CY : CHEMISTRY

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Duration: Three Hours   *Maximum Marks:* 100

Read the following instructions carefully.

1. This question paper contains 24 pages including blank pages for rough work. Please check all pages and report discrepancy, if any.

2. Write your registration number, your name and name of the examination centre at the specified locations on the right half of the Optical Response Sheet (ORS).

3. Using HB pencil, darken the appropriate bubble under each digit of your registration number and the letters corresponding to your paper code.

4. All questions in this paper are of objective type.

5. Questions must be answered on the ORS by darkening the appropriate bubble (marked A, B, C, D) using HB pencil against the question number on the left hand side of the ORS. **For each question darken the bubble of the correct answer.** In case you wish to change an answer, erase the old answer completely. More than one answer bubbled against a question will be treated as an incorrect response.

6. There are a total of 65 questions carrying 100 marks.

7. Questions Q.1 – Q.25 will carry 1-mark each, and questions Q.26 – Q.55 will carry 2-marks each.

8. Questions Q.48 – Q.51 (2 pairs) are common data questions and question pairs (Q.52, Q.53) and (Q.54, Q.55) are linked answer questions. The answer to the second question of the linked answer questions depends on the answer to the first question of the pair. If the first question in the linked pair is wrongly answered or is un-attempted, then the answer to the second question in the pair will not be evaluated.

9. Questions Q.56 – Q.65 belong to General Aptitude (GA). Questions Q.56 – Q.60 will carry 1-mark each, and questions Q.61 – Q.65 will carry 2-marks each. The GA questions will begin on a fresh page starting from page 15.

10. Un-attempted questions will carry zero marks.

11. Wrong answers will carry **NEGATIVE** marks. For Q.1 – Q.25 and Q.56 – Q.60, ⅓ mark will be deducted for each wrong answer. For Q.26 – Q.51 and Q.61 – Q.65, ⅔ mark will be deducted for each wrong answer. The question pairs (Q.52, Q.53), and (Q.54, Q.55) are questions with linked answers. There will be negative marks only for wrong answer to the first question of the linked answer question pair i.e. for Q.52 and Q.54, ⅔ mark will be deducted for each wrong answer. There is no negative marking for Q.53 and Q.55.

12. Calculator (without data connectivity) is allowed in the examination hall.

13. Charts, graph sheets or tables are NOT allowed in the examination hall.

14. Rough work can be done on the question paper itself. Additionally, blank pages are provided at the end of the question paper for rough work.

Some Useful Data

1. Physical Constants

(a) Planck Constant, $h = 6.626 \times 10^{-34}$ J s

(b) Avogadro number, $N = 6.023 \times 10^{23}$

(c) Speed of light, $c = 3 \times 10^8$ m s^{-1}

(d) Gas constant, $R = 8.314$ J K^{-1} mole^{-1} = 2 cal K^{-1} mole^{-1}

2. Atomic Numbers

B	5	Mn	25
Mg	12	Fe	26
P	15	Co	27
As	33	Cu	29
Sb	51	Zn	30
Bi	83	Mo	42
Ca	20		

Q.1 – Q.25 carry one mark each.

Q.1 The Lewis acidity of BF_3 is less than BCl_3 even though fluorine is more electronegative than chlorine. It is due to

(A) stronger 2p(B)-2p(F) σ-bonding   (B) stronger 2p(B)-2p(F) π-bonding
(C) stronger 2p(B)-3p(Cl) σ-bonding   (D) stronger 2p(B)-3p(Cl) π-bonding

Q.2 Pyroxenes are a class of silicate minerals, which exhibit a polymeric chain structure, as shown below.


• = Silicon   O = Oxygen
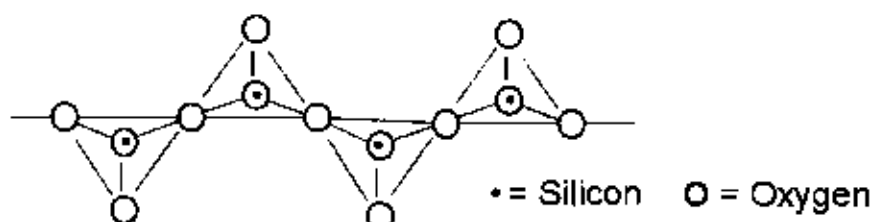
Its simplest repeat unit is

(A) $[SiO_4]^{4-}$ (B) $[SiO_3]^{2-}$ (C) $[Si_2O_7]^{6-}$ (D) $[Si_4O_{11}]^{6-}$

Q.3 Among the following pentachlorides the one which does not exist due to the 'inert-pair effect' is

(A) PCl_5 (B) $BiCl_5$ (C) $SbCl_5$ (D) $AsCl_5$

Q.4 Band theory predicts that magnesium is an insulator. However, in practice it acts as a conductor due to

(A) presence of filled 3s orbital   (B) overlap of filled 2p and filled 3s orbital
(C) overlap of filled 3s and empty 3p orbital   (D) presence of unfilled 3p orbital

Q.5 The number of 'framework electron pairs' present in the borane cluster $[B_{12}H_{12}]^{2-}$ is

(A) 10   (B) 11   (C) 12   (D) 13

Q.6 The reaction between $[PdCl_4]^{2-}$ and C_2H_4 produces a new compound. Compared to free C_2H_4, the C-C bond order of the product is

(A) between 1 and 2   (B) less than 1
(C) unaltered   (D) greater than 2

Q.7 Among the following pair of metal ions present in Nature, the first one functions as an electron-transfer agent and the second one catalyzes the hydrolysis reactions. The correct pair is

(A) Fe and Zn   (B) Mg and Fe
(C) Co and Mo   (D) Ca and Cu

Q.8 Structurally nickellocene is similar to ferrocene. Nickellocene attains stability due to the formation of

(A) a monocation   (B) a dication
(C) a monoanion   (D) a dianion

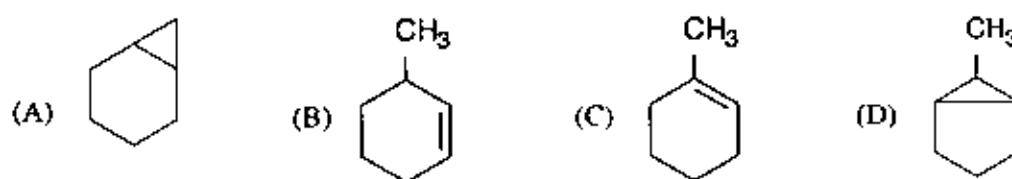Q.9   The absolute configurations for compounds X and Y, respectively, are
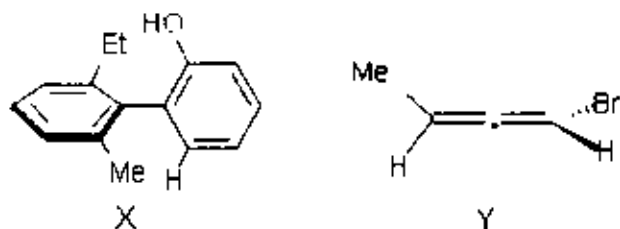
(A) R, S   (B) S, R   (C) R, R   (D) S, S
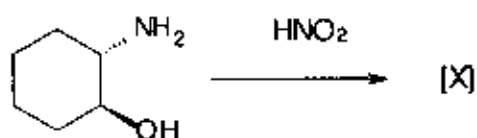
Q.10   In the reaction

the major product [X] is

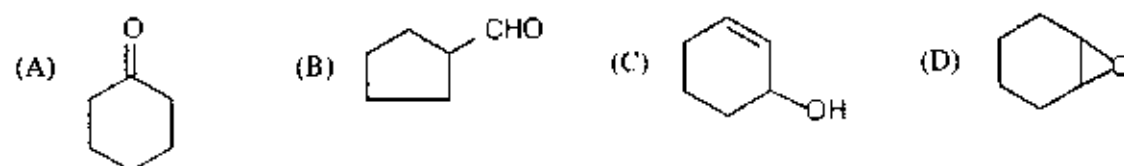(A)   (B)   (C)   (D)
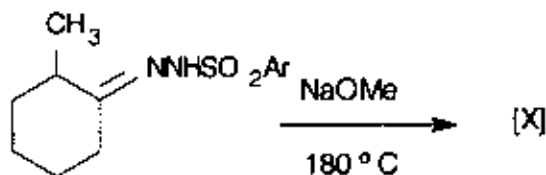
Q.11   Among the following, a pair of resolvable configurational enantiomers is given by

(A) cis-1,2-dimethylcyclohexane   (B) cis-1,3-dimethylcyclohexane
(C) cis-1,4-dimethylcyclohexane   (D) trans-1,3-dimethylcyclohexane

Q.12   In the reaction

the major product [X] is

(A)   (B)   (C)   (D)

Q.13   The decreasing order of isoelectric point for the following α-amino acids is

         Lysine   Alanine   Glutamic acid
           (I)   (II)   (III)

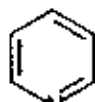   (A) I > II > III   (B) II > I > III
         (C) III > I > II   (D) I > III > II

Q.14   The decreasing order of the reactivity of the following compounds towards electrophiles is
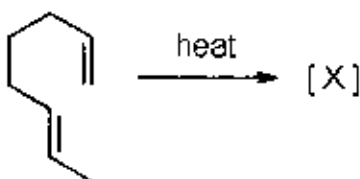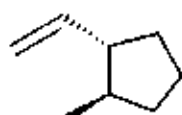
         I   II   III

         (A) II > I > III   (B) II > III > I
         (C) III > I > II   (D) I > II > III
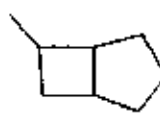
Q.15   In the reaction

         heat
         ────────▶ [X]

         the major product [X] is
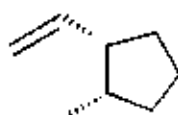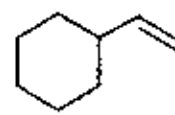
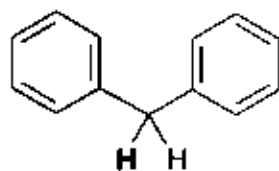   (A)   (B)   (C)   (D)
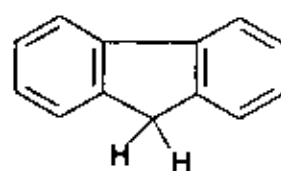
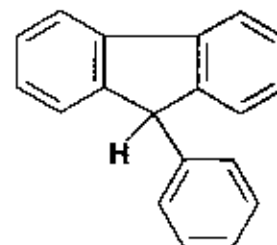Q.16   The decreasing order of acidity of the marked H of the following molecules is

         H H   H   H   H

         I   II   III
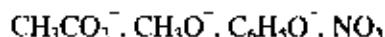
         (A) I > II > III   (B) III > I > II
         (C) III > II > I   (D) II > I > III

Q.17 The decreasing order of nucleophilicity for the following anions is

$$CH_3CO_2^-, CH_3O^-, C_6H_5O^-, NO_3^-$$

(A) $CH_3CO_2^- > CH_3O^- > C_6H_5O^- > NO_3^-$ (B) $CH_3O^- > NO_3^- > C_6H_5O^- > CH_3CO_2^-$
(C) $CH_3O^- > C_6H_5O^- > CH_3CO_2^- > NO_3^-$ (D) $C_6H_5O^- > CH_3O^- > NO_3^- > CH_3CO_2^-$

Q.18 The molar entropy of crystalline CO at absolute zero is

(A) Zero   (B) $-R\ln 2$ (C) $R\ln 2$ (D) $2R\ln 2$

Q.19 For an ideal gas

(A) $(\partial P/\partial T)_V (\partial T/\partial V)_P (\partial V/\partial P)_T = 0$
(B) $(\partial P/\partial T)_V (\partial T/\partial V)_P (\partial V/\partial P)_T = -1$
(C) $(\partial P/\partial T)_V (\partial T/\partial V)_P (\partial V/\partial P)_T = +1$
(D) $(\partial P/\partial T)_V (\partial T/\partial V)_P (\partial V/\partial P)_T = +2$

Q.20 Among W (work), Q (heat), U (internal energy) and S (entropy)

(A) W and U are path functions but Q and S are state functions
(B) W and S are path functions but Q and U are state functions
(C) S and U are path functions but Q and W are state functions
(D) W and Q are path functions but U and S are state functions

Q.21 For eigen functions $\psi_1 = \sqrt{\dfrac{1}{b}}\sin\left(\dfrac{\pi x}{b}\right)$ and $\psi_2 = \sqrt{\dfrac{2}{b}}\sin\left(\dfrac{2\pi x}{b}\right)$ of particle in a 1-D box of length $b(0 \leq x \leq b)$

(A) ψ_1 is normalized and orthogonal to ψ_2
(B) ψ_1 is normalized but not orthogonal to ψ_2
(C) ψ_2 is normalized and orthogonal to ψ_1
(D) ψ_2 is neither normalized nor orthogonal to ψ_1

Q.22 The bond order of C_2 molecule is

(A) 0   (B) 1   (C) 2   (D) 3

Q.23 Sulfur can exist in four phases. The possible number of triple points is

(A) 1   (B) 2   (C) 3   (D) 4

Q.24 The standard reduction potentials at 298 K for single electrodes are given below:

Electrode	Electrode Potential (volt)
Mg^{2+}/Mg	-2.34
Zn^{+2}/Zn	-0.76
Fe^{+2}/Fe	-0.44

From this we can infer that

(A) Zn can reduce both Mg^{2+} and Fe^{2+}
(B) Fe can reduce both Mg^{2+} and Zn^{2+}
(C) Mg can reduce both Zn^{2+} and Fe^{2+}
(D) Mg can reduce Zn^{2+} but not Fe^{2+}

Q.25   For the pair of reactions given below

    i) $N_2(g) + 3H_2(g) \rightleftharpoons 2NH_3(g)$

    ii) $\frac{1}{2}N_2(g) + \frac{3}{2}H_2(g) \rightleftharpoons NH_3(g)$
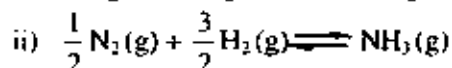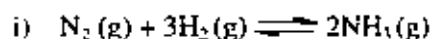
if at a particular temperature, K_{P1} and K_{P2} are the equilibrium constants for reactions i) and ii) respectively then,

(A) $K_{P1} = 2K_{P2}$ (B) $K_{P1} = K_{P2}^2$

(C) $2K_{P1} = K_{P2}$ (D) $K_{P1}^2 = K_{P2}$

Q.26 – Q.55 carry two marks each.

Q.26   According to VSEPR model, the shape of $[XeOF_5]^-$ is

(A) octahedral   (B) trigonal bipyramidal
(C) square pyramidal   (D) pentagonal monopyramidal

Q.27   The number of unpaired electron(s) present in the species $[Fe(H_2O)_5(NO)]^{2+}$ which is formed during 'brown ring test' is

(A) 2   (B) 3   (C) 4   (D) 5

Q.28 Fe_3O_4 and Co_3O_4 are metal oxides having spinel structure. Considering their CFSEs, the correct statement regarding their structure is

(A) both have normal spinel structure
(B) both have inverse spinel structure
(C) Fe_3O_4 has normal and Co_3O_4 has inverse spinel structure
(D) Fe_3O_4 has inverse and Co_3O_4 has normal spinel structure

Q.29   The mechanism of the reaction between $[Fe(CN)_6]^{4-}$ and $[Fe(bpy)_3]^{3+}$ (bpy = 2,2'-bipyridine) is

(A) outer-sphere electron-transfer
(B) inner-sphere electron-transfer
(C) self-exchange reaction
(D) ligand-exchange followed by electron-transfer

Q.30   The d-d absorption band of $[Fe(H_2O)_6]^{2+}$ is split due to

(A) presence of octahedral geometry
(B) static Jahn-Teller distortion
(C) dynamic Jahn-Teller distortion
(D) presence of trigonal bipyramidal geometry

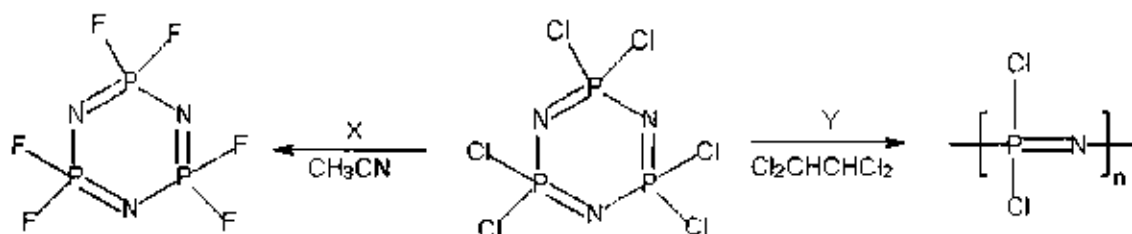Q.31   The crystal-field symbol for the ground-state of $[Mn(CN)_6]^{4-}$ is

(A) $^2T_{2g}$ (B) $^1A_{1g}$ (C) ^5E_g (D) $^6A_{1g}$

Q.32   In the following reactions:

the reagent/conditions **X** and **Y** are

(A) X = BF$_3$; Y = heating at 1250°C   (B) X = NaF; Y = heating at 250°C
(C) X = NH$_4$F; Y = HCl   (D) X = CF$_3$SO$_3$H; Y = H$_2$SO$_4$

Q.33   [CoCl$_4$]$^{2-}$ is a blue coloured complex. Controlled-treatment of this complex with water generates two isomeric light pink coloured complexes of composition [Co(H$_2$O)$_4$Cl$_2$].
Identify the correct point groups for [CoCl$_4$]$^{2-}$ and two isomeric complexes [Co(H$_2$O)$_4$Cl$_2$].

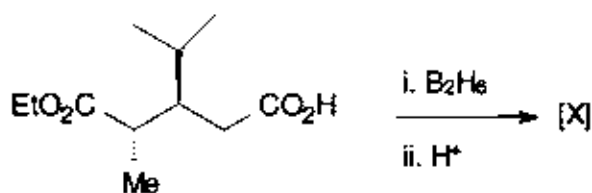(A) D$_{4h}$ and (C$_{2v}$ and C$_{2h}$)   (B) T$_d$ and (C$_{2v}$ and D$_{4h}$)
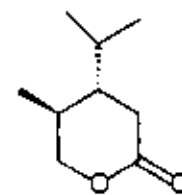(C) D$_{4h}$ and (C$_{2v}$ and D$_{4h}$)   (D) T$_d$ and (C$_{2v}$ and C$_{4v}$)

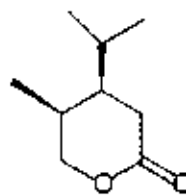Q.34   In the reaction
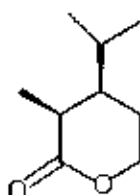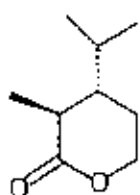

the major product [X] is

(A)   (B)   (C)   (D)

Q.35   In the reaction

the major product [X] is

(A)   (B)   (C)   (D)

Q.36   In the following reaction sequence

i. NOCl/Py
ii. light
iii. hydrolysis
→ [X]

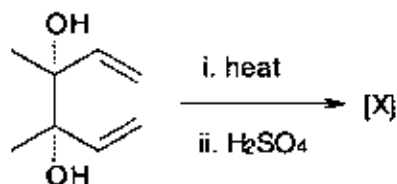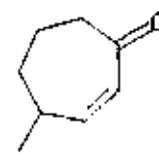the major product [X] is

(A)   (B)   (C)   (D)

Q.37   In the reactions

[Y] ← HNO₃   —   mCPBA → [X]

the major products, [X] and [Y], respectively, are

(A)   (B)

and   and

(C)   (D)

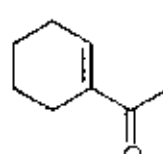and   and

Q.38   In the reaction

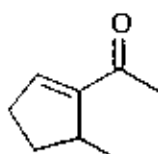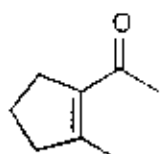
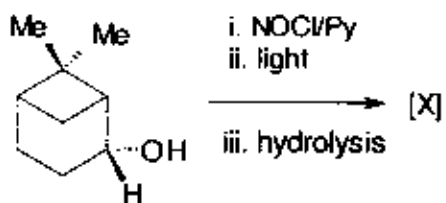the major product [X] is

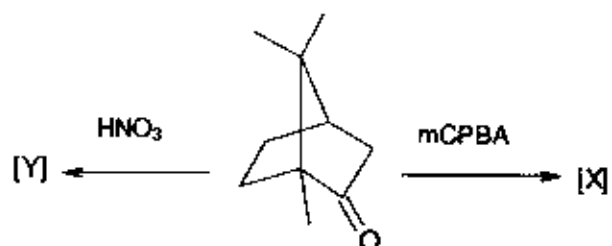(A)   (B)   (C)   (D)

Q.39   In the reaction sequence

the major products. [X] and [Y]. respectively. are

(A)   (B)

(C)   (D)
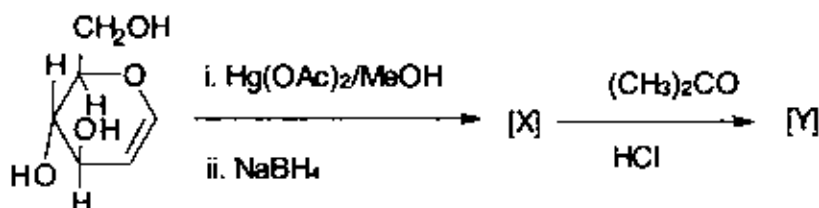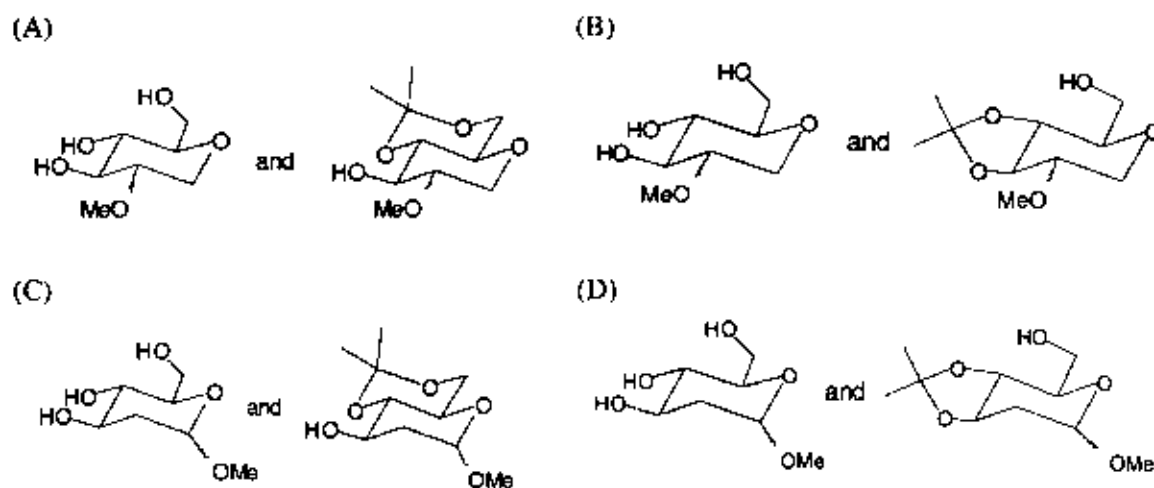
Q.40   The change in entropy when two moles of Argon gas are heated at constant volume from 300 K to
       500 K is

(A) −12.74 J K^{-1} mole^{-1} (B) −6.37 J K^{-1} mole^{-1}
(C) 6.37 J K^{-1} mole^{-1} (D) 12.74 J K^{-1} mole^{-1}

Q.41 At any temperature T, the fugacity coefficient (γ) is given by

$$\ln \gamma = \int_0^P \frac{Z-1}{P'} dP'$$

where Z is the compressibility factor. The fugacity coefficient of a real gas governed by equation of state $P(V-b) = RT$ with b a constant is given by

(A) $\frac{RT}{bP}$ (B) $e^{\frac{RT}{bP}}$ (C) $\frac{bP}{RT}$ (D) $e^{\frac{bP}{RT}}$

Q.42 The specific rate constant of decomposition of a compound is represented by

$$\ln k = 5.0 - \frac{12000}{T}$$

The activation energy of decomposition for this compound at 300 K is

(A) 24 kcal/mole   (B) 12 kcal/mole   (C) 24 cal/mole   (D) 12 cal/mole

Q.43 The commutator $[x^3, p_x]$ is equal to

(A) $-\frac{3hx^2}{2\pi i}$ (B) $\frac{hx}{2\pi i}$ (C) $\frac{hx^2}{2\pi i}$ (D) $\frac{3hx^2}{2\pi i}$

Q.44 An electron of mass 'm' is confined to a one dimensional box of length 'b'. If it makes a radiative transition from second excited state to the ground state. the frequency of the photon emitted is

(A) $\frac{9h}{8mb^2}$ (B) $\frac{3h}{8mb^2}$ (C) $\frac{h}{mb^2}$ (D) $\frac{2h}{mb^2}$

Q.45 The point group of ClF_3 molecule and its corresponding number of irreducible representations are respectively

(A) C_{3v} and 4   (B) C_{2v} and 4   (C) C_{3v} and 3   (D) C_{2v} and 3

Q.46 The most populated rotational state for HCl (B = 8.5 cm^{-1}) at 300 K is

(A) 2   (B) 3   (C) 5   (D) 7

Q.47 The ratio of life times of two states that give rise to line widths of 1.0 cm^{-1} and 0.2 cm^{-1} respectively is

(A) 1 : 2   (B) 1 : 5   (C) 2 : 1   (D) 5 : 1

Common Data Questions

Common Data for Questions 48 and 49:

A six-coordinate transition-metal complex is ESR and Mössbauer active. The effective magnetic moment of this complex is ~5.9 B.M.

Q.48 The metal-ion along with its oxidation state and the number of unpaired electron present are

(A) Fe(II) and 4   (B) Mn(II) and 5
(C) Fe(III) and 1   (D) Fe(III) and 5

Q.49 The complex is

(A) $[Mn(H_2O)_6]^{2+}$
(B) $[Fe(CN)_6]^{3-}$
(C) $[Fe(H_2O)_6]^{2+}$
(D) $[Fe(H_2O)_6]^{3+}$

Common Data for Questions 50 and 51:

An organic compound [X] ($C_{12}H_{16}O_3$) exhibits the following spectral data
IR: ~1720 cm^{-1}
^{1}H NMR: 2.35 (s, 6H), 3.30 (s, 3H), 3.83 (t, 2H), 4.42 (t, 2H), 7.07 (s, 1H), 7.58 (s, 2H)
The compound [X] with an excess of MeMgBr gives a 1:1 mixture of compounds [Y] and [Z]. The compound [Z] exhibits the following ^{1}H NMR data: 2.0 (bs, 1H), 3.30 (s, 3H), 3.56 (t, 2H), 3.70 (t, 2H)

Q.50   The compound [X] is

(A)

(B)

(C)

(D)
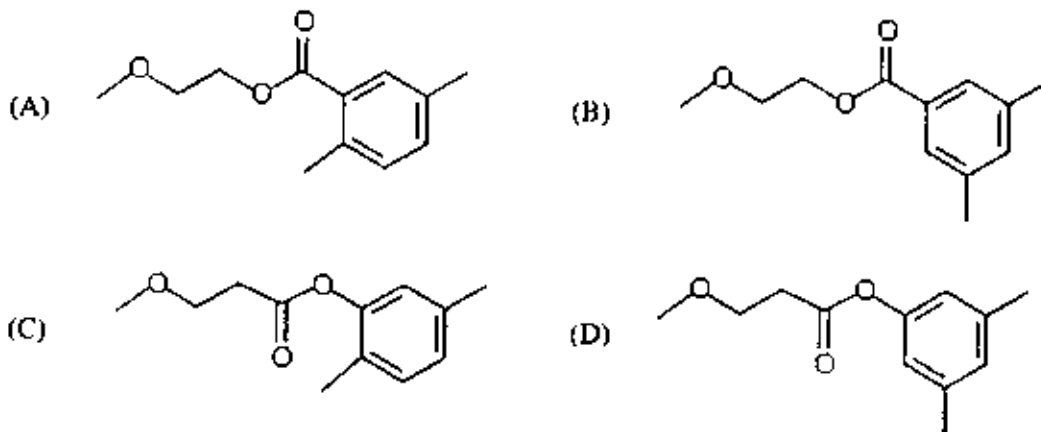
Q.51   The compound [Y] is

(A)

(B)

(C)

(D)

Linked Answer Questions

Statement for Linked Questions 52 and 53:

In the reaction sequence

Ph
\\
  CHO —MeMgBr→ [X] (major) + [Y] (minor)
/   H₃O⁺
H₃C `H

[X] —i. TsCl/Py / ii. NaOEt/EtOH→ [Z]

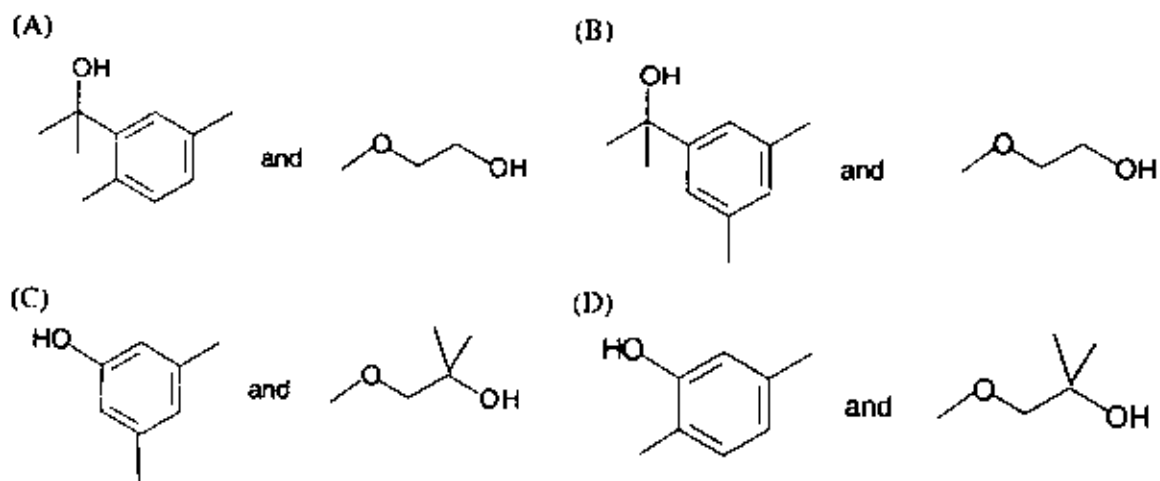Q.52   The compound [X] is

(A)

Ph
H —┼— CH₃
H₃C —┼— H
OH

(B)

Ph
H₃C —┼— H
H —┼— CH₃
OH

(C)

Ph
H₃C —┼— H
H₃C —┼--- H
OH

(D)

CH₃
Ph —┼— H
HO —┼— H
CH₃

Q.53   The compound [Z] is

(A)

Me
      `H
Me
      Ph
EtO `H

(B)

Me
      `H
EtO
      Ph
Me `H

(C)

Me
      — Ph
Me —
      H

(D)

Ph
      — Me
Me —
      H
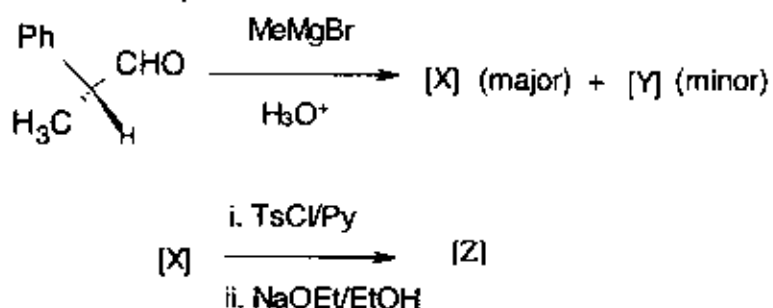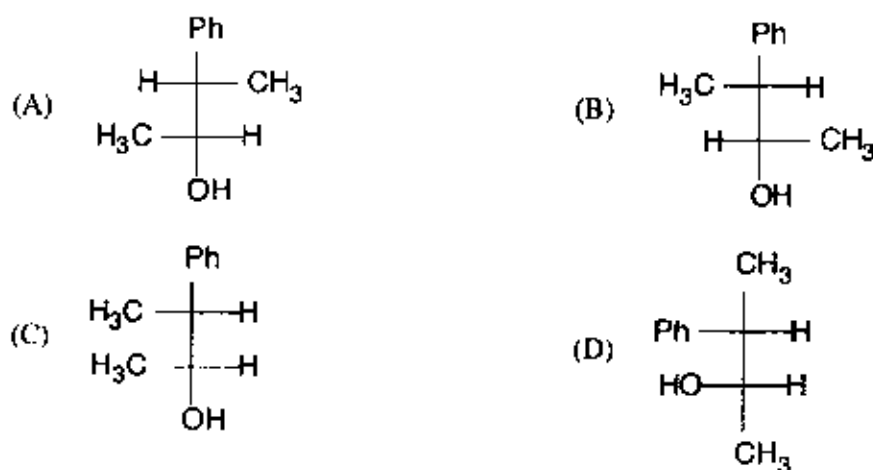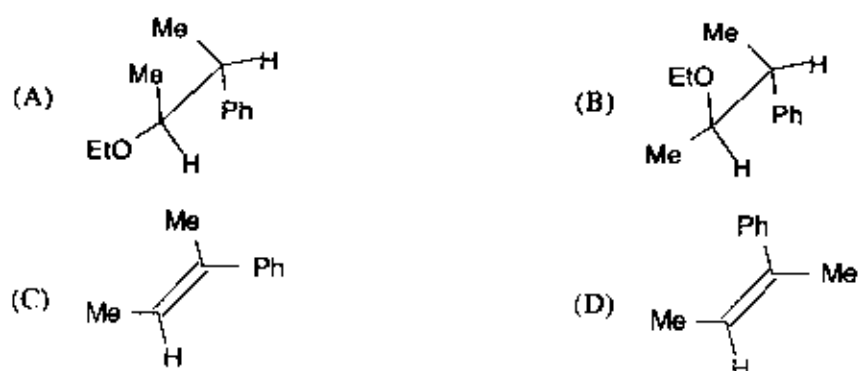
Statement for Linked Questions 54 and 55:

In the μ vs. T diagram for different phases of the same substance at one atmospheric pressure, the lines A. B and C compound to

Q.54   Based on the above diagram:

(A) A represents the change in chemical potential as a function of temperature for the solid phase. B for the liquid and C for the gas

(B) A represents the change in chemical potential as a function of temperature for the liquid phase, B for the gas and C for the solid
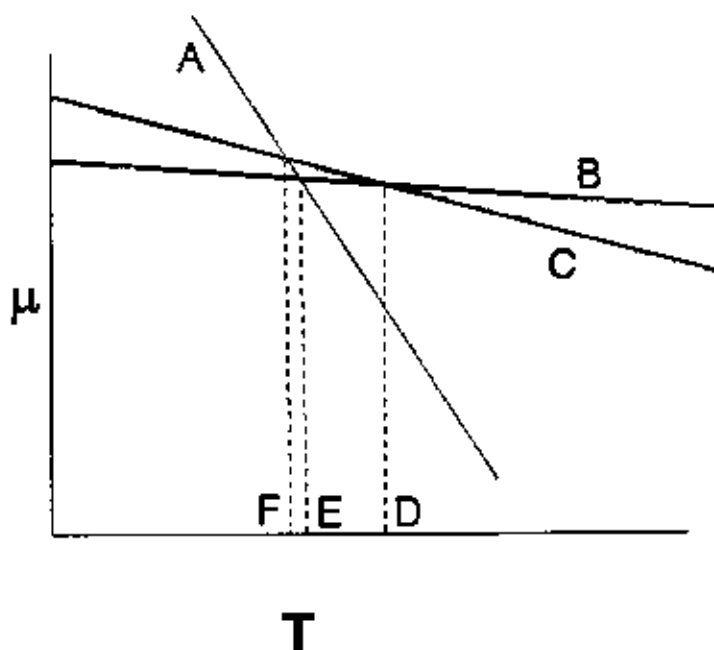
(C) A represents the change in chemical potential as a function of temperature for the gas phase. B for the liquid and C for the solid

(D) A represents the change in chemical potential as a function of temperature for the gas phase, B for solid and C for the liquid

Q.55   From the same diagram

(A) D represents boiling point. E sublimation point and F melting point

(B) E represents boiling point. D sublimation point and F melting point

(C) E represents melting point. F sublimation point and D boiling point

(D) D represents melting point, F boiling point and E sublimation point

General Aptitude (GA) Questions

Q.56 – Q.60 carry one mark each.

Q.56 25 persons are in a room. 15 of them play hockey. 17 of them play football and 10 of them play both hockey and football. Then the number of persons playing neither hockey nor football is:

(A) 2   (B) 17   (C) 13   (D) 3

Q.57 *Choose the most appropriate word from the options given below to complete the following sentence:*
If we manage to _____ our natural resources, we would leave a better planet for our children.

(A) uphold
(B) restrain
(C) cherish
(D) conserve

Q.58 *The question below consists of a pair of related words followed by four pairs of words. Select the pair that best expresses the relation in the original pair.*
Unemployed : Worker

(A) fallow : land
(B) unaware : sleeper
(C) wit : jester
(D) renovated : house

Q.59 *Which of the following options is the closest in meaning to the word below:*
Circuitous

(A) cyclic
(B) indirect
(C) confusing
(D) crooked

Q.60 *Choose the most appropriate word from the options given below to complete the following sentence:*
His rather casual remarks on politics _____ his lack of seriousness about the subject.

(A) masked
(B) belied
(C) betrayed
(D) suppressed

Q.61 – Q.65 carry two marks each.

Q.61 Hari (H), Gita (G), Irfan (I) and Saira (S) are siblings (i.e. brothers and sisters). All were born on 1st January. The age difference between any two successive siblings (that is born one after another) is less than 3 years. Given the following facts:

     i. Hari's age + Gita's age > Irfan's age + Saira's age.
     ii. The age difference between Gita and Saira is 1 year. However, Gita is not the oldest and Saira is not the youngest.
     iii. There are no twins.

In what order were they born (oldest first)?

(A) HSIG   (B) SGHI   (C) IGSH   (D) IHSG

Q.62 5 skilled workers can build a wall in 20 days; 8 semi-skilled workers can build a wall in 25 days; 10 unskilled workers can build a wall in 30 days. If a team has 2 skilled, 6 semi-skilled and 5 unskilled workers, how long will it take to build the wall?

(A) 20 days   (B) 18 days   (C) 16 days   (D) 15 days

Q.63 **Modern warfare has changed from large scale clashes of armies to suppression of civilian populations. Chemical agents that do their work silently appear to be suited to such warfare; and regretfully, there exist people in military establishments who think that chemical agents are useful tools for their cause.**

Which of the following statements best sums up the meaning of the above passage:

(A) Modern warfare has resulted in civil strife.
(B) Chemical agents are useful in modern warfare.
(C) Use of chemical agents in warfare would be undesirable.
(D) People in military establishments like to use chemical agents in war.

Q.64 Given digits 2, 2, 3, 3, 3, 4, 4, 4, 4 how many distinct 4 digit numbers greater than 3000 can be formed?

(A) 50   (B) 51   (C) 52   (D) 54

Q.65 If 137 + 276 = 435 how much is 731 + 672?

(A) 534   (B) 1403   (C) 1623   (D) 1513

END OF THE QUESTION PAPER

Space for Rough Work

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