ reaction}]{\text{aq. NaOH}}$	(3)	Mixture of enantiomers
(S)	 (single enantiomer) $\xrightarrow[S_N1 \text{ reaction}]{\text{aq. NaOH}}$	(4)	Mixture of structural isomers
		(5)	Mixture of diastereomers

Codes :

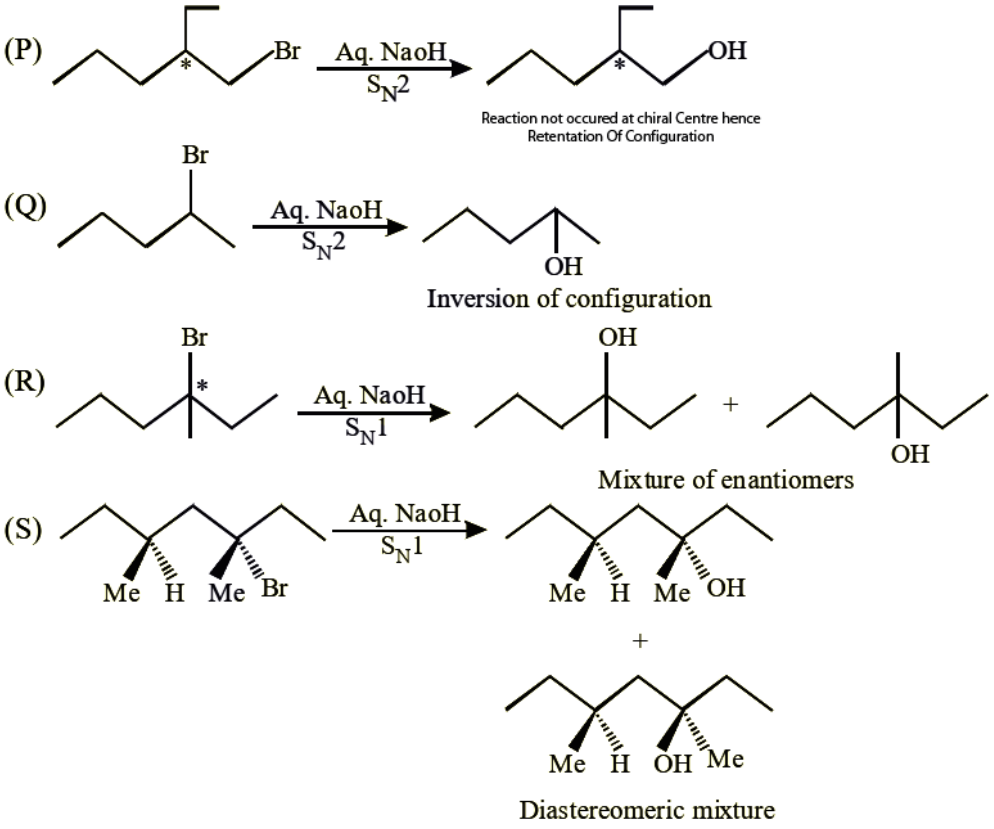
[:A] P → 1; Q → 2; R → 5; S → 3

[:B] P → 2; Q → 1; R → 3; S → 5

[:C] P → 1; Q → 2; R → 5; S → 4

[:D] P → 2; Q → 4; R → 3; S → 5

[:ANS] B



[:SOLN]

[:Q.17] The major products obtained from the reactions in List-II are the reactants for the named reactions mentioned in List-I. Match List-I with List-II and choose the correct option.

LIST-I		**LIST-II**	
(P)	Etard reaction	(1)	Acetophenone $\xrightarrow{\text{Zn-Hg, HCl}}$
(Q)	Gattermann reaction	(2)	Toluene $\xrightarrow[\text{(ii) } SOCl_2]{\text{(i) } KMnO_4, KOH, \Delta}$
(R)	Gattermann-Koch reaction	(3)	Benzene $\xrightarrow[\text{anhyd. } AlCl_3]{CH_3Cl}$
(S)	Rosenmund reduction	(4)	Aniline $\xrightarrow[\text{273-278 K}]{NaNO_2/HCl}$
		(5)	Phenol $\xrightarrow{Zn, \Delta}$

Codes :

[:A] P $\rightarrow$2; Q $\rightarrow$ 4; R $\rightarrow$ 1; S $\rightarrow$ 3 [:B] P $\rightarrow$1; Q $\rightarrow$ 3; R $\rightarrow$ 5; S $\rightarrow$ 2

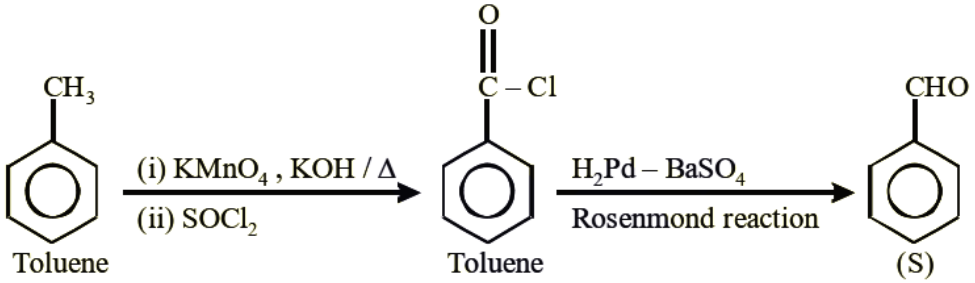
[:C] P $\rightarrow$ 3; Q $\rightarrow$ 2; R $\rightarrow$ 1; S $\rightarrow$ 4 [:D] P $\rightarrow$ 3; Q $\rightarrow$ 4; R $\rightarrow$ 5; S $\rightarrow$ 2

[:ANS] D

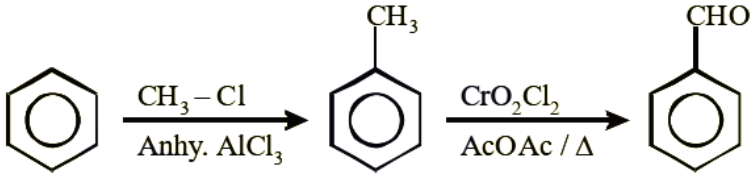
[:SOLN]

(i) $Ph-\overset{\overset{O}{\|}}{C}-CH_3 \xrightarrow{Zn-Hg/HCl} Ph-CH_2-CH_3$

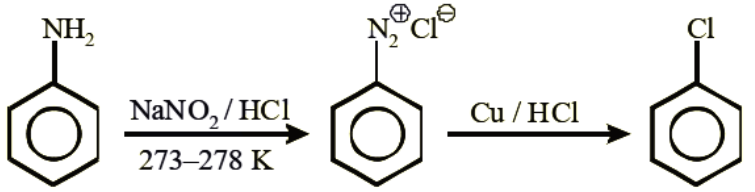
Acetophenone

(ii) 

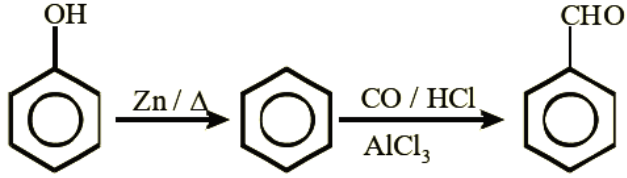
Toluene Toluene (S)

(iii) 

Etard reaction
(P)

(iv) 

Gattermann reaction
(Q)

(v) 

Gattermann Koch reaction
(R)