PAPER : IIT-JAM 2020

CHEMISTRY-CY

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1. **Section-A contains 30 Multiple Choice Questions (MCQ). Each question has 4 choices (a), (b), (c) and (d), for its answer, out of which ONLY ONE is correct. From Q.1 to Q.10 carries 1 Marks and Q.11 to Q.30 carries 2 Marks each.**
2. **Section-B contains 10 Multiple Select Questions(MSQ). Each question has 4 choices (a), (b), (c) and (d) for its answer, out of which ONE or MORE than ONE is/are correct. For each correct answer you will be awarded 2 marks.**
3. **Section-C contains 20 Numerical Answer Type (NAT) questions. From Q.1 to Q.10 carries 1 Mark each and Q.11 to Q.20 carries 2 Marks each. For each NAT type question, the value of answer in between 0 to 9.**
4. **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.**

SECTION-A

Multiple Choice Questions (MCQ)

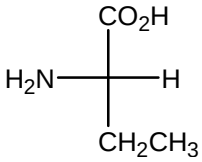
Q.1 – Q.10 carry ONE mark each.

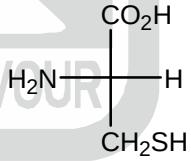
1. Treatment of formic acid with concentrated sulfuric acid gives

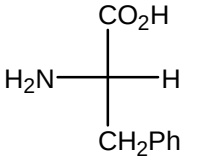
(a) $CO + H_2O$ (b) $CO_2 + H_2$

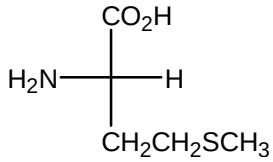
(c) $HCHO + ½O_2$ (d) no product (no reaction)

2. The amino acid with R configuration is

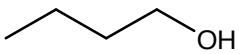
(a) 

(b) 

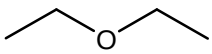
(c) 

(d) 

3. The correct order of boiling points of compounds I-IV is



(I)



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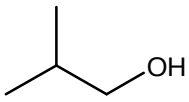

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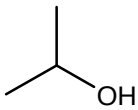


(IV)

(a) II > I > III > IV (b) II > III > I > IV

(c) I > III > IV > II (d) I > IV > III > II

4. 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}

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

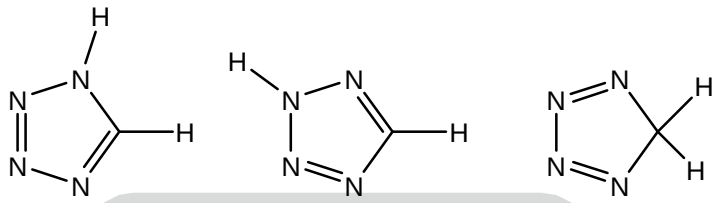
Step-1: $Br_2 + M \longrightarrow 2Br\bullet + M$

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

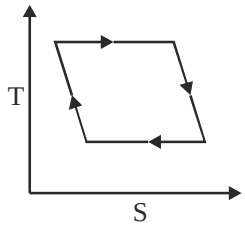
6. The correct statement for the following structures is

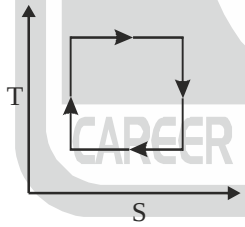


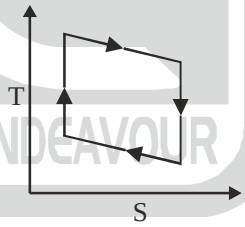
1 **2** **3**

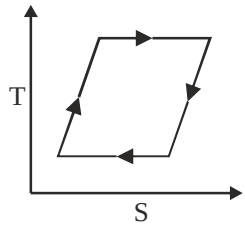
(a) **1**, **2** and **3** are resonance structures
(b) **1** and **2** are resonance structures, whereas **3** is an isomer of **1** and **2**
(c) **1** and **3** are resonance structures, whereas **2** is an isomer of **1** and **3**
(d) **1**, **2** and **3** are constitutional isomers.

7. The graph that represents the temperature (T)-entropy(S) variation of a Carnot cycle is

(a) 

(b) 

(c) 

(d) 

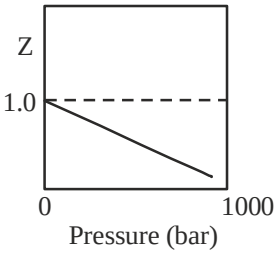
8. One of the products of the hydrolysis of calcium phosphide at 25ºC is
(a) Phosphine (b) phosphoric acid (c) phosphorus pentoxide (d) white phosphorus

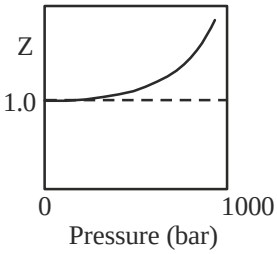
9. The salt bridge in a galvanic cell allows the flow of
(a) ions but NOT electrons (b) BOTH ions and electrons
(c) electrons but NOT ions (d) NEITHER ions NOR electrons

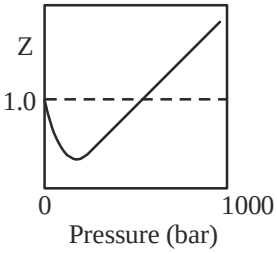
10. The nucleobase NOT found in DNA is
(a) Thymine (b) Uracil (c) Guanine (d) Adenine

Q.11 – Q.30 carry TWO marks each.

11. 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)


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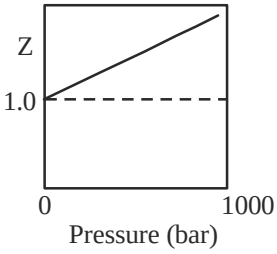
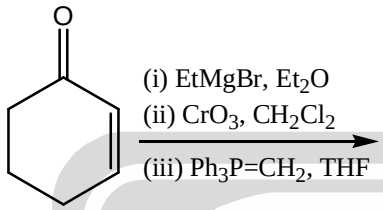
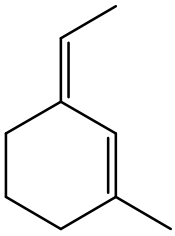
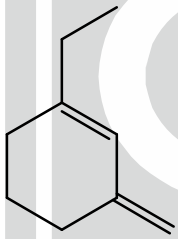
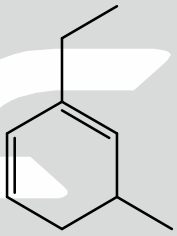
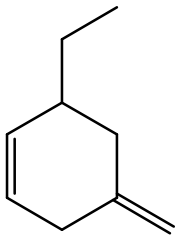


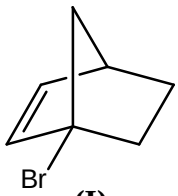
12. The major product formed in the following reaction sequence is



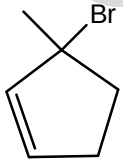
(a) 
(b) 
(c) 
(d) 

13. The number of non-bonding electrons present in the frontier molecular orbitals of HF is
(a) 10 (b) 4 (c) 6 (d) 8

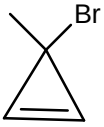
14. The rate of solvolysis of I-IV follows



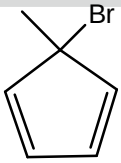
(I)



(II)



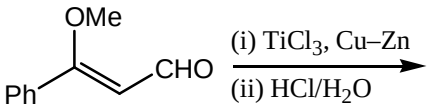
(III)

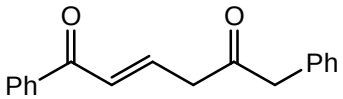


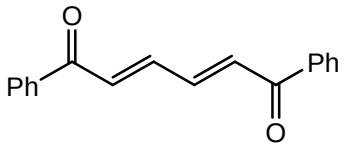
(IV)

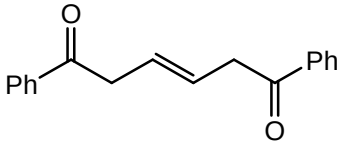
(a) I > II > III > IV (b) III > I > II > IV (c) III > II > I > IV (d) IV > I > II > III

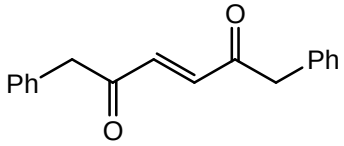
15. The major product formed in the following reaction sequence is



(a) 

(b) 

(c) 

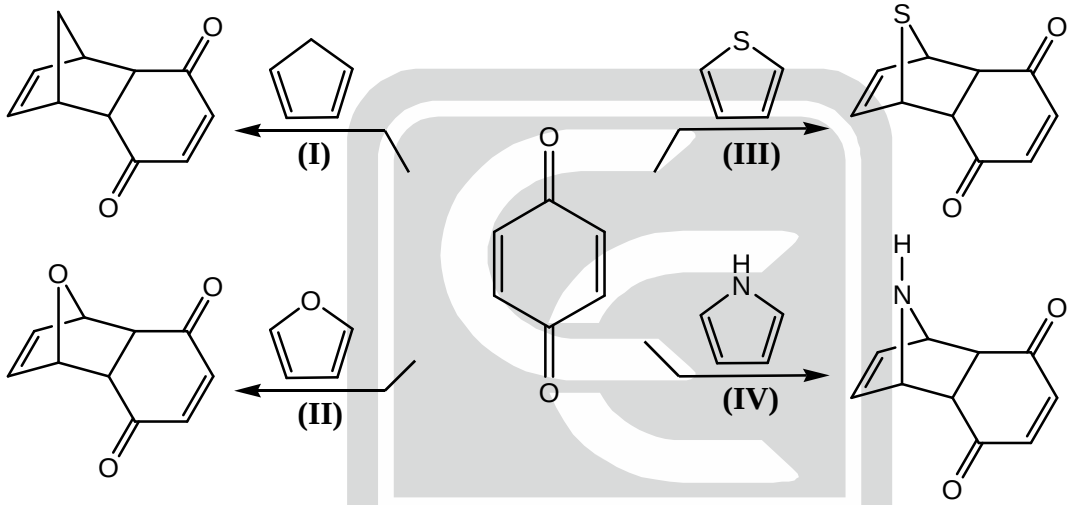
(d) 

16. 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

17. 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

18. 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

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

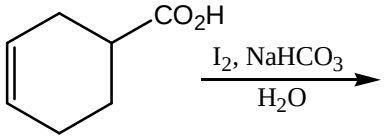
(a) $\left[Co_2(CO)_8\right]$ (b) $\left[Fe(CO)_4\right]^{2-}$

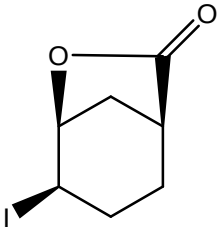
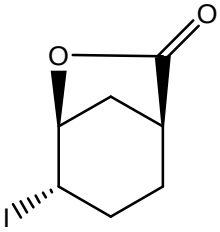
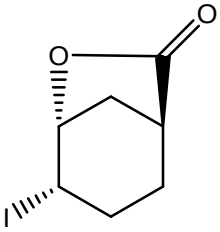
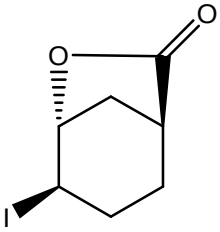
(c) $\left[HMn(CO)_5\right]$ (d) $\left[\left(\eta^5\text{-}C_5H_5\right)RuCl(CO)(PPh_2)\right]$

20. The geometries of the species $\left[Br_3\right]^+$, $\left[Br_3\right]^-$ and $\left[BrF_3\right]$ are, respectively

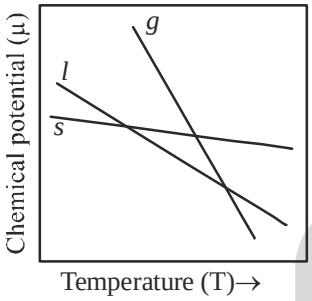
(a) linear, trigonal bipyramidal and trigonal bipyramidal
(b) linear, linear and trigonal planar
(c) tetrahedral, trigonal bipyramidal and trigonal bipyramidal
(d) tetrahedral, trigonal pyramidal and trigonal planar

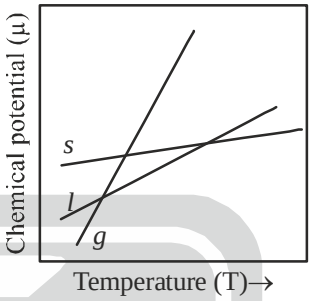
21. The major product formed in the following reaction is

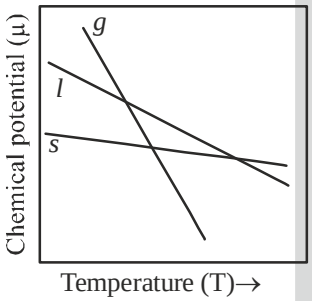


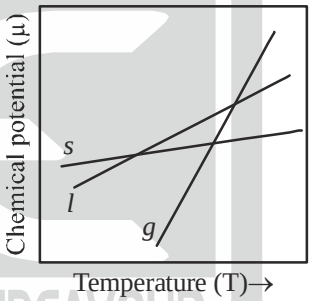
(a) 
(b) 
(c) 
(d) 

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

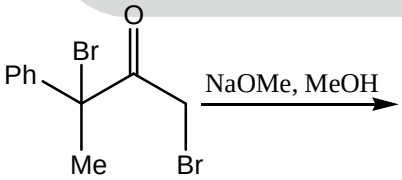
(a) 

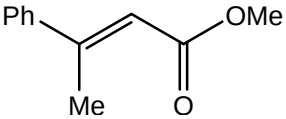
(b) 

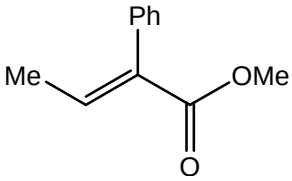
(c) 

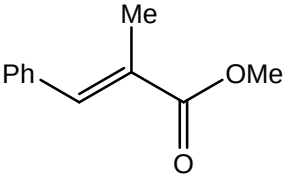
(d) 

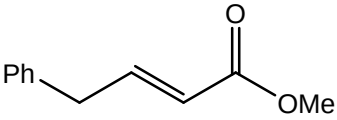
23. The major product formed in the following reaction is



(a) 

(b) 

(c) 

(d) 

24. The correct statements regarding the determinants (Det) of matrices *R*, *S* and *T* is

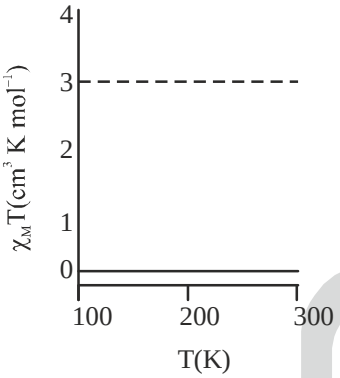
$$R = \begin{bmatrix} 3 & 2 & 4 \\ 4 & 5 & 7 \\ 1 & 3 & 8 \end{bmatrix} \qquad S = \begin{bmatrix} 2 & 3 & 4 \\ 5 & 4 & 7 \\ 3 & 1 & 8 \end{bmatrix} \qquad T = \begin{bmatrix} 3 & 4 & 1 \\ 2 & 5 & 3 \\ 4 & 7 & 8 \end{bmatrix}$$

(a) $\mathrm{Det}(R) = \mathrm{Det}(S) \neq \mathrm{Det}(T)$ (b) $\mathrm{Det}(R) = \mathrm{Det}(T) \neq \mathrm{Det}(S)$

(c) $\mathrm{Det}(R) = \mathrm{Det}(S) = \mathrm{Det}(T)$ (d) $\mathrm{Det}(R) \cdot \mathrm{Det}(S) \cdot \mathrm{Det}(T)$ are all different

25. The plot showing the magnetic behaviour of oxy-(solid line) and deoxy-haemoglobin (dashed line) is

$(\chi_M = \text{molar magnetic susceptibility, T = temperature})$

(a)


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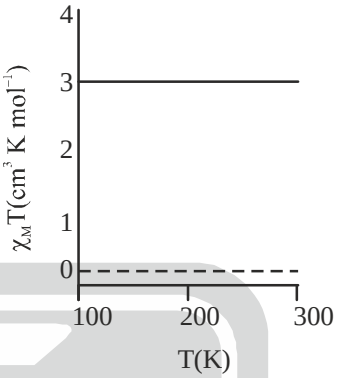
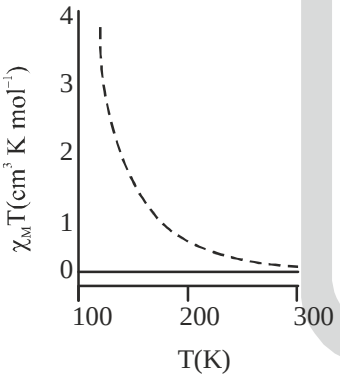
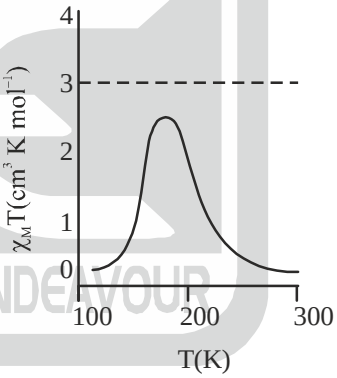
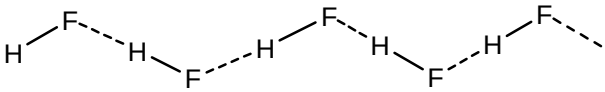


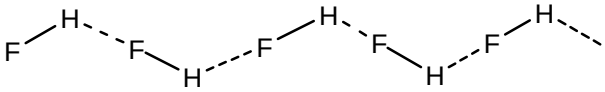
(c)


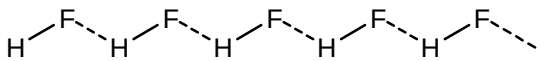
(d)


26. The solid state structures of HF is

(a) H—F------H—F-----H—F----

(b) 

(c) 

(d) 

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

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

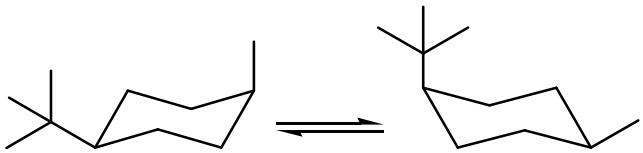
28. The force constant for $H^{35}Cl$ and $D^{35}Cl$ are the same and both can be considered as harmonic oscillators. $H^{35}Cl$ has a has a fundamental vibrational transition at 2886 cm^{-1}. The ratio of the zero-point energy of $H^{35}Cl$ to that of $D^{35}Cl$ is

(a) 0.515 (b) 0.717 (c) 1.395 (d) 1.946

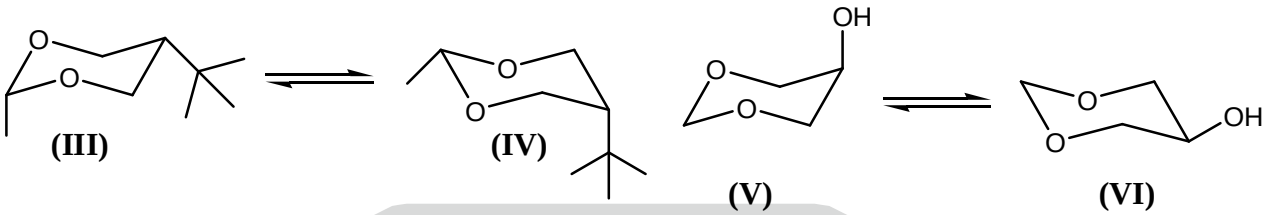
29. The cage-type structure adopted by boron hydride, $\left[B_5H_{11}\right]$, is

(a) *closo* (b) *nido* (c) *hypo* (d) *arachno*

30. 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

SECTION-B

Multiple Select Questions (MSQ)

Q.1 – Q.10 carry TWO marks each.

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

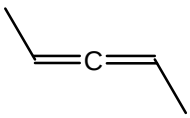
(a) $\left[Mn\left(CO\right)_5\left(CH_3\right)\right]$

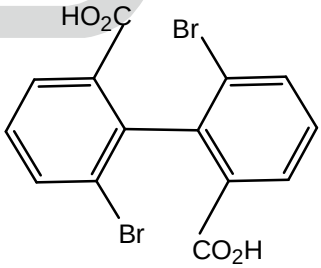
(b) [*trans*-Ni(ethylene diamine)$_2$Cl$_2$]

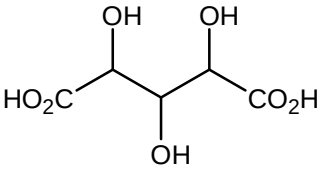
(c) [*trans*-$Co(CN)_4(H_2O)_2]^-$

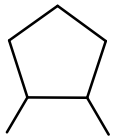
(d) [trans-$Fe(CN)_4Cl_2]^{4-}$

2. Achiral stereoisomer(s) is(are) possible for

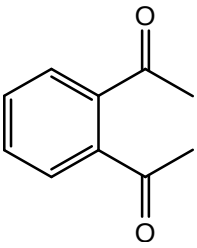
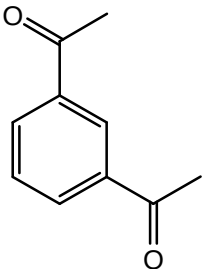
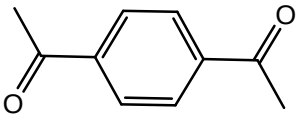
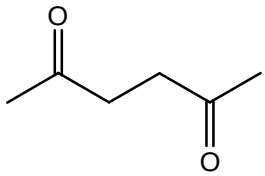
(a) 

(b) 

(c) 

(d) 

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

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

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

5. The soft Lewis base(s) is(are)

(a) I^- (b) CO (c) H^- (d) CH_3NC

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

(a) Lithium divinylcuprate

(b) Lithium diisopropylamide

(c) Potassium *tert*-butoxide

(d) Isopropyl magnesiumiodide

7. In water, the enthalpy of a protein in its folded sate (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 at a temperature T, is(are)

(a) $S_{UF} < S_F$

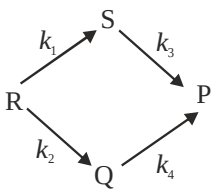
(b) $S_{UF} = 0$

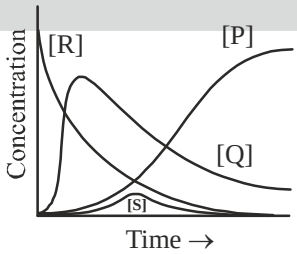
(c) $S_{UF} = S_F$

(d) $(S_F - S_{UF}) > (H_F - H_{UF})/T$

8. For the reaction shown in Scheme-1, the concentration profiles of different species are

Scheme-1

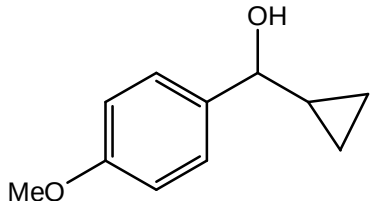




Based on this graph, the correct condition(s) regarding the rate constants is(are)

(a) $k_2 > k_4$ (b) $k_3 > k_1$ (c) $k_2 > k_1$ (d) $k_1 = k_2$

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



(a) (i) 4-Iodophenol, Mg, ether
(ii) Cyclopropane carboxaldehye, 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

10. 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) $(CH_3CH_2)_3B:NH_3$

SECTION-C

Numerical Answer Type (NAT)

Q.1 – Q.10 carry ONE mark each.

1. 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)

2. 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)

3. The number of lone pairs present in phoshonic acid (phosphorus acid) is _____

4. 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})

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

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

7. 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 (in Å) between the centers of two C_{60} molecules is _____(Round off to two decimal places)

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

9. The value of *n* in $\left[P_nO_{18}\right]^{6-}$ is _____

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

Q.11 – Q.20 carry TWO marks each.

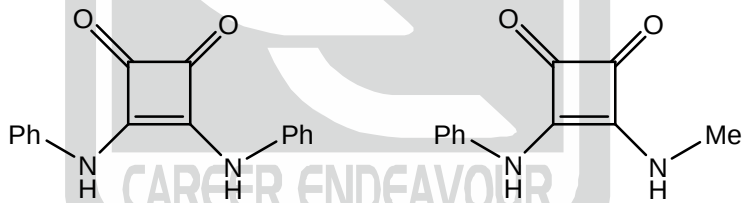
11. Titanium tetrachloride ($TiCl_4$) reacts with THF to form an octahedral complex X under inert atmosphere at 25ºC. If 5.0 of $TiCl_4$ is used and the yield is 80%, the amount of X (in grams) formed is _____(Round off to one decimal place)
(Use atomic weights: Ti=48, Cl=35.5, O=16, C=12 and H=1)

12. 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)

13. Sea water containing 1M NaCl has to be desalinated at 300K 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)

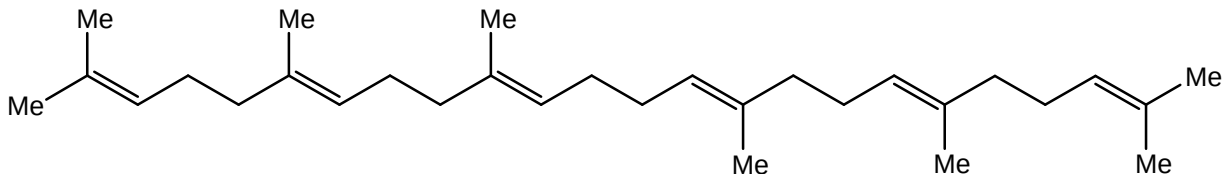
14. For the reaction, $CuSO_4(aq) + Zn(s) \longrightarrow ZnSO_4(aq) + Cu(s)$, the value of ΔG° (in kJ mol^{-1}) is _____(Round off to nearest integer)
(Reduction potential: $Cu^{2+}(aq)/Cu(s) = +0.34$ V; $Zn^{2+}(aq)/Zn(s) = -0.76$V)
(Faraday constant = 96485 C mol^{-1})

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

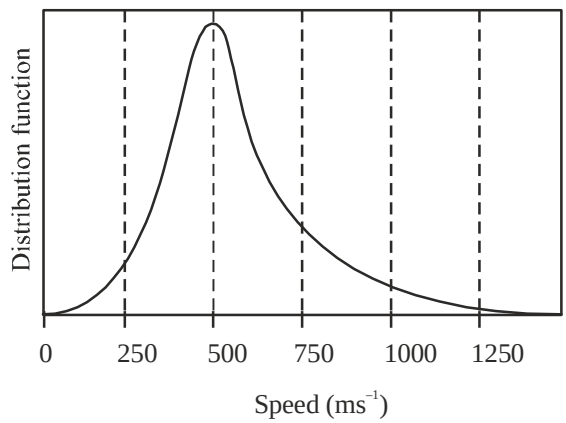


(I) **(II)**

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



17. The Maxwell distribution of speeds of a gas at 300K 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})

18. 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

19. A bacterial colony grows via cell division where each mother bacterium independently produces two daughter cells in 20 minutes. If the concentration of bacterial 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).

20. 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)

$$\left(\text{Given: } \log_{10}\gamma_{\pm} = -0.509\ z_{+}|z_{-}|\sqrt{I}\right)$$