Paper Specific Instructions

1. The examination is of 3 hours duration. There are a total of 60 questions carrying 100 marks. The entire paper is divided into three sections, **A**, **B** and **C**. All sections are compulsory. Questions in each section are of different types.

2. **Section A** contains a total of 30 **Multiple Choice Questions (MCQ).** Each MCQ type question has four choices out of which only **one** choice is the correct answer. Questions Q.1 – Q.30 belong to this section and carry a total of 50 marks. Q.1 – Q.10 carry 1 mark each and Questions Q.11 – Q.30 carry 2 marks each.

3. **Section B** contains a total of 10 **Multiple Select Questions (MSQ).** Each MSQ type question is similar to MCQ but with a difference that there will be **more than one** choices that are correct out of the four given choices. The candidate gets full credit if he/she selects all the correct answers only and no wrong answers. Questions Q.31 – Q.40 belong to this section and carry 2 marks each with a total of 20 marks.

4. **Section C** contains a total of 20 **Numerical Answer Type (NAT)** questions. For these NAT type questions, the answer is a real number which needs to be entered using the virtual keyboard on the monitor. No choices will be shown for these type of questions. Questions Q.41 – Q.60 belong to this section and carry a total of 30 marks. Q.41 – Q.50 carry 1 mark each and Questions Q.51 – Q.60 carry 2 marks each.

5. In all sections, questions not attempted will result in zero mark. In **Section A** (MCQ), wrong answer will result in **NEGATIVE** marks. For all 1-mark questions, 1/3 marks will be deducted for each wrong answer. For all 2-mark questions, 2/3 marks will be deducted for each wrong answer. In **Section B** (MSQ), there is **NO NEGATIVE** and **NO PARTIAL** marking provisions. There is **NO NEGATIVE** marking in **Section C** (NAT) as well.

6. Only Virtual Scientific Calculator is allowed. Charts, graph sheets, tables, cellular phone or other electronic gadgets are **NOT** allowed in the examination hall.

7. A Scribble Pad will be provided for rough work.

Special Instructions / Useful Data

Section A: Q.1 – Q.10 Carry ONE mark each.

Q.1 Maximum value of the function $f(r) = r^2 e^{-r}$, when $0 < r < \infty$ is

(A) $4\,e^{-2}$

(B) e^{-1}

(C) $2\,e^{-\sqrt{2}}$

(D) $4\,e^{-\sqrt{2}}$

Q.2 Consider 10 balls each having different colors including a blue ball. If 6 balls are selected randomly, the probability of the blue ball being selected is

(A) 0.3

(B) 0.4

(C) 0.6

(D) 0.8

Q.3 Sulfide ores are concentrated by

(A) froth floatation

(B) smelting

(C) roasting

(D) reduction

Q.4 Crystal system with the unit cell parameters $a = b \neq c$ and $\alpha = \beta = \gamma = 90°$ is

(A) monoclinic

(B) orthorhombic

(C) tetragonal

(D) hexagonal

Q.5 The correct trend of acidity of the ions is

(A) $[Fe(H_2O)_6]^{2+} > [Fe(H_2O)_6]^{3+} > [Al(H_2O)_6]^{3+}$

(B) $[Al(H_2O)_6]^{3+} > [Fe(H_2O)_6]^{3+} > [Fe(H_2O)_6]^{2+}$

(C) $[Fe(H_2O)_6]^{2+} > [Al(H_2O)_6]^{3+} > [Fe(H_2O)_6]^{3+}$

(D) $[Fe(H_2O)_6]^{3+} > [Fe(H_2O)_6]^{2+} > [Al(H_2O)_6]^{3+}$

Q.6 Dissolution of SbF_5 in BrF_3 produces

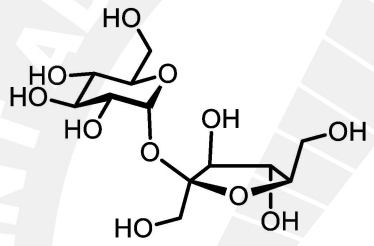
(A) BrF_5 and SbF_3

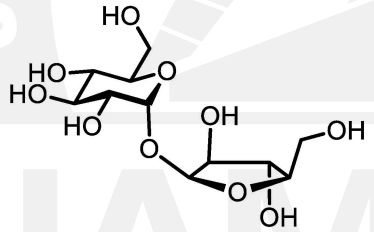
(B) BrF and SbF_7

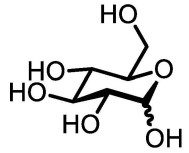
(C) $[BrF_2]^+ [SbF_6]^-$

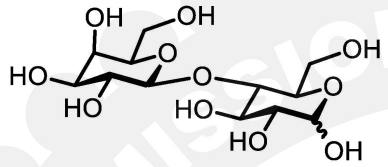
(D) $[SbF_4]^+ [BrF_4]^-$

Q.7 The molecular structure of table sugar is

(A) 

(B) 

(C) 

(D) 

Q.8 The product formed when (*R*)-2-bromopropionic acid is treated with low concentration of hydroxide ion is

(A) predominantly of *S* configuration

(B) predominantly of *R* configuration

(C) a racemic mixture

(D) achiral

Q.9 A system having Hamiltonian $\hat{H}$ follows the eigenvalue equation, $\hat{H}\,\Psi_n = E_n\,\Psi_n$, with $E_n = \left(n + \frac{1}{2}\right)$.

If the state of the system is prepared as, $\Psi = N(\Psi_1 + \Psi_2 + \Psi_3 - \Psi_4 - \Psi_5)$, where N is the normalization constant, then the expectation value of energy is

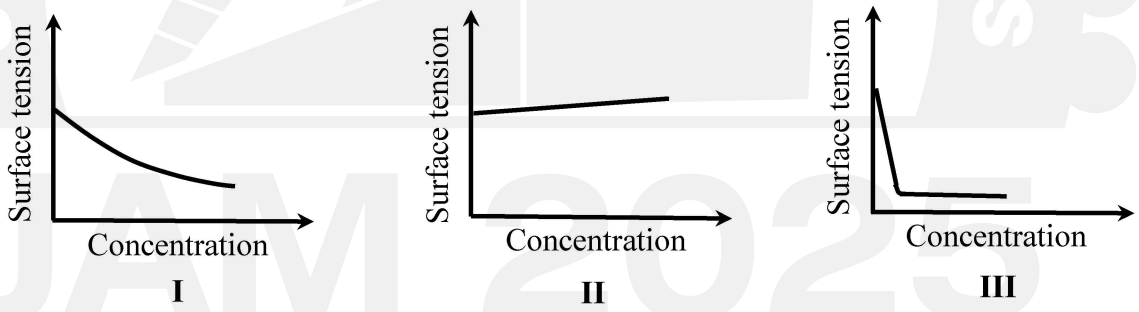
(A) – 0.5

(B) – 2.5

(C) 3.5

(D) 17.5

Q.10 The figures (**I**, **II**, **III**) given below schematically represent variation of surface tension of three different aqueous solutions with increasing concentration of each of the solutes (surfactant, sodium chloride, and n-propanol). Match the figures with appropriate solutes and choose the correct option.



(A) I – surfactant, II – sodium chloride, III – n-propanol

(B) I – sodium chloride, II – n-propanol, III – surfactant

(C) I – surfactant, II – n-propanol, III – sodium chloride

(D) I – n-propanol, II – sodium chloride, III – surfactant

Section A: Q.11 – Q.30 Carry TWO marks each.

Q.11 The correct option for x which satisfies the following equation is

$$\begin{vmatrix} x & 2 & 3 \\ 4 & x & 6 \\ x & 8 & 9 \end{vmatrix} = \begin{vmatrix} 102 & 18 & 36 \\ 1 & 3 & 4 \\ 17 & 3 & 6 \end{vmatrix}$$

(A) $3 \pm \sqrt{5}$

(B) $\dfrac{3 \pm \sqrt{5}}{2}$

(C) $2\left(3 \pm \sqrt{5}\right)$

(D) $3 \pm 2\sqrt{5}$

Q.12 The type of carboxypeptidase metalloenzyme and the metal ion present in it, respectively, are

(A) hydrolase and Zn(II)

(B) isomerase and Zn(II)

(C) hydrolase and Cu(II)

(D) isomerase and Cu(II)

Q.13 The biomolecule that does **NOT** contain iron is

(A) cytochromes

(B) hemocyanin

(C) hydrogenases

(D) hemerythrin

Q.14 Hydrolysis of P_4O_{10} produces a compound R, which on heating above 320 °C yields a compound S. The compounds R and S, respectively, are

(A) H_3PO_4 and $(HPO_3)_n$

(B) H_3PO_3 and $(HPO_3)_n$

(C) H_3PO_4 and $H_4P_2O_7$

(D) H_3PO_3 and $H_4P_2O_7$

Q.15 Ion-dipole interactions vary with distance (r) as

(A) $1/r$

(B) $1/r^2$

(C) $1/r^4$

(D) $1/r^6$

Q.16 In the following transformation, the number of α and β particles emitted, respectively, are

$$^{223}_{88}Ra \longrightarrow {}^{207}_{82}Pb$$

(A) 4, 2

(B) 4, 3

(C) 2, 4

(D) 3, 4

Q.17 Wilkinson's catalyst contains

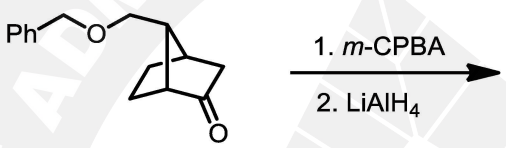
(A) ruthenium(I) in square planar geometry

(B) ruthenium(I) in tetrahedral geometry

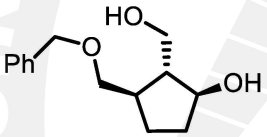
(C) rhodium(I) in square planar geometry

(D) rhodium(I) in tetrahedral geometry

Q.18 The major product of the following transformation is



(A)



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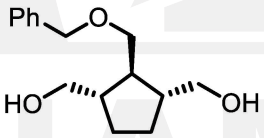

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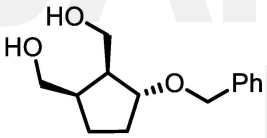

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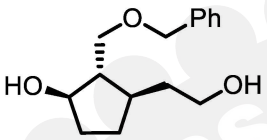
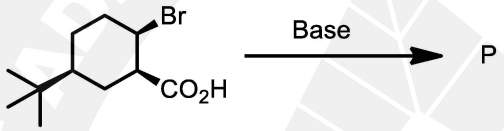
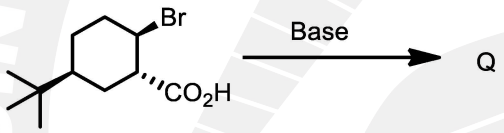
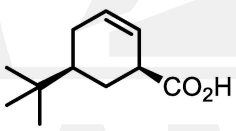
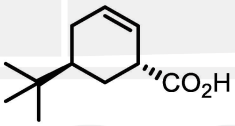
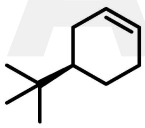
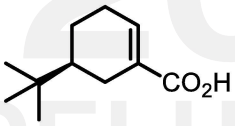


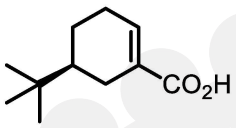
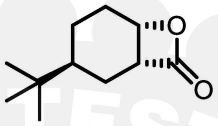
Q.19 The major products P and Q of the following transformations are

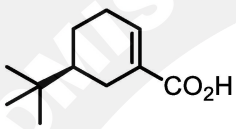
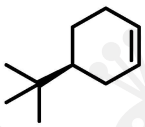




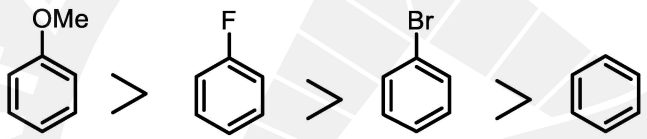
(A) P =  Q = 

(B) P =  Q = 

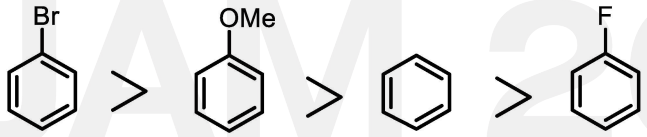
(C) P =  Q = 

(D) P =  Q = 

Q.20 The correct order of the rate of mononitration using conc. H_2SO_4 /conc. HNO_3 at room temperature is

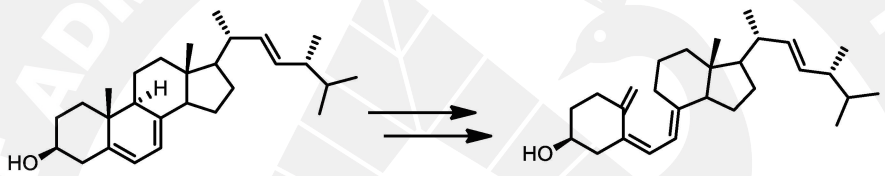
(A) 

(B) 

(C) 

(D) 

Q.21 Pericyclic reactions involved in the synthesis of Vitamin D_2 from Ergosterol are



Ergosterol Vitamin D_2

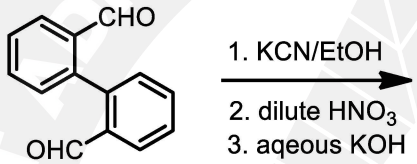
(A) 6 π electrocyclic ring opening followed by [1,7] sigmatropic shift

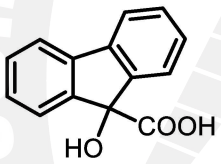
(B) [1,5] sigmatropic shift followed by 6 π electrocyclic ring opening

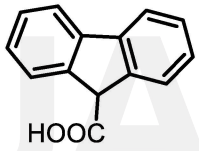
(C) [3,3] sigmatropic rearrangement followed by [1,7] sigmatropic shift

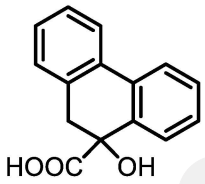
(D) 4 π electrocyclization followed by 6 π electrocyclic ring opening

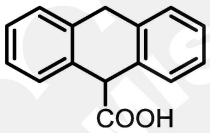
Q.22 The major product in the following reaction sequence is



(A) 

(B) 

(C) 

(D) 

Q.23 An organic compound P (C_8H_{16}) produces a *meso* compound upon oxidation with OsO_4/ NMO. The compound P is

[Where, NMO = N-methylmorpholine N-oxide]

(A) (*E*)-4-octene

(B) (*Z*)-4-octene

(C) (*E*)-3-octene

(D) (*Z*)-3-octene

Q.24 The correct order of the dipole moment among the following is

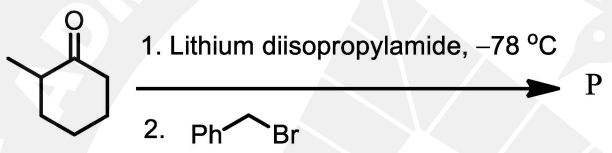
(A) fluoromethane > methanol > chloromethane > dimethylether

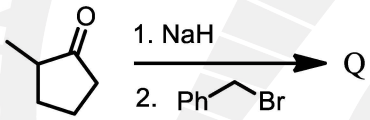
(B) fluoromethane > chloromethane > methanol > dimethylether

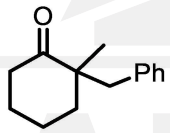
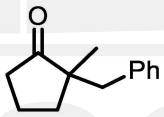
(C) chloromethane > fluoromethane > methanol > dimethylether

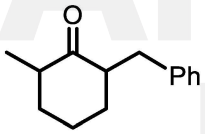
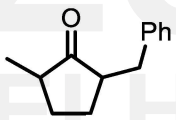
(D) chloromethane > fluoromethane > dimethylether > methanol

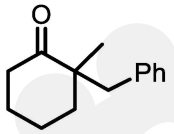
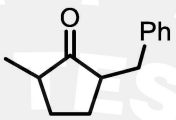
Q.25 The major products P and Q of the following reactions are

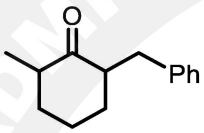
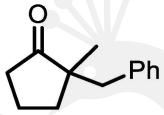




(A) P =  and Q = 

(B) P =  and Q = 

(C) P =  and Q = 

(D) P =  and Q = 

Q.26 A vessel contains 1 mol of gas A and 2 mol of gas B at 2 bar and 25 °C. The gas mixture is compressed such that the final pressure becomes 3 bar without any change in temperature. Considering ideal gas behaviour, the change in Gibbs free energy (in kJ) during the compression is closest to

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

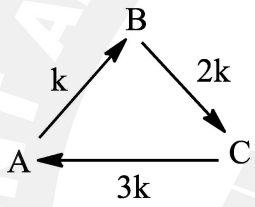
(A) 1

(B) 3

(C) 6

(D) 9

Q.27 The substances, A, B and C undergo chemical reactions according to the scheme given below.



At time t = 0, the [A] = 0.11 M. Considering them to be first order reactions, the concentration of B (in M) at equilibrium is

(A) 0.06

(B) 0.03

(C) 0.02

(D) 0.05

Q.28 For van der Waals gases, at the critical point, $\frac{dP}{dV_m} = 0$ and

(A) $\frac{d^2P}{dV_m^2} = 0$

(B) $\frac{d^2P}{dV_m^2} < 0$

(C) $\frac{d^2P}{dV_m^2} > 0$

(D) $\frac{d^2P}{dV_m^2}$ diverges

Q.29 The set of asymmetric top molecules is

(A) CH_3CN, CH_3OH, H_2CO

(B) H_2CO, H_2O, CH_3CN

(C) H_2O, CH_3CN, CH_3OH

(D) CH_3OH, H_2O, H_2CO

Q.30 Consider Langmuir adsorption of a gas on a uniform solid surface having N number of surface sites. The free and adsorbed gas molecules are in dynamic equilibrium. If the fractional surface coverage is θ, the rate of adsorption of the gas is proportional to

(A) $N\theta$

(B) $N(1-\theta)$

(C) $N\left(\frac{\theta}{1-\theta}\right)$

(D) $N\left(\frac{1}{1-\theta}\right)$

Section B: Q.31 – Q.40 Carry TWO marks each.

Q.31 According to VSEPR theory, the set(s) of species having trigonal bipyramidal geometry is(are)

(A) PCl_5 and SF_4

(B) ClF_3 and I_3^-

(C) PCl_5 and $Sb(Ph)_5$

(D) ClF_3 and BrF_5

Q.32 In alkaline medium, which of the following metal ion(s) form(s) red precipitate/coloration with dimethylglyoxime?

(A) Ni(II)

(B) Bi(III)

(C) Zn(II)

(D) Fe(II)

Q.33 The correct statement(s) about the octahedral Mn-complex with spin only magnetic moment of approximately 6.0 μ_B is(are)

(A) possible oxidation state of Mn in the complex is +4

(B) possible oxidation state of Mn in the complex is +2

(C) ligands associated with the complex is strong field ligand

(D) ligands associated with the complex is weak field ligand

Q.34 For $[Mn(CO)_6]^+$ and $[V(CO)_6]^-$ complexes, the correct statement(s) is(are)

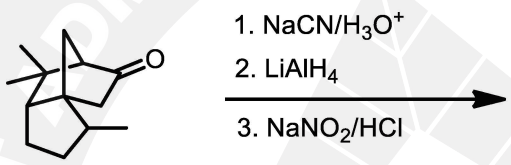
(A) stretching frequency of the CO is higher in the Mn-complex

(B) metal-carbonyl bond is stronger in the V-complex

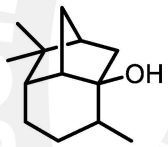
(C) Mn-complex does not obey $18e^-$ rule

(D) V-complex obeys $18e^-$ rule

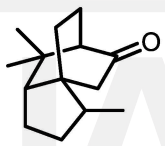
Q.35 The product(s) in the following transformation is(are)



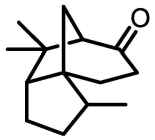
(A)



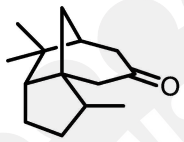
(B)



(C)



(D)



Q.36 The set(s), in which all the compounds yield *achiral* products upon treatment with CH_3MgBr/ether followed by hydrolysis with dilute mineral acid, is(are)

(A) 3,4-epoxyhexane, cyclohexanone and butanone

(B) ethyl propionate, phenylacetyl chloride and cyclohexanone

(C) butanone, ethyl propionate and cyclohexanone

(D) ethyl phenyl ketone, 3,4-epoxyhexane, and phenylacetyl chloride

Q.37 The reaction(s) that will yield cyclic product is(are)

(A) (*E*)-2-hexene with CH_2I_2/Zn-Cu

(B) 2-butanone with ethyl 2-chloropropionate with NaOEt/EtOH

(C) hexane-2,5-dione with ammonia

(D) cyclohexane-1,2-diol with $NaIO_4$

Q.38 The correct statement(s) among the following is(are)

(A) In natural nucleic acids, the nucleosides are linked through phosphodiester bonds

(B) Natural nucleic acids have sulphur containing heterocyclic bases

(C) The isoelectric point of arginine is higher than that of isoleucine

(D) The molecular weight of guanine is higher than that of cytosine

Q.39 Among the following, the correct condition(s) for spontaneity is(are)

(A) $\left(\Delta G_{sys}\right)_{P,T} < 0$

(B) $\left(\Delta A_{sys}\right)_{V,T} < 0$

(C) $\left(\Delta H_{sys}\right)_{P,S} < 0$

(D) $\left(\Delta U_{sys}\right)_{V,P} < 0$

Q.40 Correct statement(s) with respect to defects in solids is(are)

(A) In Schottky defect, atoms move from interior lattice sites to surface lattice sites

(B) Equilibrium concentration of defects remain unchanged with change in temperature

(C) A perfect solid is thermodynamically less stable than the solid with defects

(D) Common point defects in pure alkali halides are Frenkel-type

Section C: Q.41 – Q.50 Carry ONE mark each.

Q.41 $\int_0^\infty x\, e^{-x} dx =$ _____.

(round off to the nearest integer)

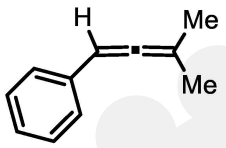
Q.42 Consider $\vec{C} = \vec{A} \times \vec{B}$, where $\vec{A} = 3\hat{\imath} - 2\hat{\jmath} + 5\hat{k}$ and $\vec{B}$, a unit vector in xy-plane, makes an angle of 37° with the x-axis. Projection of $\vec{C}$ on the x-axis is _____.

(round off to one decimal place)

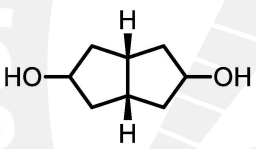
Q.43 A yellow compound X is produced after the reaction of $K_2[Ni(CN)_4]$ with excess of K/liq. NH_3 at –33 °C. The oxidation state of Ni in the compound X is_____.

Q.44 Number of spin allowed transition(s) possible for d^2 octahedral configuration is_____.

Q.45 Number of ^1H NMR signals observed for the following compound is_____.



Q.46 The number of stereoisomers possible for the following compound is_____.



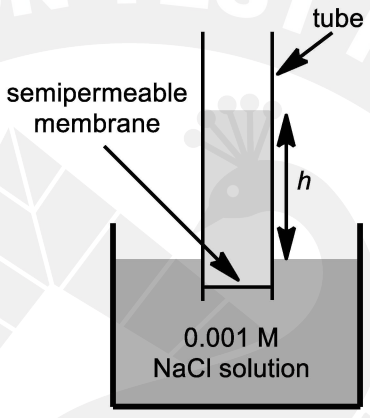
Q.47 An electron at rest is accelerated through 10 kV potential. The de Broglie wavelength (in Å) of the electron is_____.

(round off to three decimal places)

[Given: Mass of an electron, $m_e = 9.11 \times 10^{-31}$ kg;
Planck's constant (h) = 6.63×10^{-34} J s; 1 eV = 1.6×10^{-19} J]

Q.48 A tube fitted with a semipermeable membrane is dipped into 0.001 M NaCl solution at 300 K as shown in the figure. Assume density of the solvent and solution are same. At equilibrium, the height of the liquid column, h (in cm) is_____.

(round off to one decimal place)



[Given: Acceleration due to gravity, g = 9.8 m s^{-2},
density of solution (ρ) = 1 kg dm^{-3}, gas constant, R = 8.314 J mol^{-1} K^{-1}]

Q.49 The resonance frequency of ^{1}H nuclei is 300 MHz in an NMR spectrometer. If the spectrometer is operated at 12 T magnetic field, the resonance frequency (in MHz) of the same ^{1}H nuclei is_____.

(round off to one decimal place)

[Given: Nuclear magneton (β_N) = 5.05×10^{-27} J T^{-1}, Nuclear g-factor (g_N) for ^{1}H = 5.586, Planck's constant (h) = 6.63×10^{-34} J s]

Q.50 The first rotational absorption of $^{12}C^{16}O$ molecule is observed at 3.84 cm^{-1}. If an isotopic substitution is made with ^{18}O in the molecule, the frequency (in cm^{-1}) of first rotational absorption is_____.

(round off to two decimal places)

Section C: Q.51 – Q.60 Carry TWO marks each.

Q.51 If $y + x\,e^{y} = \sin x + \tan x$, then the value of $\frac{dy}{dx}$ at $x = 0$ is_____.

(round off to the nearest integer)

Q.52 Consider the following matrices A and B.

$$A = \begin{pmatrix} 1 & 2 & 0 & 0 & 0 \\ 3 & 4 & 0 & 0 & 0 \\ 0 & 0 & 5 & 0 & 0 \\ 0 & 0 & 0 & 6 & 7 \\ 0 & 0 & 0 & 8 & 9 \end{pmatrix} \text{ and } B = \begin{pmatrix} 10 & 11 & 0 & 0 & 0 \\ 12 & 13 & 0 & 0 & 0 \\ 0 & 0 & 4 & 0 & 0 \\ 0 & 0 & 0 & 15 & 16 \\ 0 & 0 & 0 & 17 & 18 \end{pmatrix}$$

If C = AB, sum of the diagonal elements of C is_____.

Q.53 The number of species among the following, having bond order of three is_____.

N_2, F_2, NO^+, O_2^-, N_2^+, CO, O_2, O_2^{2-}

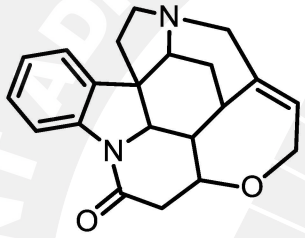
`

Q.54 1.84 g of a mixture of $CaCO_3$ and $MgCO_3$ is heated till no further weight loss. The weight of the residue is 0.96 g. The % composition of $CaCO_3$ in the mixture is_____.

(round off to two decimal places)

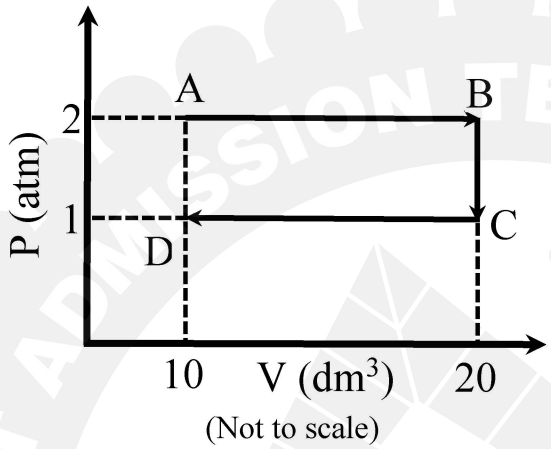
[Given: Atomic weight of Ca = 40; Mg = 24; C = 12; O = 16]

Q.55 The number of chiral carbon centers in the following molecule is_____.



Q.56 One mole of a monoatomic ideal gas starting from state A, goes through B and C to state D, as shown in the figure. Total change in entropy (in J K^{-1}) during this process is_____.

(round off to two decimal places)



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

Q.57 In one second, 95 moles of He gas particles are hitting a wall of a cubic container of volume 1 dm^3. If the average velocity component of the particles perpendicular to the wall is 1000 m s^{-1}, then the pressure of the gas in the container is X × 10^5 N m^{-2}. The value of X is_____.

(round off to two decimal places)

[Given: Avogadro's number, $N_A = 6.02 \times 10^{23}$, mass of He = 4 g mol^{-1}]

Q.58 Solubility of $PbCO_3$ in a buffer of pH 5 is X × 10^{-4}. The value of X is _____.

(round off to one decimal place)

[Given: K_{sp} of $PbCO_3$ = 1.5 × 10^{-13}; for H_2CO_3, $K_{a1} = 4.2 \times 10^{-7}$, $K_{a2} = 4.8 \times 10^{-11}$]

Q.59 The molar conductivity of a 0.02 M weak acid HA is 3.2 mS m^2 mol^{-1} at 298 K. The pK_a of HA is_____.

(round off to one decimal place)

[Given: Limiting molar conductivity of HA = 39 mS m^2 mol^{-1} at 298 K]

Q.60 A cell is constructed by Cl_2/Cl^-(aq) and a standard hydrogen electrode half-cells. The standard potential of the complete cell is 1.38 V and $\left(\frac{\partial E^0}{\partial T}\right)_P = -1.24\, mVK^{-1}$. The $\Delta S^0_{reaction}$ (in J K^{-1} mol^{-1}) for the following cell reaction is _____.

$$H_2(gas) + Cl_2(gas) \rightarrow 2H^+(aq) + 2Cl^-(aq)$$

(round off to one decimal place)

[Given: Faraday constant (F) = 96480 C mol^{-1}]