GATE – 2019 – Chemistry

Q.1 – Q.13 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

1. The INCORRECT statement about the solid-state structure of CsCl and CaF_2 is:

(a) Cations in both solids exhibit coordination number 8

(b) CsCl has bcc type structure and CaF_2 has cubic close pack structure

(c) Radius ratio for Cs/Cl and Ca/F is 0.93 and 0.73, respectively

(d) Both exhibit close pack structure

2. The INCORRECT statement about the interhalogen compound ICl_3 is:

(a) It exists as a dimer

(b) Geometry around the iodine is tetrahedral in solid-state

(c) It decomposes as ICl and Cl_2 in gas-phase

(d) Liquid ICl_3 conducts electricity

3. Among the following carbon allotropes, the one with discrete molecular structure is

(a) Diamond (b) α-Graphite (c) β-Graphite (d) Fullerene

4. The INCORRECT statement about the silicones is:

(a) They are thermally unstable because of the Si–C bond

(b) They are insoluble in water

(c) They are organosilicon polymers

(d) They have stable silica-like skeleton (–Si–O–Si–O–Si–)

5. The Δ_o value of $[Ni(H_2O)_6]^{2+}$ is 8500 cm^{-1}. The Δ_o values for $[NiCl_6]^{4-}$ and $[Ni(NH_3)_6]^{2+}$ compared to $[Ni(H_2O)_6]^{2+}$ are

(a) higher and lower, respectively (b) lower and higher, respectively

(c) higher in both complex ions (d) lower in both complex ions

6. In Freundlich isotherm, a linear relationship is obtained in the plot of

(θ = surface coverage and p = partial pressure of the gas)

(a) θ vs p (b) ln(θ) vs ln (p) (c) ln(θ) vs p (d) θ vs ln (p)

7. Micelle formation is accompanied by the

(a) decrease in overall entropy due to ordering

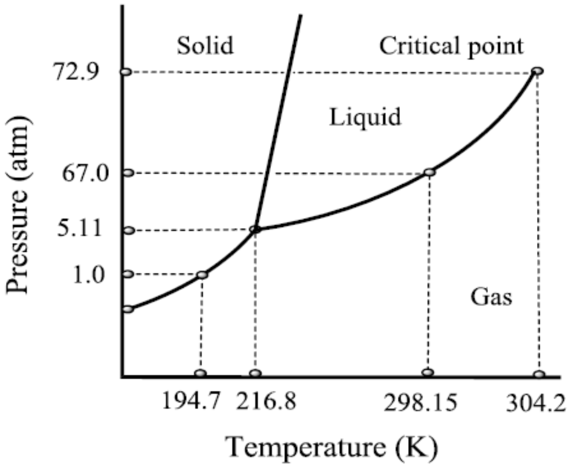
(b) increase in overall entropy mostly due to increase in solvent entropy

(c) increase in overall entropy mostly due to increase in solute entropy

(d) increase in overall entropy and decrease in enthalpy

8. Consider the following phase diagram of CO_2 (not to scale). At equilibrium, the

INCORRECT statement is:



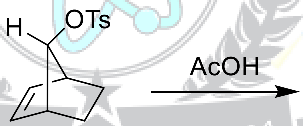
(a) At 200 K, on increasing the pressure from 1 to 50 atm, CO_2 gas condenses to liquid

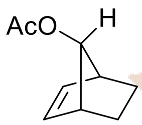
(b) It is not possible to obtain liquid CO_2 from gaseous CO_2 below 5.11 atm

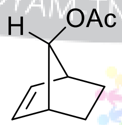
(c) Both liquid and gas phase of CO_2 coexist at 298.15 K and 67 atm

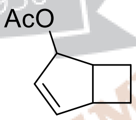
(d) With increasing pressure, the melting point of solid CO_2 increases

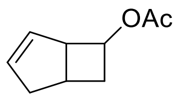
9. The major product formed in the following reaction is,



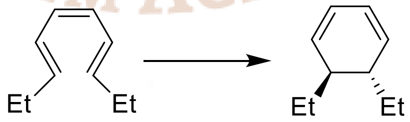
(a) 

(b) 

(c) 

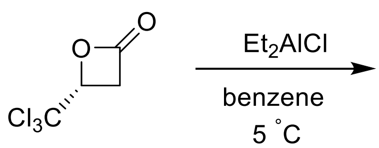
(d) 

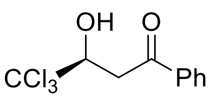
10. The Woodward-Hoffmann condition to bring out the following transformation is

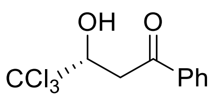


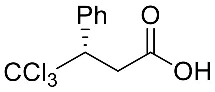
(a) Δ, conrotatory (b) Δ, disrotatory (c) hν, disrotatory (d) hν, conrotatory

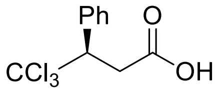
11. The major product formed in the following reaction is



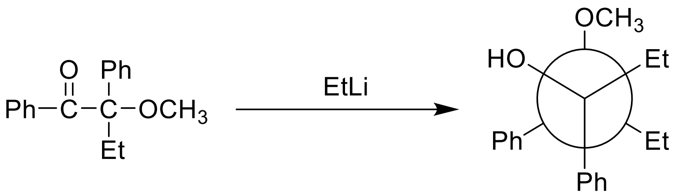
(a) 

(b) 

(c) 

(d) 

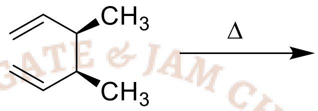
12. In the following reaction, the stereochemistry of the major product is predicted by the

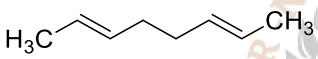


(a) Cram's model (b) Cram's chelation model

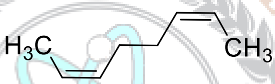
(c) Felkin model (d) Felkin-Anh model

13. The product(s) formed in the following reaction is (are)

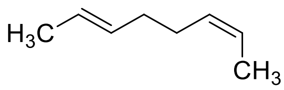




I



II

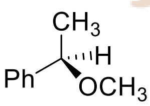


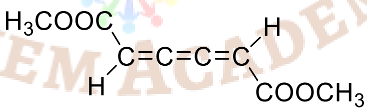
III

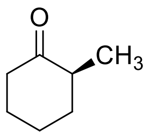
(a) I only (b) II only (c) III only (d) mixture of I and II

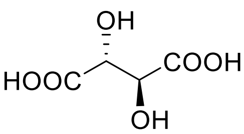
Q.14 – Q.25 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

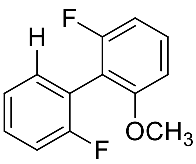
14. Among the following compounds, the number of compounds that DO NOT exhibit optical activity at room temperature is ________.

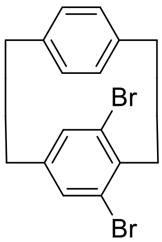




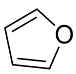


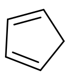


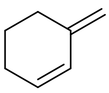


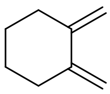


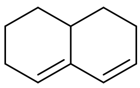
15. The number of following diene(s) that undergo Diels-Alder reaction with methyl acrylate is ________.

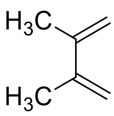


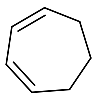




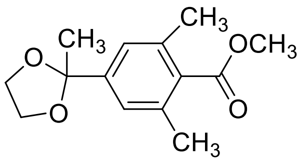








16. The number of ^{1}H-NMR signals observed for the following compound is ________.



17. The number of CO stretching bands in IR spectrum of trigonal bipyramidal Cis-$M(CO)_3L_2$ is ____________. (M = metal and L = monodentate ligand)

18. On heating a sample of 25 mg hydrated compound (molecular weight = 250 g/mol) in thermogravimetric analysis, 16 mg of dehydrated compound remains. The number of water molecules lost per molecule of hydrated compound is _________.

(Molecular weight of water = 18 g/mol)

19. The total number of α and β particles emitted in the given radioactive decay is ___.

$$^{238}_{92}U \longrightarrow ^{210}_{82}Pb$$

20. An ideal gas occupies an unknown volume V liters (L) at a pressure of 12 atm. The gas is expanded isothermally against a constant external pressure of 2 atm so that its final volume becomes 3 L. The work involved for this expansion process is ________cal. (Round off to two decimal places)

(Gas constant $R = 0.082\ L\ atm\ mol^{-1}K^{-1} = 2\ cal\ mol^{-1}K^{-1}$)

21. The entropy change for the melting of 'x' moles of ice (heat of fusion is 80 cal g^{-1}) at 273 K and 1 atm pressure is 28.80 cal K^{-1}. The value of 'x' is _______. (Round off to two decimal places) (Molecular weight of water = 18 g/mol)

22. Consider a two-state system at thermal equilibrium having energies 0 and $2k_BT$ for which the degeneracies are 1 and 2, respectively. The value of the partition function at the same absolute temperature T is_______. (Round off to two decimal places)

(k_B is the Boltzmann constant)

23. Consider a system of three identical and distinguishable non-interacting particles and three available nondegenerate single particle energy levels having energies 0, ε and 2ε. The system is in contact with a heat bath of temperature T K. A total energy of 2 ε is shared by these three particles. The number of ways the particles can be distributed is _______.

24. In a 400 MHz ^{1}H-NMR spectrometer, a proton resonates at 1560 Hz higher than that of tetramethylsilane. The chemical shift value of this proton is _______ ppm. (Round off to one decimal place & Chemical shift of TMS is fixed at zero ppm)

25. Gas phase bond length and dipole moment of a compound (MX) is 3 Å and 10.8 D, respectively. The ionic character in gas phase MX is _________%.

(Round off to one decimal place & $1D = 3.336 \times 10^{-30}$ C m)

Q.26 – Q.44 Multiple Choice Question (MCQ), carry TWO marks each (for each wrong answer: – 2/3).

26. **The experimentally observed magnetic moment values, which match well with the spin-only values for the pair of aqueous ions is**

(Atomic number: Cr = 24, Co = 27, Gd = 64, Tb = 65, Dy = 66 and Lu = 71)

(a) Cr(III) and Gd(III) (b) Co(II) and Gd (III)

(c) Cr(III) and Dy(III) (d) Lu(III) and Tb(III)

27. **Among the following compounds, a normal spinel is**

(a) $MgFe_2O_4$ (b) $ZnFe_2O_4$ (c) $CoFe_2O_4$ (d) $CuFe_2O_4$

28. **Following are the examples of silicate minerals**

Zircon, $ZrSiO_4$	Beryl, $Be_3Al_2Si_6O_{18}$	Pyrophyllite, $Al_2(OH)_2[(Si_2O_5)_2]$
I	II	III

The correct structural description of the minerals is

	I		II		III
(a)	Ortho silicate	;	Cyclic silicate	and	Sheet silicate
(b)	Ortho silicate	;	Sheet silicate	and	Cyclic silicate
(c)	Cyclic silicate	;	Sheet silicate	and	Ortho silicate
(d)	Sheet silicate	;	Ortho silicate	and	Cyclic silicate

29. **In the EPR spectrum of a methyl radical, the number of lines and their relative intensities, respectively, are**

(a) 1 and 1 (b) 3 and 1:2:1 (c) 4 and 1:2:2:1 (d) 4 and 1:3:3:1

30. **The product obtained in the reaction of $Mn_2(CO)_{10}$ with Br_2 is**

(a) $Mn(CO)_5Br$ (b) $Mn_2(CO)_8Br_2$ (c) $Mn(CO)_4Br_2$ (d) $Mn_2(CO)_9Br$

31. **The correct molecular representation of $W(Cp)_2(CO)_2$ is, (Cp = cyclopentadienyl)**

(a) $[W(\eta^1\text{- Cp})(\eta^3\text{- Cp})(CO)_2]$ (b) $[W(\eta^1\text{- Cp})(\eta^5\text{- Cp})(CO)_2]$

(c) $[W(\eta^3\text{- Cp})(\eta^5\text{- Cp})(CO)_2]$ (d) $[W(\eta^5\text{- Cp})_2(CO)_2]$

32. **Match the metalloproteins with their respective functions.**

P.	**Ferritin**	**I.**	**Electron transfer**
Q.	**Rubredoxin**	**II.**	**Acid-base catalysis**
R.	**Cobalamin**	**III.**	**Metal storage**
S.	**Carbonic anhydrase**	**IV.**	**Methyl transfer**

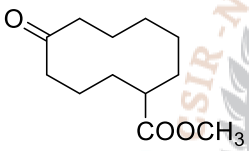
	P	Q	R	S
(a)	III	II	I	IV
(b)	III	I	IV	II
(c)	IV	I	III	II
(d)	IV	II	I	III

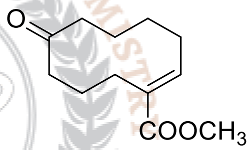
33. **Suppose the wave function of a one-dimensional system is $\varphi = \sin(kx)\exp(3ikx)$. In an experiment measuring the momentum of the system, one of the expected outcomes is**

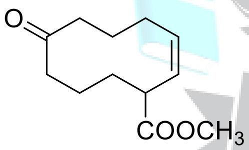
(a) 0 (b) ħk (c) 2 ħk (d) 3 ħk

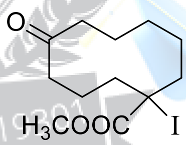
34. **The major product formed in the following reaction is**

(AIBN = azobisisobutyronitrile)

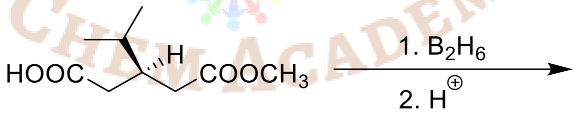
(a) 

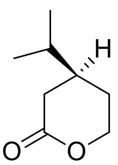
(b) 

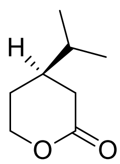
(c) 

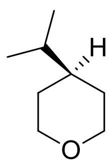
(d) 

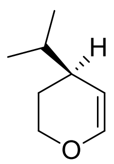
35. **The major product formed in the following reaction is,**



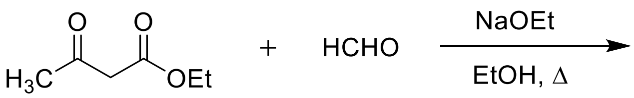
(a) 

(b) 

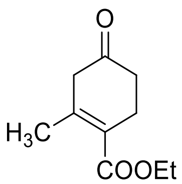
(c) 

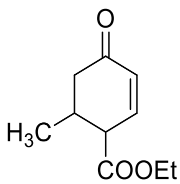
(d) 

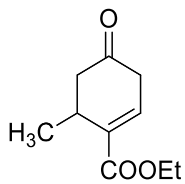
36. **The major product formed in the following reaction is**

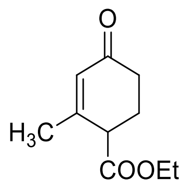


(2 equiv.)

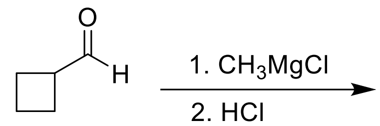
(a) 

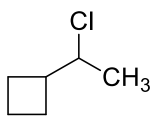
(b) 

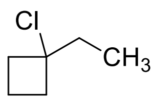
(c) 

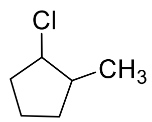
(d) 

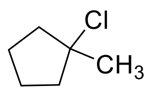
37. **The major product formed in the following reaction is**



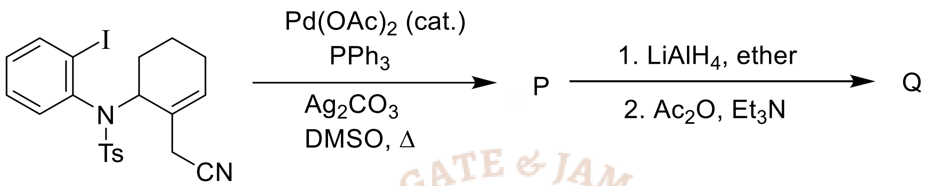
(a) 

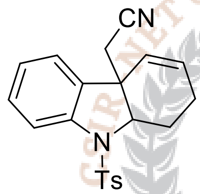
(b) 

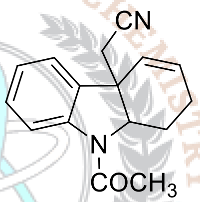
(c) 

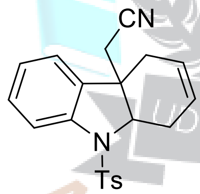
(d) 

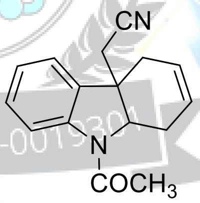
38. **In the following reaction sequence, the products P and Q are**

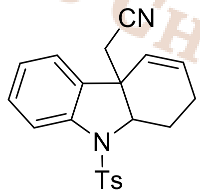


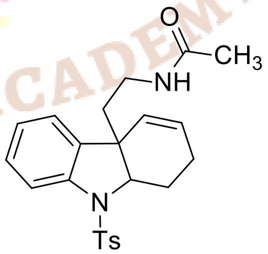
(a) P = 

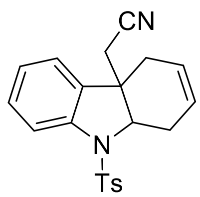
; Q = 

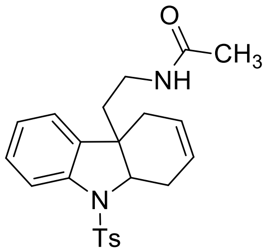
(b) P = 

; Q = 

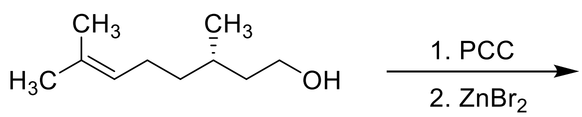
(c) P = 

; Q = 

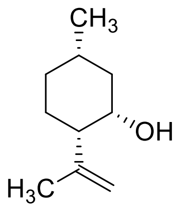
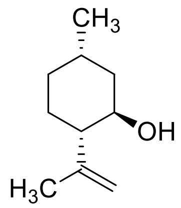
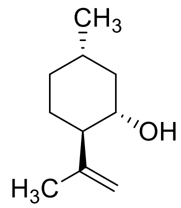
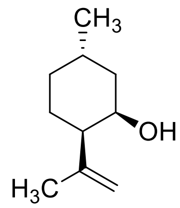
(d) P = 

; Q = 

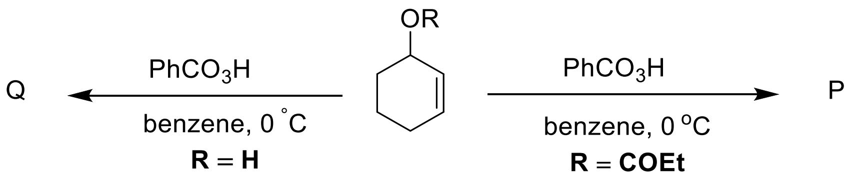
39. **The major product formed in the following reaction is**

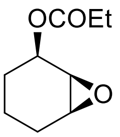
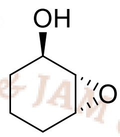


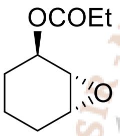
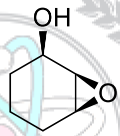
(PCC = Pyridinium chlorochromate)

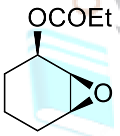
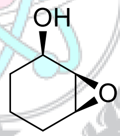
(a)  (b)  (c)  (d) 

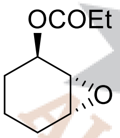
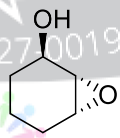
40. In the following reactions, the major products P and Q are



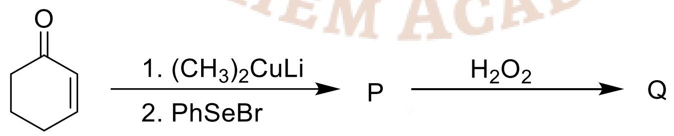
(a) P =  ; Q = 

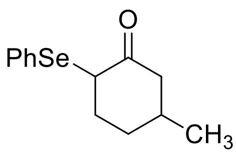
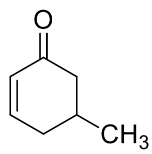
(b) P =  ; Q = 

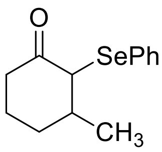
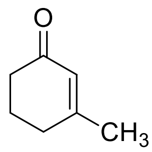
(c) P =  ; Q = 

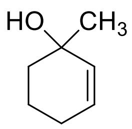
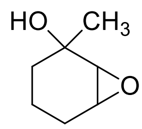
(d) P =  ; Q = 

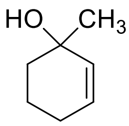
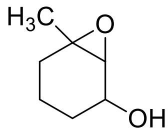
41. In the following reaction sequence, the products P and Q are



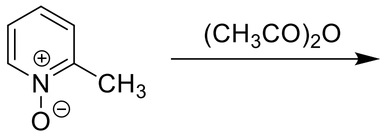
(a) **P** =  ; **Q** = 

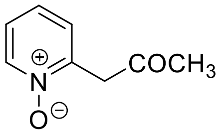
(b) **P** =  ; **Q** = 

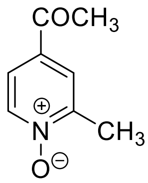
(c) **P** =  ; **Q** = 

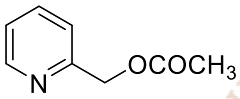
(d) **P** =  ; **Q** = 

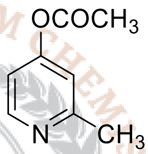
42. The major product formed in the following reaction is



(a) 

(b) 

(c) 

(d) 

43. The rate of the following redox reaction is slowest when X is,

$$[Co^{III}(NH_3)_5X]^{3+/2+} + [Cr^{II}(H_2O)_6]^{2+} \longrightarrow [Co^{II}(NH_3)_5(H_2O)]^{2+} + [Cr^{III}(H_2O)_5X]^{3+/2+}$$

(a) H_2O (b) NH_3 (c) Cl^- (d) N_3^-

44. A complex is composed of one chromium ion, three bromides and six water molecules. Upon addition of excess $AgNO_3$, 1.0 g aqueous solution of the complex gave 0.94 g of AgBr. The molecular formula of the complex is,

(Atomic weight: Cr = 52, Br = 80, Ag = 108, O = 16 and H = 1)

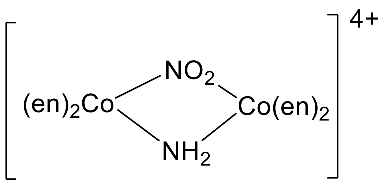
(a) $[Cr(H_2O)_6]Br_3$ (b) $[Cr(H_2O)_5Br]Br_2.H_2O$

(c) $[Cr(H_2O)_4Br_2]Br.2H_2O$ (d) $[Cr(H_2O)_3Br_3].3H_2O$

Q.45 – Q.55 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).

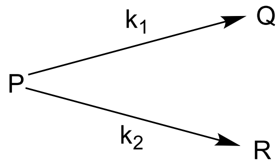
45. The number of possible optically active isomer(s) for the following complex is ___.

(en = ethylenediamine)



46. The specific rotation of optically pure (R)-2-bromobutane is −112.00. A given sample of 2-bromobutane exhibited a specific rotation of −82.88. The percentage of (S)-(+)-enantiomer present in this sample is ________.

47. Consider the following two parallel irreversible first order reactions at temperature T,



where k_1 and k_2 are the rate constants and their values are 5×10^{-2} and 15×10^{-2} min^{-1}, respectively, at temperature T. If the initial concentration of the reactant 'P' is 4 mol L^{-1}, then the concentration of product 'R' after 10 min of reaction is ______________ mol L^{-1}. (Round off to two decimal places)

(Assume only P is present at the beginning of the reaction)

48. Consider the following equilibrium

$$SO_{2(g)} + \frac{1}{2} O_2 \rightleftharpoons SO_{3(g)}$$

At 298 K, the standard molar Gibbs energies of formation, $\Delta_f G^0$, of $SO_2(g)$ and $SO_3(g)$ are −300 and −371 kJ mol^{-1}, respectively. The value of the equilibrium constant, K_P, at this temperature is ______ $\times 10^{10}$.

(Round off to the nearest integer & Gas constant $R = 8.31$ J $mol^{-1}K^{-1}$)

49. Consider the electrochemical cell: $M_{(s)} \left| MI_{2(s)} \right| MI_{2(aq)} \left| M_{(s)} \right.$.

where 'M' is a metal. At 298 K, the standard reduction potentials are $E^0_{M^{2+}(aq)/M(s)} = -0.12$ V, $E^0_{MI_{2(s)}/M(s)} = -0.36$ V and the temperature coefficient is $\left(\frac{\partial E^0_{cell}}{\partial T}\right)_P = 1.5 \times 10^{-4}$ VK^{-1}. At this temperature the standard enthalpy change for the overall cell reaction, $\Delta_r H^0$, is _________kJ mol^{-1}.

(Round off to two decimal places & Faraday constant $F = 96500$ C mol^{-1})

50. The normal boiling point of a compound (X) is 350 K (heat of vaporization, $\Delta_{vap}H = 30$ kJ mol^{-1}). The pressure required to boil 'X' at 300 K is _____ Torr. (Round off to two decimal places & Ignore the temperature variation of $\Delta_{vap}H$)

(Gas constant $R = 8.31$ J $mol^{-1}K^{-1}$ and 1 atm = 760 Torr)

51. For a bimolecular gas phase reaction $P + Q \longrightarrow R$, the pre-exponential factor is 1×10^{13} dm^3 mol^{-1} s^{-1}. The standard entropy of activation at 25℃ is __________ JK^{-1} mol^{-1}. (Round off to two decimal points)

(The standard concentration $c^o = 1$ mol dm^{-3}; Planck constant $h = 6.62 \times$

10^{-34} Js ; Boltzmann constant $k_B = 1.38 \times 10^{-23}$ J K^{-1}; Gas constant $R = 8.31$ J $mol^{-1}K^{-1}$)

52. Character table of point group D_8 is given below.

D_8	E	$2C_8$	$2C_4$	$2C_8^3$	C_2	$4C_2'$	$4C_2''$
A_1	a	1	1	1	1	1	1
A_2	b	1	1	1	1	h	i
B_1	c	−1	1	−1	1	1	j
B_2	d	−1	1	−1	1	−1	1
E_1	e	$\sqrt{2}$	0	$-\sqrt{2}$	−2	0	0
E_2	f	0	−2	0	k	0	0
E_3	g	$-\sqrt{2}$	0	$\sqrt{2}$	−2	0	0

Value of $(a + b + c + d + e + f + g + h + i + j + k)$ is equal to __________.

53. If $\langle\alpha|\widehat{S_x}\,\widehat{S_y} - \widehat{S_y}\widehat{S_x}|\alpha\rangle = -i\hbar^2 a$ where $\widehat{S_x}$ and $\widehat{S_y}$ are spin angular momentum operators and $|\alpha\rangle$ is spin up eigen function, then the value of 'a' is _________.

(Round off to one decimal place)

54. A particle in one dimensional box of length 2a with potential energy

$$V = \begin{cases} 0 & |x| < a \\ \infty & |x| > a \end{cases}$$

is perturbed by the potential $V' = cx$ eV, where c is a constant. The 1st order correction to the 1st excited state of the system is __________$\times$ c eV.

55. Consider a two-dimensional harmonic oscillator with angular frequency $\omega_x = 2\omega_y = 6.5 \times 10^{14}$ rad s^{-1}. The wavelength of x polarized light required for the excitation of a particle from its ground state to the next allowed excited state is ________$\times 10^{-6}$ m. (Round off to one decimal place)

(Speed of light $c = 3.0 \times 10^8$ m s^{-1})

Answer Key

Q.No	Ans		Q.No	Ans		Q.No	Ans
1.	d		21.	5.40 to 5.55		41.	b
2.	b		22.	1.25 to 1.30		42.	c
3.	d		23.	6		43.	b
4.	a		24.	3.9		44.	b
5.	b		25.	74 to 76		45.	2

6.	b		26.	a		46.	13
7.	b		27.	b		47.	2.50 to 2.65
8.	a		28.	a		48.	265 to 295
9.	b		29.	d		49.	-38 to -37
10.	d		30.	a		50.	135 to 137
11.	b		31.	c		51.	-12.9 to -12.4
12.	b		32.	b		52.	9
13.	c		33.	c		53.	0.5
14.	4		34.	a		54.	0
15.	5		35.	b		55.	2.8 to 3.0
16.	5		36.	d			
17.	3		37.	d			
18.	5		38.	c			
19.	11		39.	c			
20.	-126 to -120		40.	b			