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 may be **one or more than one** choice(s) 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 this 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 marks 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. The Scribble Pad will be provided for rough work.

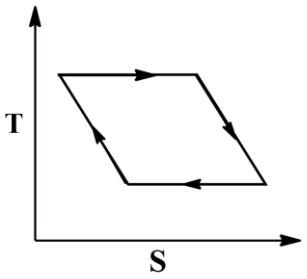
SECTION – A

MULTIPLE CHOICE QUESTIONS (MCQ)

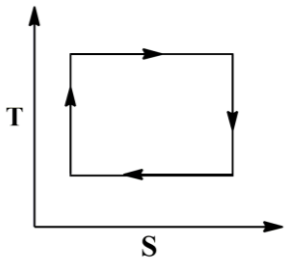
Q. 1 – Q.10 carry one mark each.

Q.1 The graph that represents the temperature (T) – entropy (S) variation of a Carnot cycle is

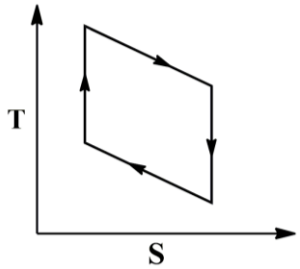
(A)



(B)



(C)



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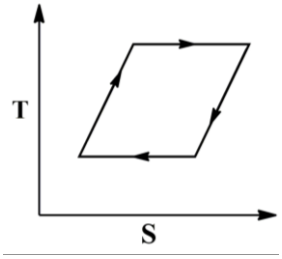


Q.2 For the radical chain reaction below, the correct classification for step 2 and step 3 is, respectively,

Step 1: $Br_2 + M \longrightarrow 2Br\bullet + M$

Step 2: $Br\bullet + H_2 \rightleftharpoons HBr + H\bullet$

Step 3: $H\bullet + Br_2 \longrightarrow HBr + Br\bullet$

(A) chain propagating, chain terminating

(B) chain branching, chain terminating

(C) chain propagating, chain propagating

(D) chain propagating, chain branching

Q.3 The salt bridge in a galvanic cell allows the flow of

(A) ions but NOT electrons

(B) BOTH ions and electrons

(C) electrons but NOT ions

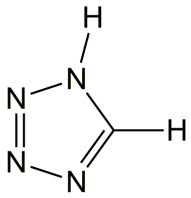
(D) NEITHER ions NOR electrons

Q.4 The nucleobase NOT found in DNA is

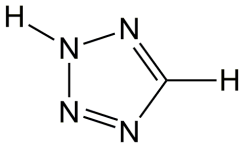
(A) Thymine (B) Uracil

(C) Guanine (D) Adenine

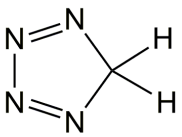
Q.5 The correct statement for the following structures is



1



2



3

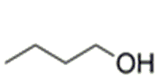
(A) **1**, **2** and **3** are resonance structures

(B) **1** and **2** are resonance structures, whereas **3** is an isomer of **1** and **2**

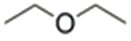
(C) **1** and **3** are resonance structures, whereas **2** is an isomer of **1** and **3**

(D) **1**, **2** and **3** are constitutional isomers

Q.6 The correct order of boiling points of compounds I–IV is



I



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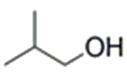


III

IV

(A) II > I > III > IV (B) II > III > I > IV

(C) I > III > IV > II (D) I > IV > III > II

Q.7 One of the products of the hydrolysis of calcium phosphide at 25° C is

(A) phosphine

(B) phosphoric acid

(C) phosphorus pentoxide

(D) white phosphorus

Q.8 Treatment of formic acid with concentrated sulfuric acid gives

(A) $CO + H_2O$ (B) $CO_2 + H_2$

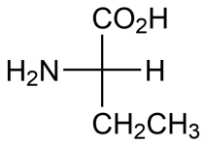
(C) $HCHO + ½\ O_2$ (D) no product (no reaction)

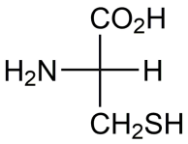
Q.9 The *d*-orbitals involved in the hybridization to form square planar and trigonal bipyramidal geometries are, respectively,

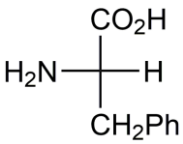
(A) d_{z^2} and d_{z^2} (B) d_{yz} and d_{z^2}

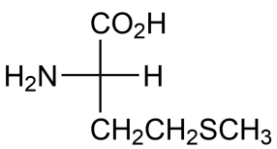
(C) $d_{x^2-y^2}$ and d_{z^2} (D) $d_{x^2-y^2}$ and d_{yz}

Q.10 The amino acid with *R* configuration is

(A) 

(B) 

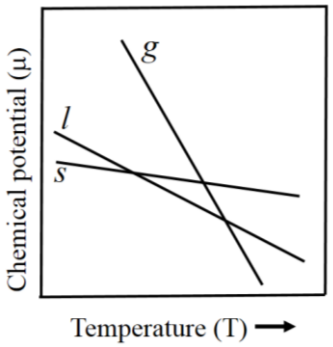
(C) 

(D) 

Q. 11 – Q. 30 carry two marks each.

Q.11 At constant pressure, the μ – T diagram for a pure substance that sublimes is (*s* = solid, *l* = liquid and *g* = gas)

(A)



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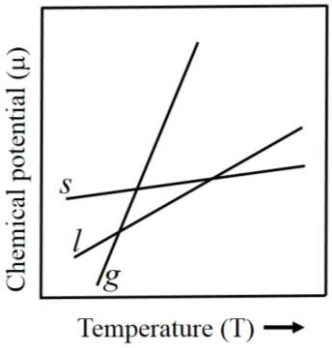
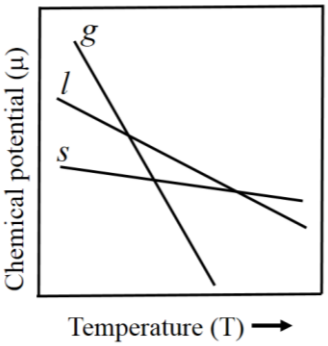


(C)



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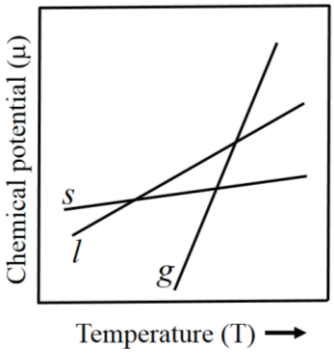


Q.12 The force constant for $H^{35}Cl$ and $D^{35}Cl$ are the same and both can be considered as harmonic oscillators. $H^{35}Cl$ has a fundamental vibrational transition at 2886 cm^{-1}. The ratio of the zero-point energy of $H^{35}Cl$ to that of $D^{35}Cl$ is

(A) 0.515 (B) 0.717 (C) 1.395 (D) 1.946

Q.13 The correct statement regarding the determinants (Det) of matrices *R*, *S* and *T* is

$$R = \begin{bmatrix} 3 & 2 & 4 \\ 4 & 5 & 7 \\ 1 & 3 & 8 \end{bmatrix} \qquad S = \begin{bmatrix} 2 & 3 & 4 \\ 5 & 4 & 7 \\ 3 & 1 & 8 \end{bmatrix} \qquad T = \begin{bmatrix} 3 & 4 & 1 \\ 2 & 5 & 3 \\ 4 & 7 & 8 \end{bmatrix}$$

(A) Det(*R*) = Det(*S*) ≠ Det(*T*)

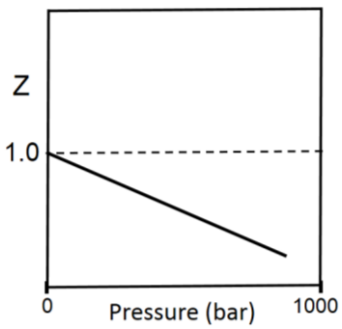
(B) Det(*R*) = Det(*T*) ≠ Det(*S*)

(C) Det(*R*) = Det(*S*) = Det(*T*)

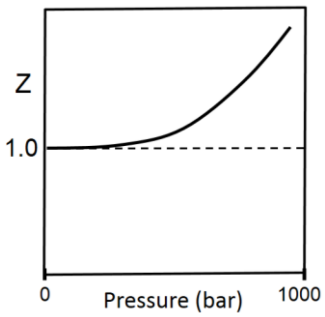
(D) Det(*R*), Det(*S*), Det(*T*) are all different

Q.14 The Boyle temperature (T_B) is defined as the temperature at which the properties of a real gas coincide with those of an ideal gas in the low pressure limit. The graph that shows the pressure dependence of the compression factor (Z) for a real gas at T_B is

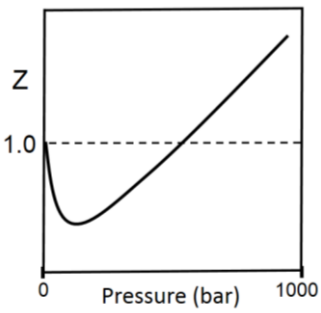
(A)



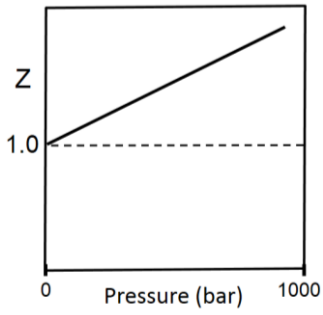
(B)



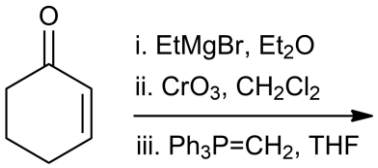
(C)

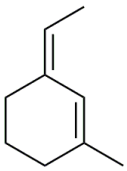


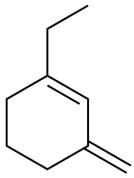
(D)

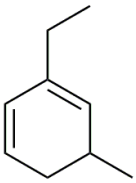


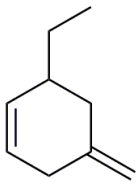
Q.15 The major product formed in the following reaction sequence is



(A) 

(B) 

(C) 

(D) 

Q.16 The geometries of the species $[Br_3]^+$, $[Br_3]^-$ and $[BrF_3]$ are, respectively,

(A) linear, trigonal bipyramidal and trigonal bipyramidal

(B) linear, linear and trigonal planar

(C) tetrahedral, trigonal bipyramidal and trigonal bipyramidal

(D) tetrahedral, trigonal pyramidal and trigonal planar

Q.17 The cage – type structure adopted by boron hydride, $[B_5H_{11}]$, is

(A) *closo* (B) *nido* (C) *hypo* (D) *arachno*

Q.18 The order of the M–C bond strength in the following species is
(Atomic number for Cr = 24, Mn = 25, Ti = 22, Co = 27)

$[Cr(CO)_6]$ $[Mn(CO)_6]^+$ $[Ti(CO)_6]^{2-}$ $[Co(CO)_4]^-$
I II III IV

(A) II > I > IV > III (B) I > III > II > IV

(C) III > IV > I > II (D) III > I > II > IV

Q.19 The number of non-bonding electrons present in the frontier molecular orbitals of HF is

(A) 10 (B) 4 (C) 6 (D) 8

Q.20 The coordination number of aluminum ion and the number of bridging hydrogen atoms in $[Al(BH_4)_4]^-$ are, respectively,

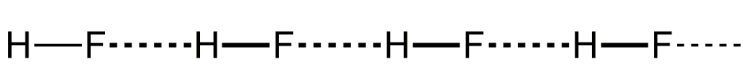
(A) 8 and 8 (B) 6 and 6 (C) 4 and 6 (D) 8 and 12

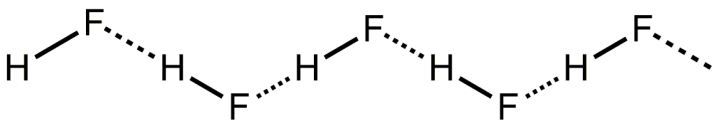
Q.21 The complex which does NOT obey 18-electron rule is
(atomic number for Mn = 25, Fe = 26, Co = 27, Ru = 44)

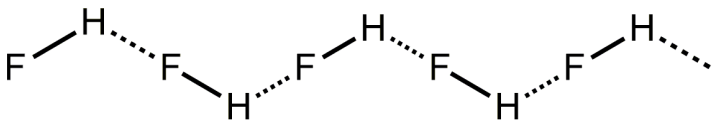
(A) $[Co_2(CO)_8]$ (B) $[Fe(CO)_4]^{2-}$

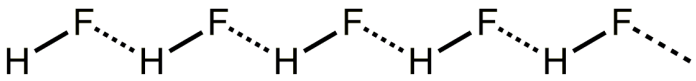
(C) $[HMn(CO)_5]$ (D) $[(\eta^5\text{-}C_5H_5)RuCl(CO)(PPh_2)]$

Q.22 The solid state structure of HF is

(A) 

(B) 

(C) 

(D) 

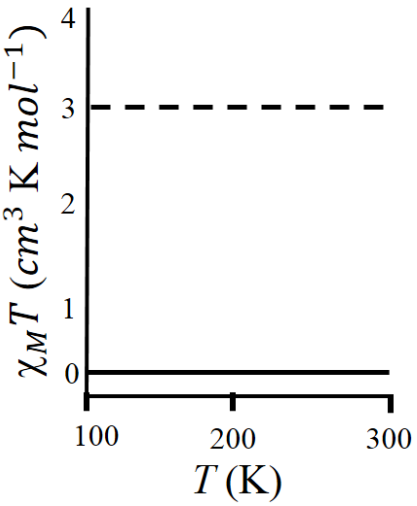
Q.23 The number of *d-d* transition(s) expected for the complex $[Cu(NH_3)_2(H_2O)_4]^{2+}$ is

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

Q.24 The plot showing the magnetic behavior of oxy- (solid line) and deoxy-haemoglobin (dashed line) is

(χ_M = molar magnetic susceptibility, T = temperature)

(A)



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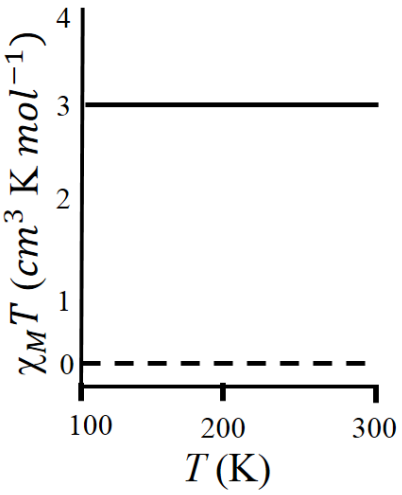
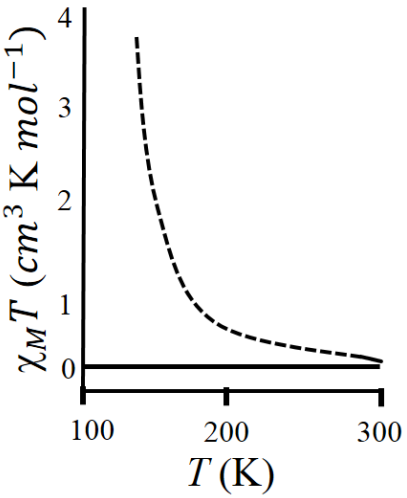


(C)



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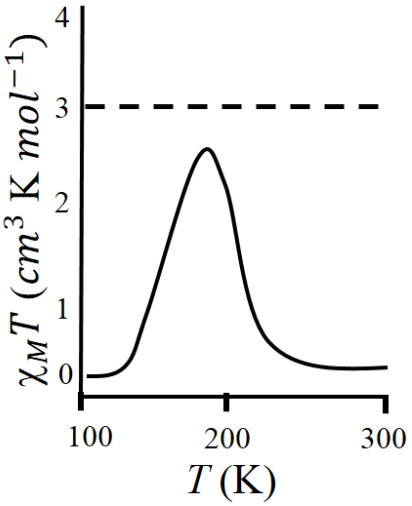
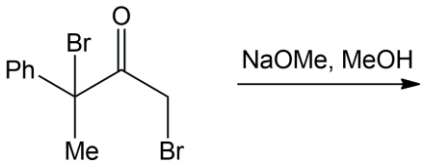
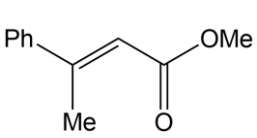
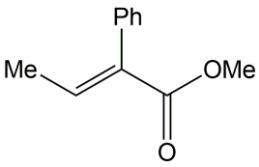
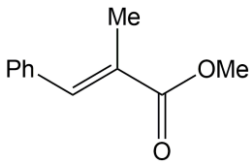


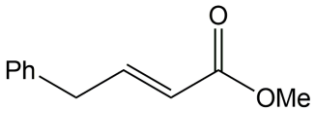
Q.25 The major product formed in the following reaction is



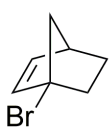
(A) 

(B) 

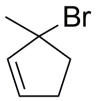
(C) 

(D) 

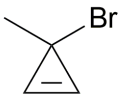
Q.26 The rate of solvolysis of I–IV follows



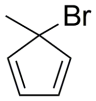
I



II



III



IV

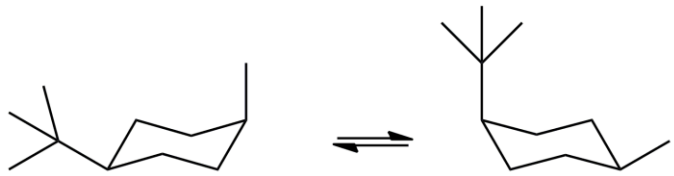
(A) I > II > III > IV

(B) III > I > II > IV

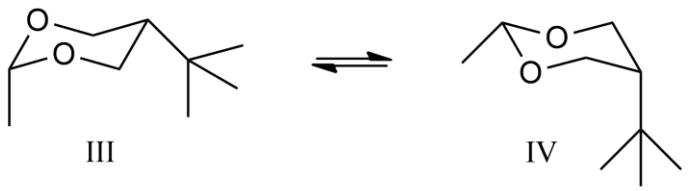
(C) III > II > I > IV

(D) IV > I > II > III

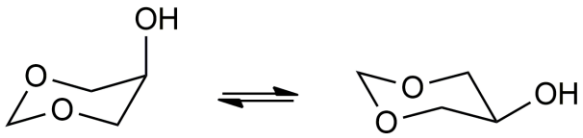
Q.27 The more stable species in each pair of conformers are



I II



III IV

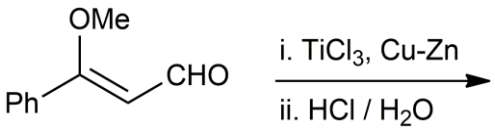


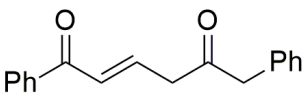
V VI

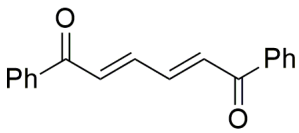
(A) II, IV and V (B) I, IV and V

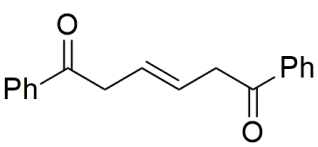
(C) II, III and V (D) I, IV and VI

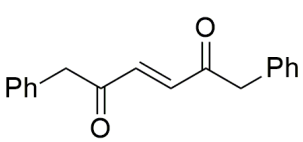
Q.28 The major product formed in the following reaction sequence is



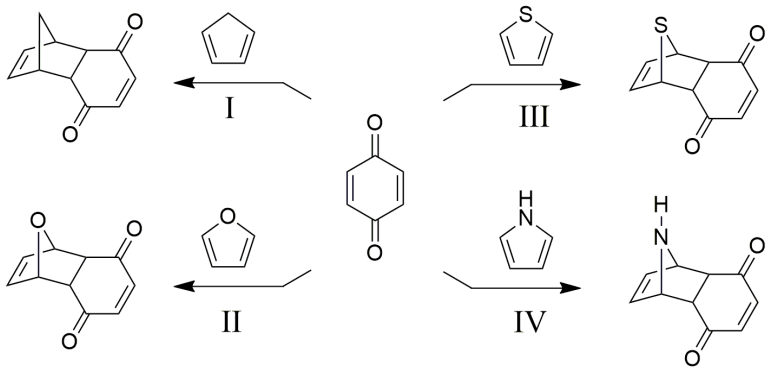
(A) 

(B) 

(C) 

(D) 

Q.29 For the Diels-Alder reactions I–IV, the activation barriers follow the order



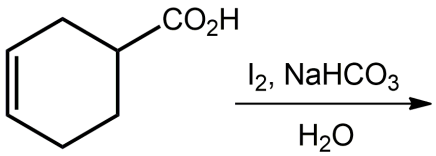
(A) II > I > III > IV

(B) I > III > IV > II

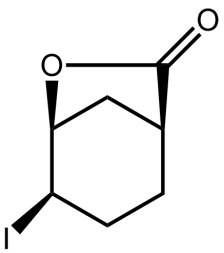
(C) III > IV > II > I

(D) IV > III > II > I

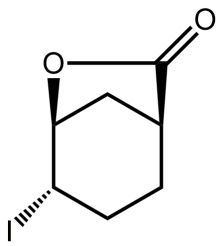
Q.30 The major product formed in the following reaction is



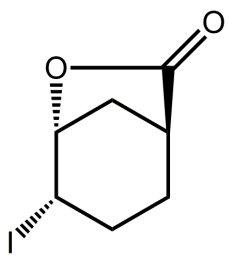
(A)



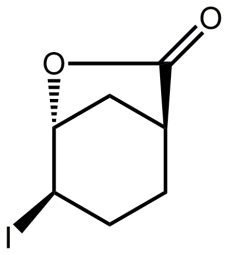
(B)



(C)



(D)

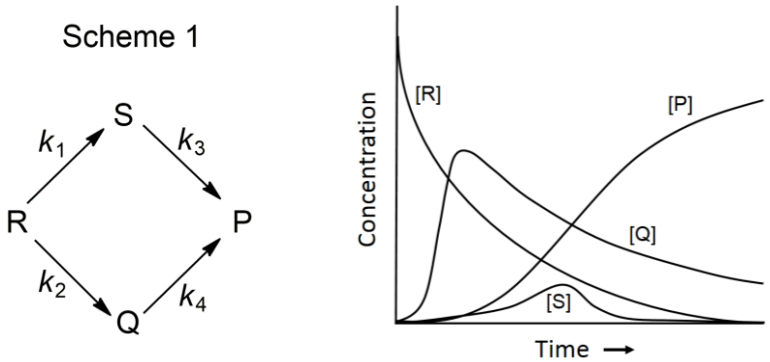


SECTION - B

MULTIPLE SELECT QUESTIONS (MSQ)

Q. 31 – Q. 40 carry two marks each.

Q.31 For the reaction shown in Scheme 1, the concentration profiles of different species are provided.



Based on this graph, the correct condition(s) regarding the rate constants is(are)

(A) $k_2 > k_4$ (B) $k_3 > k_1$ (C) $k_2 > k_1$ (D) $k_1 = k_2$

Q.32 $\psi(x,y,z)$ describes the wavefunction of a particle. The probability of finding the particle between x and $x + dx$, y and $y + dy$, z and $z + dz$, can be expressed as

(A) $\psi^*(x,y,z)\ \psi(x,y,z)$

(B) $|\psi(x,y,z)|^2\ dx\ dy\ dz$

(C) $\psi^*(x,y,z)\ \psi(x,y,z) dx\ dy\ dz$

(D) $\int_{-\infty}^{\infty} dx \int_{-\infty}^{\infty} dy \int_{-\infty}^{\infty} dz\ \psi^*(x,y,z)\ \psi(x,y,z)$

Q.33 In water, the enthalpy of a protein in its folded state (H_F) is lower than that in its unfolded state (H_{UF}). The entropies of the folded and unfolded states are S_F and S_{UF}, respectively. The condition(s) under which this protein spontaneously folds in water at a temperature T, is(are)

(A) $S_{UF} < S_F$ (B) $S_{UF} = 0$

(C) $S_{UF} = S_F$ (D) $(S_F - S_{UF}) > (H_F - H_{UF})/T$

Q.34 The soft Lewis base(s) is(are)

(A) I^- (B) CO (C) H^- (D) CH_3NC

Q.35 The boron adduct(s), which show(s) three signals in ^1H NMR spectrum with the intensity ratio 1:2:3 is(are)

(A) $(CH_3)_3B{:}N(CH_3)_3$ (B) $(CH_3CH_2)_3B{:}N(CH_2CH_3)_3$

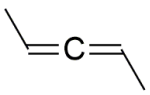
(C) $H_3B{:}N(CH_2CH_3)_3$ (D) $(CH_3CH_2)_3B{:}NH_3$

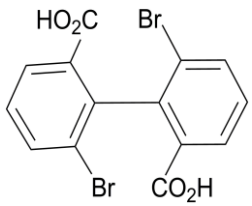
Q.36 The transition metal complex(es) with zero magnetic moment, zero dipole moment and CFSE of $-2.4\ \Delta_o$ is(are)

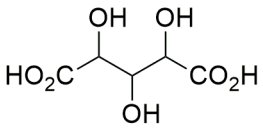
(A) $[Mn(CO)_5(CH_3)]$ (B) [*trans*-Ni(ethylene diamine)$_2Cl_2$]

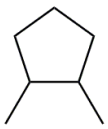
(C) $[trans\text{-}Co(CN)_4(H_2O)_2]^-$ (D) $[trans\text{-}Fe(CN)_4Cl_2]^{4-}$

Q.37 Achiral stereoisomer(s) is(are) possible for

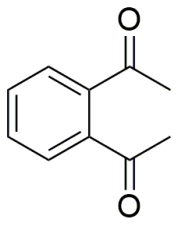
(A) 

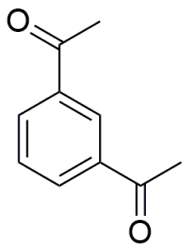
(B) 

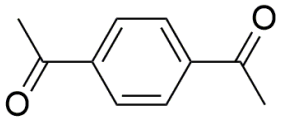
(C) 

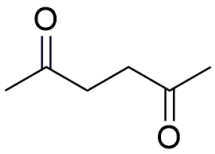
(D) 

Q.38 The compound(s) which will have only two signals in the ^1H NMR spectrum in 3:2 ratio is(are)

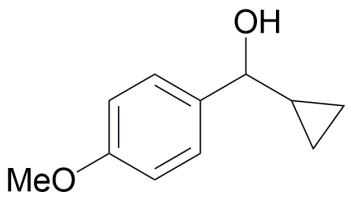
(A) 

(B) 

(C) 

(D) 

Q.39 The correct sequence of reactions for the synthesis of the following molecule is(are)



(A) (i) 4-Iodophenol, Mg, ether
(ii) Cyclopropane carboxaldehyde, THF
(iii) $CsCO_3$, MeI, THF

(B) (i) Cyclopropyl bromide, Mg, ether
(ii) 4-Hydroxybenzaldehyde, THF
(iii) $CsCO_3$, MeI, THF

(C) (i) 4-Iodophenol, $CsCO_3$, MeI, THF
(ii) Mg, ether
(iii) Cyclopropane carboxaldehyde, THF

(D) (i) Cyclopropyl bromide, Mg, ether
(ii) Methyl 4-methoxybenzoate, THF

Q.40 The organometallic reagent(s) among the following is(are)

(A) Lithium divinylcuprate

(B) Lithium diisopropylamide

(C) Potassium *tert*-butoxide

(D) Isopropyl magnesiumiodide

SECTION – C

NUMERICAL ANSWER TYPE (NAT)

Q. 41 – Q. 50 carry one mark each.

Q.41 The function $x^4 e^{-2x/3}$ (for $x > 0$) has a maximum at a value of x equal to _____ (Round off to two decimal places)

Q.42 The longest wavelength of light absorbed by a hydrogen-like atom is 2.48 nm. The nuclear charge (Z) of the atom is _____ (Round off to nearest integer)
(Rydberg constant R_H = 109700 cm^{-1})

Q.43 Fullerene (C_{60}) crystallizes in an FCC unit cell (edge length = 14.14 Å) with one C_{60} centered at each lattice point. The smallest distance (in Å) between the centers of two C_{60} molecules is _____ (Round off to two decimal places)

Q.44 A film of stearic acid partially covers the water surface in a container. The work needed to decrease this coverage by 1 cm^2 is 25.0×10^{-7} J. The surface tension (in N/m) of the film is _____ (Round off to three decimal places)
(Surface tension of pure water is 0.072 N/m)

Q.45 The value of 'n' in $[P_nO_{18}]^{6-}$ is _____

Q.46 The total number of all possible isomers of $[Co(H_2NCH_2CH_2NH_2)_2Cl_2]^+$ and $[Co(H_2NCH_2CH_2NH_2)_3]^{3+}$ together is _____

Q.47 The number of lone pairs present in phosphonic acid (phosphorus acid) is _____

Q.48 Total number of constitutional isomers possible for trimethyl cyclohexane is _____

Q.49 The dihedral (torsional) angle (in degrees) between the two methyl groups in the most stable conformation of *n*-butane is _____ (Round off to nearest integer)

Q.50 The degree of unsaturation (double bond equivalent) for a compound with molecular formula $C_{14}H_{12}O_2$ is _____

Q. 51 – Q. 60 carry two marks each.

Q.51 The heat of formation of MgO at 300 K and 1 bar pressure is –600.60 kJ mol^{-1}. The free energy (in kJ mol^{-1}) of formation of MgO at 280 K is _____ (Round off to nearest integer)

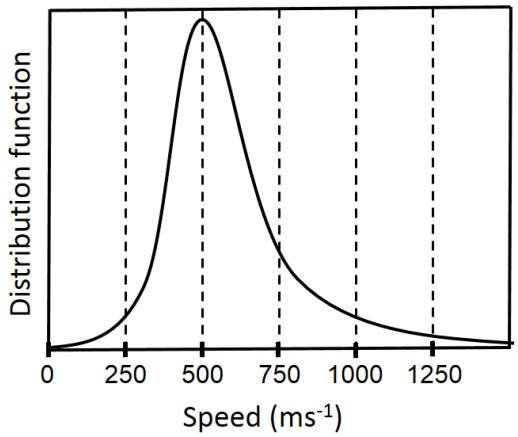
Given: In the range 280-300 K, the constant pressure heat capacities (C_P) and molar entropies (S_m) are:

	Mg	O_2	MgO
C_P (in J mol^{-1} K^{-1})	24.9	29.4	27.0
S_m (in J mol^{-1} K^{-1})	0	205.2	0

Q.52 Sea water containing 1 M NaCl has to be desalinated at 300 K using a membrane permeable only to water. The minimum pressure (in bars) required on the sea-water side of the membrane is _____ (Round off to one decimal place)
(R = 8.3 J mol^{-1} K^{-1}, 1 bar = 10^5 N/m^2)

Q.53 A bacterial colony grows via cell division where each mother bacterium independently produces two daughter cells in 20 minutes. If the concentration of bacteria is 10^4 cm^{-3}, the colony becomes harmful. Starting from a colony with an initial concentration of 5 cm^{-3}, the time taken (in minutes) for the colony to become harmful is _____ (Round off to nearest integer)

Q.54 The Maxwell distribution of speeds of a gas at 300 K is given below



The molar mass (in g mol^{-1}) of this gas is _____ (Round off to one decimal place)
($R = 8.3$ J mol^{-1} K^{-1})

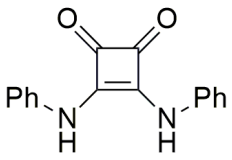
Q.55 At a certain wavelength, liquid P transmits 70%, whereas liquid Q transmits 30% of the incident light when separately placed in a spectrophotometric cell (path length = 1 cm). In a binary mixture of liquids P and Q (assume non-interacting liquids), the absorbance in the same cell is 0.25. The volume fraction of liquid P in the binary mixture is _____
(Round off to two decimal places)

Q.56 The mean ionic activity coefficient for a 0.01 M aqueous solution of $Ca_3(PO_4)_2$ is _____ (Round off to three decimal places)
(Given: $\log_{10} \gamma_{\pm} = -0.509\, z_+ |z_-| \sqrt{I}$)

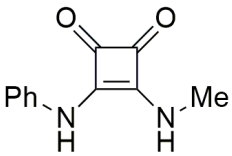
Q.57 For the reaction, $CuSO_4(aq) + Zn(s) \rightarrow ZnSO_4(aq) + Cu(s)$, the value of $\Delta G°$ (in kJ mol^{-1}) is _____ (Round off to the nearest integer)
(Reduction potential: $Cu^{2+}(aq)/Cu(s) = +0.34$ V; $Zn^{2+}(aq)/Zn(s) = -0.76$ V)
(Faraday constant = 96485 C mol^{-1})

Q.58 Titanium tetrachloride ($TiCl_4$) reacts with THF to form an octahedral complex **X** under inert atmosphere at 25 °C. If 5.0 g of $TiCl_4$ is used and the yield is 80%, the amount of **X** (in grams) formed is _____ (Round off to one decimal place)
(Use atomic weights: Ti = 48, Cl = 35.5, O = 16, C = 12, and H = 1)

Q.59 The total number of tautomers possible for I and II together is _____

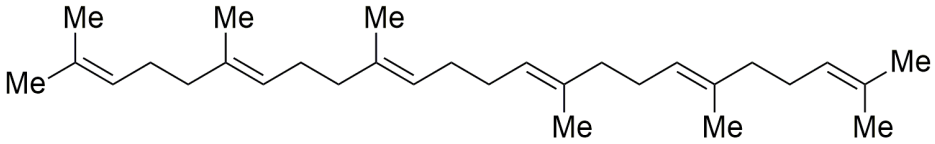


I



II

Q.60 The total number of head to tail isoprene linkages in the following molecule is _____



END OF THE QUESTION PAPER

Chemistry (CY)					
Q. NO.	**Session**	**QT**	**Section**	**Key**	**Marks**
1	2	MCQ	A	B	1
2	2	MCQ	A	C	1
3	2	MCQ	A	A	1
4	2	MCQ	A	B	1
5	2	MCQ	A	D	1
6	2	MCQ	A	C	1
7	2	MCQ	A	A	1
8	2	MCQ	A	A	1
9	2	MCQ	A	C	1
10	2	MCQ	A	B	1
11	2	MCQ	A	C	2
12	2	MCQ	A	C	2
13	2	MCQ	A	B	2
14	2	MCQ	A	B	2
15	2	MCQ	A	B	2
16	2	MCQ	A	C	2
17	2	MCQ	A	D	2
18	2	MCQ	A	C	2
19	2	MCQ	A	C	2
20	2	MCQ	A	A	2
21	2	MCQ	A	D	2
22	2	MCQ	A	B	2
23	2	MCQ	A	C	2
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25	2	MCQ	A	A	2
26	2	MCQ	A	C	2
27	2	MCQ	A	B	2
28	2	MCQ	A	C	2
29	2	MCQ	A	C	2
30	2	MCQ	A	B	2
31	2	MSQ	B	A;B;C	2
32	2	MSQ	B	B;C	2
33	2	MSQ	B	A;B;C;D	2
34	2	MSQ	B	A;B;C;D	2
35	2	MSQ	B	C;D	2
36	2	MSQ	B	C;D	2
37	2	MSQ	B	C;D	2
38	2	MSQ	B	C;D	2
39	2	MSQ	B	C	2
40	2	MSQ	B	A;D	2
41	2	NAT	C	5.97 to 6.06	1
42	2	NAT	C	7 to 7	1
43	2	NAT	C	9.90 to 10.10	1
44	2	NAT	C	0.040 to 0.050	1
45	2	NAT	C	6 to 6	1
46	2	NAT	C	5 to 5	1
47	2	NAT	C	6 to 6	1
48	2	NAT	C	6 to 6	1

49	2	NAT	C	180 to 180	1
50	2	NAT	C	9 to 9	1
51	2	NAT	C	-570 to -574	2
52	2	NAT	C	24.8 to 25.0 OR 49.7 to 49.9	2
53	2	NAT	C	210 to 225	2
54	2	NAT	C	19.8 to 20.2	2
55	2	NAT	C	0.73 to 0.75	2
56	2	NAT	C	0.063 to 0.069	2
57	2	NAT	C	-211 to -213	2
58	2	NAT	C	6.9 to 7.1	2
59	2	NAT	C	7 to 7	2
60	2	NAT	C	4 to 4	2