PAPER (पेपर)- 1

- **This question paper has three (03) parts: PART-I: Physics, PART-II: Chemistry and PART-III: Mathematics.**
- **Each part has total of eighteen (18) questions divided into three (03) sections (Section-1, Section-2 and Section-3).**
- **Total number of questions in Paper-1 : Fifty four (54).**
- **Paper-1 Maximum Marks : One Hundred Eighty (180).**

Instructions for Section-1 : Questions and Marking Scheme

SECTION-1 (Maximum Marks : 24)

- 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).
- For each question, choose the correct option(s) to answer the question.
- Answer to each question will be evaluated according to the following marking chosen.

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 options.
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 :** If first, third and fourth are the ONLY three correct options for a question with second option being an incorrect option; selecting only two of the three correct options (e.g. the first and fourth options), without selecting any incorrect option (second option in this case), will result in +2 marks. Selecting only one of the three correct options (either first or third or fourth option), without selecting any incorrect option (second option in this case), will result in +1 marks. Selecting any incorrect option(s) (second option in this case), with or without selection of any correct option(s) will result in –2 marks.

Answering Section-1 Questions :

- To select the option(s), **using the mouse click** on the corresponding button(s) of the option(s).
- To deselect chosen option(s), click on the button(s) of the chosen option(s) again or click on the **Clear Response** button to clear all the chosen options.
- To change the option(s) of a previously answered question, if required, first click on the **Clear Response** button to clear all the chosen options and then select the new option(s).
- To mark a question ONLY for review (i.e. without answering it), click on the **Mark for Review & Next button**.
- To mark a question for review (after answering it), click on **Mark for Review & Next button** – answered question which is also marked for review will be evaluated.
- To save the answer, click on the **Save & Next** button – the answered question will be evaluated.

Instructions for Section-2 : Questions and Marking Scheme

SECTION-2 (Maximum Marks : 24)

- This section contains **EIGHT (08)** questions. The answer to each question is **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, –0.30,,30.27, –127.30) 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 : **+3** If ONLY the correct numerical value is entered as answer.

Zero Marks : **0** In all other cases.

Answering Section-2 Questions :

- Using the attached computer mouse, click on numbers (and/or symbols) on the on-screen virtual numeric keypad to enter the numerical value as answer in the space provided for answer.
- To change the answer, if required, first click on the **Clear Response** button to clear the entered answer and then enter the new numerical value.
- To mark a question ONLY for review (i.e. answering it), click on **Mark for Review & Next button** – the answered question which is also marked for review will be evaluated.
- To mark a question for review (after answering it), click **Mark for Review & Next button** – the answered question which is also marked for review will be evaluated.
- To save the answer, click on the **Save & Next button** – the answered question will be evaluated.

Instructions for Section-3 : Questions and Marking Scheme

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. **ONLY ONE** of these four options corresponds to 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.

Answering Section-3 Questions :

- To select an option, using the mouse click on the corresponding button of the option.
- To deselect the chosen answer, click on the button of the chosen option again or click on the **Clear Response button**.
- To change the chosen answer, click on the button of another option.
- To mark a question ONLY for review (i.e. without answering it), click on **Mark for Review & Next button**.
- To mark a question for review (after answering it), click on **Mark for Review & Next button** – the answered which is also marked for review will be evaluated.
- To save the answer, click on the **Save & Next button** – the answered question will be evaluated.

PART-II : CHEMISTRY

SECTION – 1 : (Maximum Marks : 24)

- This section contains **SIX (06)** questions.
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1. The compound(s) which generate(s) N_2 gas upon thermal decomposition below 300°C is (are)

(A) NH_4NO_3 (B) $(NH_4)_2Cr_2O_7$

(C) $Ba(N_3)_2$ (D) Mg_3N_2

Ans. **(B, C)**

Sol. (A) NH_4NO_3(decompose below 300°C to produce N_2O & H_2O, but to produce N_2, it should be heated above 300°C).

(B) $(NH_4)_2Cr_2O_7 \xrightarrow{\Delta} N_2 + Cr_2O_3 + H_2O$

(C) $Ba(N_3)_2 \xrightarrow{\Delta} Ba + N_2$

(D) Mg_3N_2 (an ionic compound; will not decompose below 300°C)

2. The correct statement(s) regarding the binary transition metal carbonyl compounds is (are)
(Atomic numbers: Fe = 26, Ni = 28)

(A) Total number of valence shell electrons at metal centre in $Fe(CO)_5$ or $Ni(CO)_4$ is 16

(B) These are predominantly low spin in nature

(C) Metal–carbon bond strengthens when the oxidation state of the metal is lowered

(D) The carbonyl C−O bond weakens when the oxidation state of the metal is increased

Ans. **(B, C)**

Sol. $\Rightarrow$ $Fe(CO)_5$: Total number of valence electrons is 18
: low spin complex.

$\Rightarrow$ $Ni(CO)_4$: Total number of valence electrons is 18
: low spin complex

$\Rightarrow$ Metal-carbonyl bond strengthens when the oxidation state of metal is lowered.

$\Rightarrow$ The carbonyl C–O bond is stronger in case of increased oxidation state of metal.

3. Based on the compounds of group 15 elements, the correct statement(s) is (are)

(A) Bi_2O_5 is more basic than N_2O_5

(B) NF_3 is more covalent than BiF_3

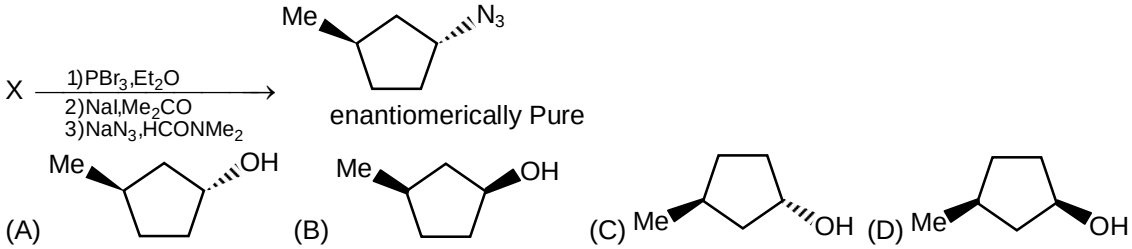
(C) PH_3 boils at lower temperature than NH_3

(D) The N–N single bond is stronger than the P–P single bond

Ans. **(A, B, C)**

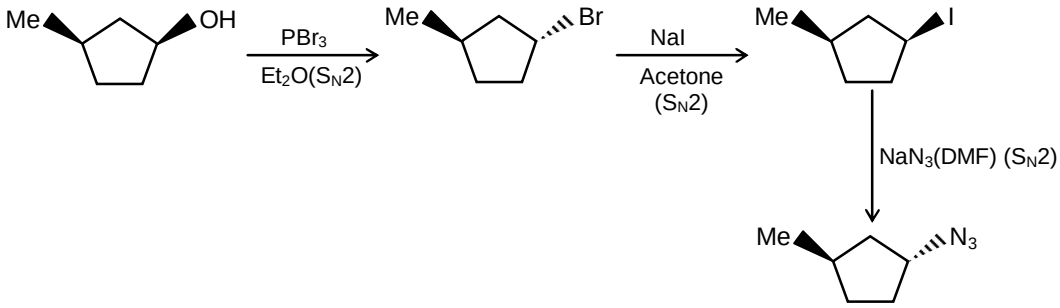
Sol. $\Rightarrow Bi_2O_5$ is more basic than N_2O_5
$\Rightarrow NF_3$ is more covalent than BiF_3
$\Rightarrow NH_3$ boiling point is higher than PH_3
$\Rightarrow$ P–P single bond is stronger than N–N single bond.

4. In the following reaction sequence, the correct structure(s) of **X** is (are)

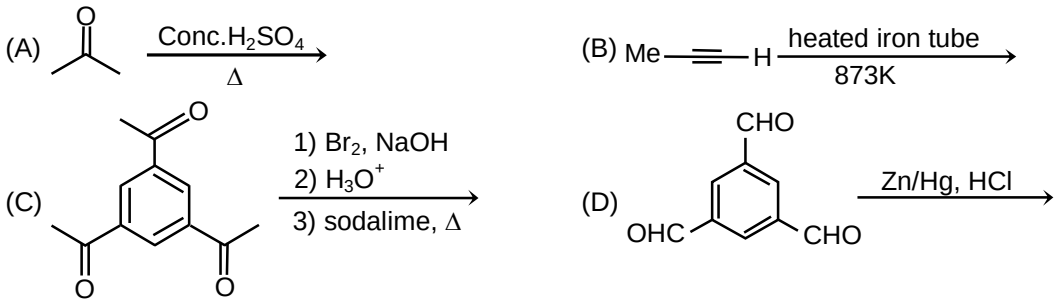


Ans. **(B)**

Sol.

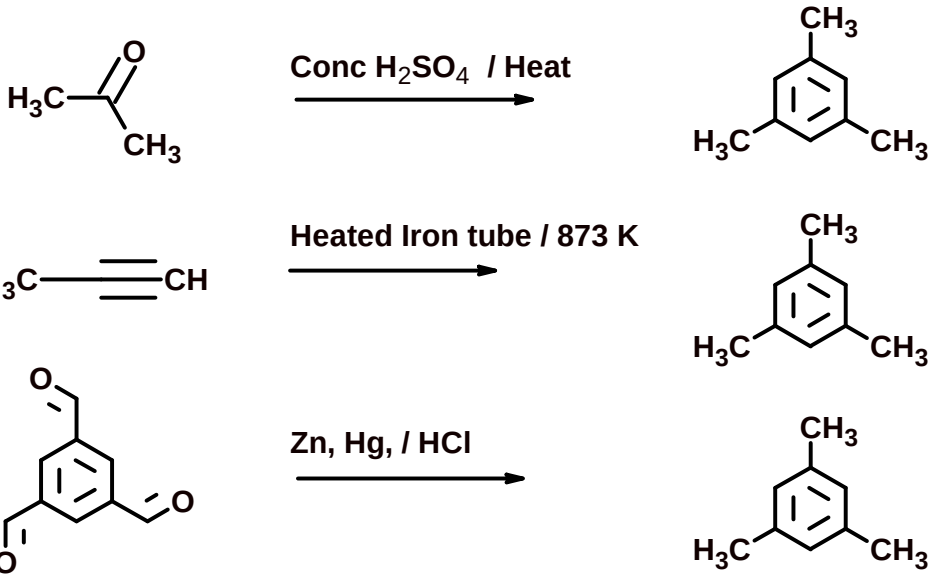


5. The reaction(s) leading to the formation of 1,3,5-trimethylbenzene is (are)

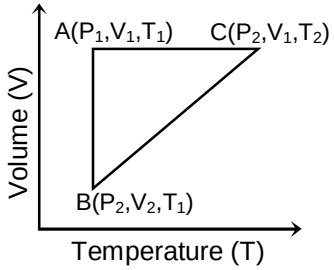


Ans. **(A,B,D)**

Sol. **Detail mechanism of mesitylene formation from acetone can be found in our video solution by SM Sir, HOD Chemistry Resonance.**



6. A reversible cyclic process for an ideal gas is shown below. Here, P, V, and T are pressure, volume and temperature, respectively. The thermodynamic parameters q, w, H and U are heat, work, enthalpy and internal energy, respectively.



The correct option(s) is (are)

(A) $q_{AC} = \Delta U_{BC}$ and $w_{AB} = P_2 (V_2 – V_1)$

(B) $W_{BC} = P_2 (V_2 – V_1)$ and $q_{BC} = \Delta H_{AC}$

(C) $\Delta H_{CA} < \Delta U_{CA}$ and $q_{AC} = \Delta U_{BC}$

(D) $q_{BC} = \Delta H_{AC}$ and $\Delta H_{CA} > \Delta U_{CA}$

Ans. **(B, C)**

Sol. AC $\Rightarrow$ isochoric process

AB $\Rightarrow$ isothermal process

BC $\Rightarrow$ isobaric process

$\Rightarrow q_{AC} = \Delta U_{AC} = nC_{v,m}(T_2 – T_1) = \Delta U_{BC}$

$\Rightarrow W_{AB} = -nRT_1 \ell n\left(\frac{V_2}{V_1}\right)$

$\Rightarrow W_{BC} = -P_2(V_1 – V_2) = P_2(V_2 – V_1)$

$\Rightarrow q_{BC} = \Delta H_{BC} = nC_{P,m}(T_2 – T_1) = \Delta H_{AC}$

$\Rightarrow \Delta H_{CA} = nC_{P,m}(T_1 – T_2)$

$\Rightarrow \Delta U_{CA} = nC_{V,m}(T_1 – T_2)$

$\Delta H_{CA} < \Delta U_{CA}$ since both are negative ($T_1 < T_2$)

SECTION 2 (Maximum Marks: 24)

- 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.
- Answer to each question will be evaluated according to the following marking scheme:
  Full Marks : +3 If ONLY the correct numerical value is entered as answer.
  Zero Marks : 0 In all other cases.

7. Among the species given below, the total number of diamagnetic species is ___.
H atom, NO_2 monomer, O_2^- (superoxide), dimeric sulphur in vapour phase,
Mn_3O_4, $(NH_4)_2[FeCl_4]$, $(NH_4)_2[NiCl_4]$, K_2MnO_4, K_2CrO_4

Ans. **1**

Sol. Paramagnetic : Mn_3O_4, $(NH_4)_2[FeCl_4]$, $(NH_4)_2[NiCl_4]$, K_2MnO_4
Diamagnetic : K_2CrO_4

8. The ammonia prepared by treating ammonium sulphate with calcium hydroxide is completely used by $NiCl_2.6H_2O$ to form a stable coordination compound. Assume that both the reactions are 100% complete. If 1584 g of ammonium sulphate and 952 g of $NiCl_2.6H_2O$ are used in the preparation, the combined weight (in grams) of gypsum and the nickel-ammonia coordination compound thus produced is ____.
(Atomic weights in g mol^{-1}: H = 1, N = 14, O = 16, S = 32, Cl = 35.5, Ca = 40, Ni = 59)

Ans. 2992

Sol. $Ca(OH)_2 + (NH_4)_2SO_4 \longrightarrow 2NH_3 + CaSO_4.2H_2O$
1584 g
$[Ni(H_2O)_6]Cl_2$
Complex Compound

Number of Moles of $(NH_4)_2SO_4 = \frac{1584}{132} = 12$ moles

Moles of NH_3 released = 24 moles

Moles of moles of $NiCl_2.6H_2O = \frac{952}{238} = 4$ moles

Number of moles of Gypsum ($CaSO_4.2H_2O$) formed = 12 moles
Mass of Gypsum formed = 12 × 172 = 2064

Number of moles of complex formed $[Ni(NH_3)_6]Cl_2 = \frac{24}{6} = 4$ moles

Mass of complex formed = 4 × 232 = 928 g
Total Mass = 2064 + 928 = 2992 g

9. Consider an ionic solid **MX** with NaCl structure. Construct a new structure (**Z**) whose unit cell is constructed from the unit cell of **MX** following the sequential instructions given below. Neglect the charge balance.
(i) Remove all the anions (**X**) except the central one
(ii) Replace all the face centered cations (**M**) by anions (**X**)
(iii) Remove all the corner cations (M)
(iv) Replace the central anion (**X**) with cation (**M**)

The value of $\left(\frac{\text{number of anions}}{\text{number of catons}}\right)$ in Z is _____.

Ans. **3**

Sol. As per given information cation form FCC lattice and anion occpy all the actahedral void.

So	M^+	X^-	&	Formula MX
	4 ion	4 ion		
After step I	4 ion	1 ion		
After step II	1 ion	4 ion		
After step III	0 ion	4 ion		
After step IV	1 ion	3 ion		

So ratio of $\frac{\text{No. of anion}}{\text{No. of cation}} = \frac{3}{1}$

10. For the electrochemical cell,
$Mg(s) \mid Mg^{2+}(aq,1\ M) \parallel Cu^{2+}(aq,1M) \mid Cu(s)$
the standard emf of the cell is 2.70 V at 300 K. When the concentration of Mg^{2+} is changed to *x* M, the cell potential changes to 2.67 V at 300 K. The value of *x* is ____.
(given, $\frac{F}{R} = 11500\ K\ V^{-1}$, where F is the Faraday constant and R is the gas constant,
ln(10) = 2.30)

Ans. **10**

Sol. $Mg \longrightarrow Mg^{2+} + 2e^-$

$Cu^{2+} + 2e^- \longrightarrow Cu$

$Mg + Cu^{2+}\ Mg \longrightarrow Mg^{2+} + Cu$

$$E = 2.67 = 2.7 - \frac{RT}{nF}\ell n\frac{x}{1}$$

$$0.03 = \frac{300}{2\times 11500}\ \ell nx$$

$2.3 = \ell nx$

$X = 10$

11. A closed tank has two compartments **A** and **B**, both filled with oxygen (assumed to be ideal gas). The partition separating the two compartments is fixed and is a perfect heat insulator (Figure 1). If the old partition is replaced by a new partition which can slide and conduct heat but does **NOT** allow the gas to leak across (Figure 2), the volume (in m^3) of the compartment **A** after the system attains equilibrium is ____.

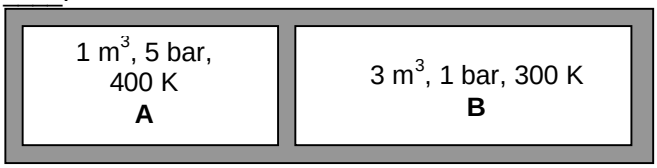


Figure 1

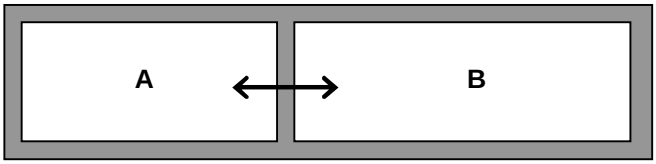
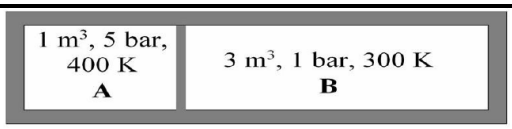


Figure 2

Sol.



Finally, $P_A = P_B$ also $T_A = T_B$

So $\frac{n_A}{n_B} = \frac{V_A}{V_B}$

$$\frac{\frac{5}{400R}}{\frac{3}{300R}} = \frac{V_A}{V_B} \Rightarrow \frac{V_A}{V_B} = \frac{5}{4} \Rightarrow V_A = \frac{5}{9} \times 4 = \frac{20}{9} = 2.22$$

12. Liquids **A** and **B** form ideal solution over the entire range of composition. At temperature T, equimolar binary solution of liquids **A** and **B** has vapour pressure 45 Torr. At the same temperature, a new solution of **A** and **B** having mole fractions x_A and x_B, respectively, has vapour pressure of 22.5 Torr. The value of x_A / x_B in the new solution is ____.
(given that the vapour pressure of pure liquid A is 20 Torr at temperature T)

Ans. **19**

Sol. $\mathbf{p_T = p°_A X_A + p°_B X_B}$

$45 = 20(0.5) + P_B^{\circ}(0.5)$

$P_B^{\circ} = 70$

$22.5 = 20\,X_A + 70(1 - X_A)$

$50X_A = 47.5$

$X_A = \frac{4.75}{5} = 0.95$

$X_B = 0.05$

$\frac{X_A}{X_B} = 19$

13. The solubility of a salt of weak acid **(AB)** at pH 3 is **Y**$\times 10^{-3}$ mol L^{-1}. The value of Y is ____.
(Given that the value of solubility product of **AB** (K_{sp}) = 2×10^{-10} and the value of ionization constant of HB (K_a) = 1×10^{-8})

Ans. **4.47**

Sol.

$AB \rightleftharpoons A^+ + B^-$

solubility x x x – y

$2 \times 10^{-10} = x(x - y)$ .....(1)

$B^- + H^+ \rightleftharpoons HB$

$x - y \quad 10^{-3} \quad y$

$$10^8 = \frac{y}{(x-y)10^{-3}}$$

$$\frac{y}{x-y} = 10^5$$

$x - y = 10^{-5} y$ .....(2)

From (1) & (2)

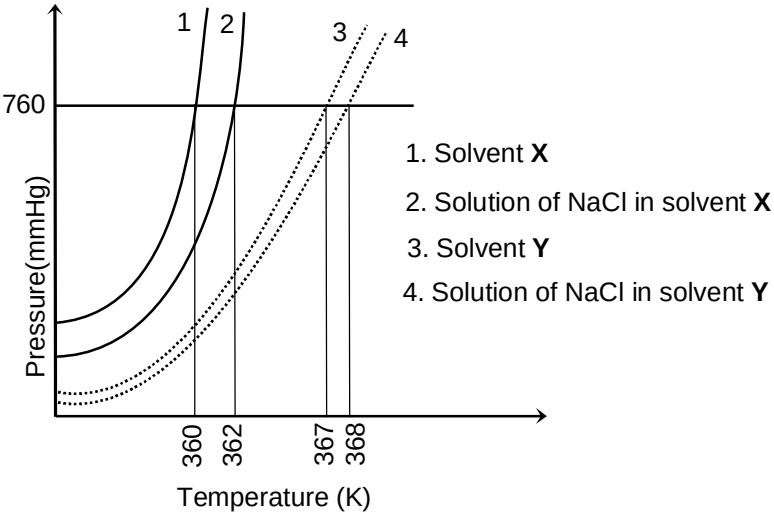
$2 \times 10^{-10} = x^2 - 2 \times 10^{-5}$

$x^2 = 2 \times 10^{-5}$

$x = \sqrt{20} \times 10^{-3}$

$= 4.47 \times 10^{-3}$

14. The plot given below shows P–T curves (where P is the pressure and T is the temperature) for two solvents X and Y and isomolal solutions of NaCl in these solvents. NaCl completely dissociates in both the solvents.



On addition of equal number of moles of a non-volatile solute **S** in equal amount (in kg) of these solvents, the elevation of boiling point of solvent **X** is three times that of solvent **Y**. Solute **S** is known to undergo dimerization in these solvents. If the degree of dimerization is 0.7 in solvent **Y**, the degree of dimerization in solvent **X** is ____.

Ans. **0.05**

Sol. $2 = 2\,(K_b)_x\,m$

$1 = 2\,(K_b)_y\,m$

$$\frac{(K_b)_x}{(K_b)_y} = 2$$

$$\Delta(T_b)_x = \left(1-\frac{\beta}{2}\right)(K_b)_x\,m \qquad \ldots(1)$$

$$\Delta(T_b)_y = \left(1-\frac{0.7}{2}\right)(K_b)_y\,m \qquad \ldots(2)$$

On taking the ratio of eq. no. (1) & (2)

$$\Rightarrow 3 = \frac{1-\frac{\beta}{2}}{0.65} \times 2$$

$$1-\frac{\beta}{2} = 1.5 \times 0.65$$

$$\beta = 0.05$$

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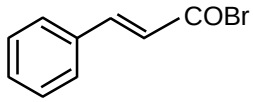
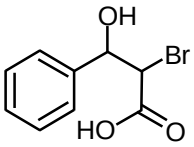
PARAGRAPH "X"

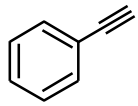
Treatment of benzene with CO/HCl in the presence of anhydrous $AlCl_3$/CuCl followed by reaction with Ac_2O/NaOAc gives compound **X** as the major product. Compound **X** upon reaction with Br_2/Na_2CO_3, followed by heating at 473 K with moist KOH furnishes **Y** as the major product. Reaction of **X** with H_2/Pd-C, followed by H_3PO_4 treatment gives **Z** as the major product.

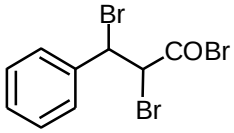
(***There are two questions based on PARAGRAPH "X", the question given below is one of them***)

15. The compound **Y** is

(A) 

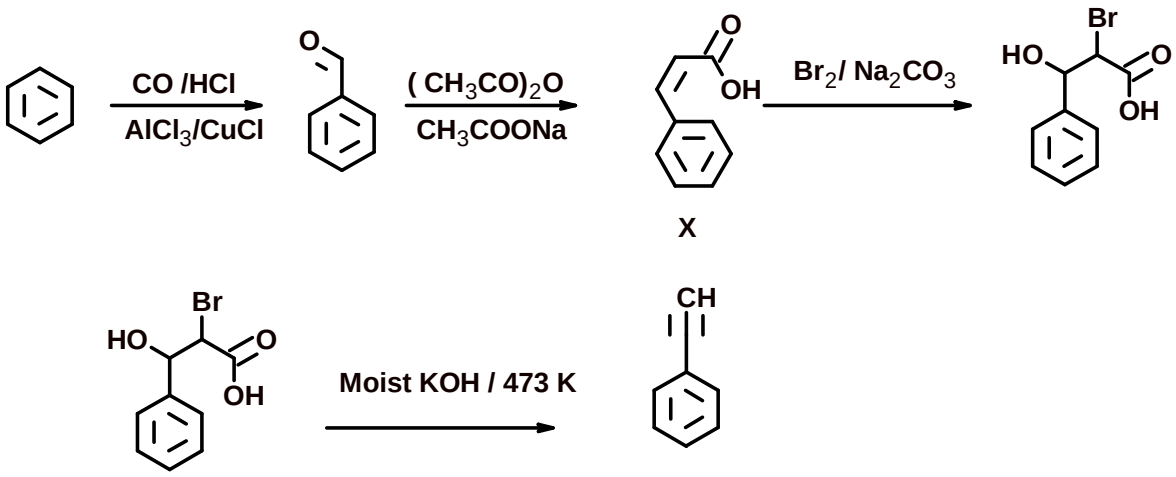
(B) 

(C) 

(D) 

Ans. **C**

Sol.



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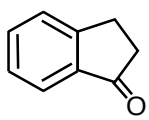
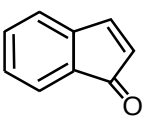
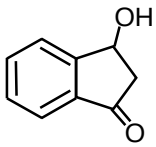
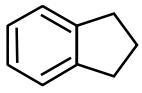
(***There are two questions based on PARAGRAPH "X", the question given below is one of them***)

16. The compound **Z** is

(A) 

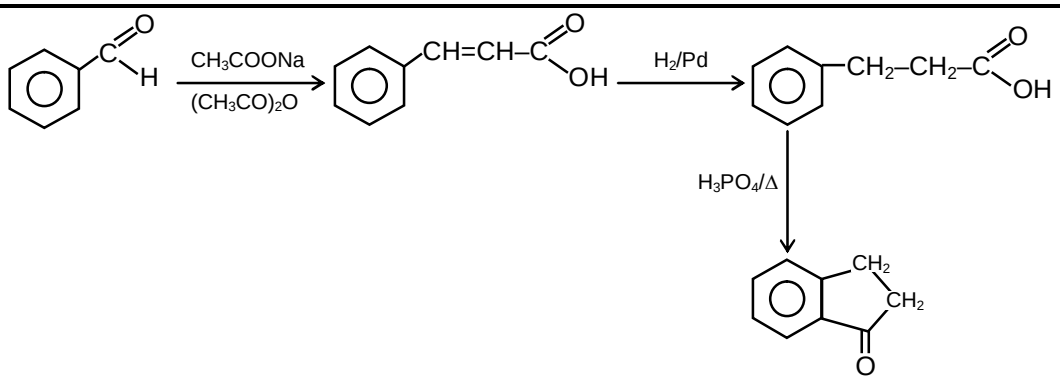
(B) 

(C) 

(D) 

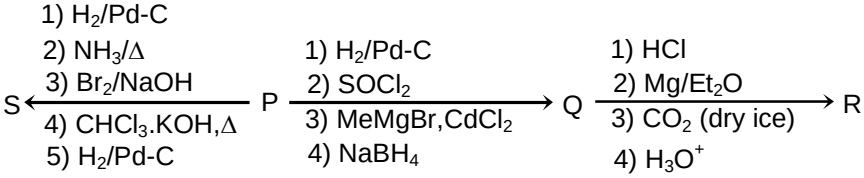
Ans. **(A)**

Sol.



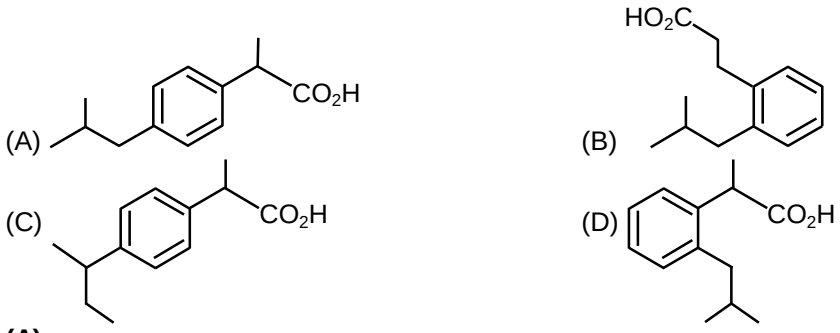
PARAGRAPH "A"

An organic acid **P** ($C_{11}H_{12}O_2$) can easily be oxidized to a dibasic acid which reacts with ethyleneglycol to produce a polymer dacron. Upon ozonolysis, **P** gives an aliphatic ketone as one of the products. **P** undergoes the following reaction sequences to furnish **R** *via* **Q**. The compound **P** also undergoes another set of reactions to produce **S**.



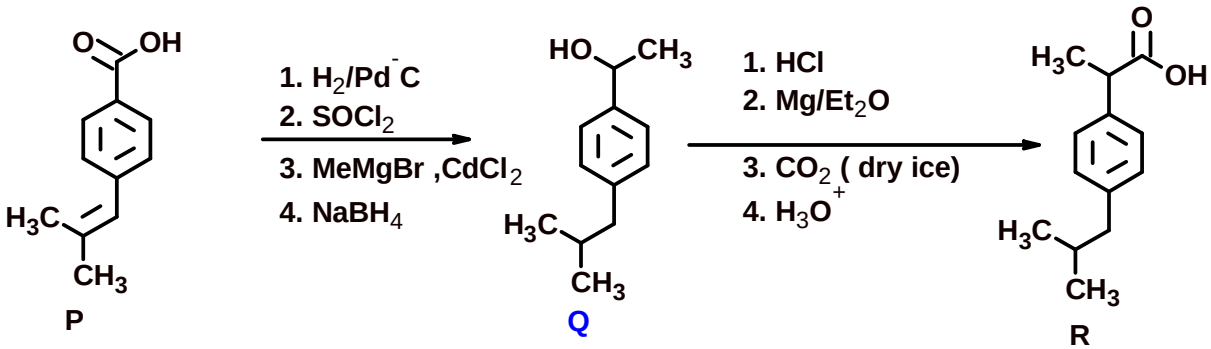
(There are two questions based on PARAGRAPH "A", the question given below is one of them)

17. The compound **R** is



Ans. **(A)**

Sol.



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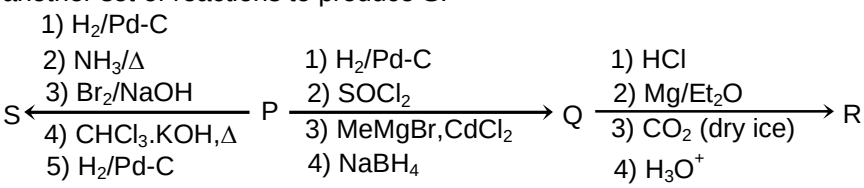
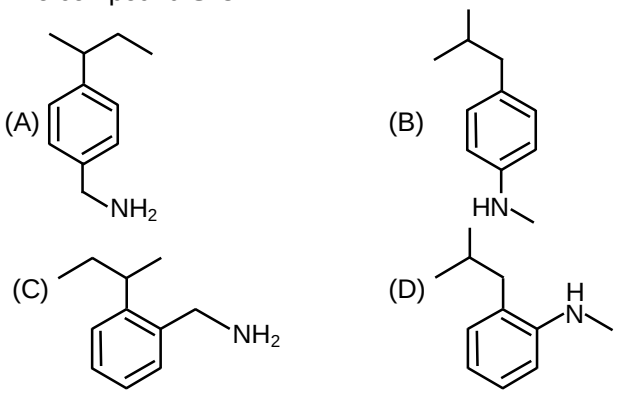


(There are two questions based on PARAGRAPH "A", the question given below is one of them)

18. The compound **S** is



Ans. **(B)**

Sol.