PAPER : IIT-JAM 2021

CHEMISTRY-CY

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. Two sets of quantum numbers with the same number of radial nodes are

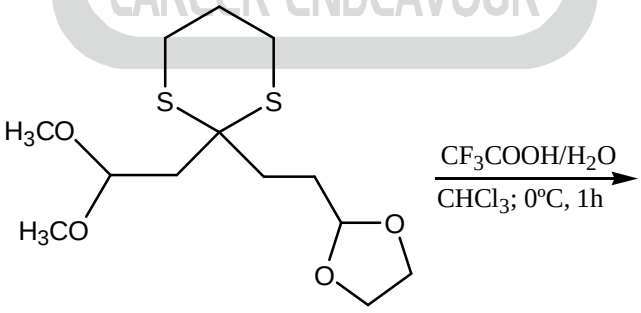
   (a) $n=3;\ \ell=0;\ m_\ell=0$ and $n=2;\ \ell=0;\ m_\ell=0$

   (b) $n=3;\ \ell=2;\ m_\ell=0$ and $n=2;\ \ell=1;\ m_\ell=0$

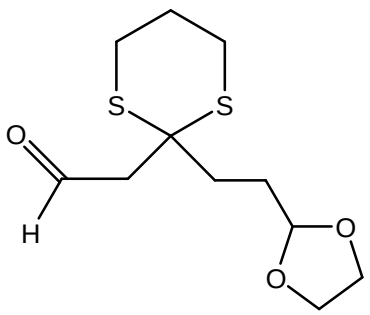
   (c) $n=3;\ \ell=1;\ m_\ell=-1$ and $n=2;\ \ell=1;\ m_\ell=0$

   (d) $n=3;\ \ell=1;\ m_\ell=1$ and $n=2;\ \ell=1;\ m_\ell=0$

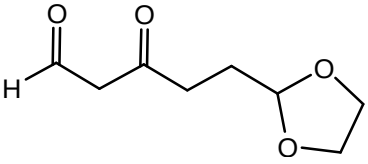
2. The major product formed in the following reaction is

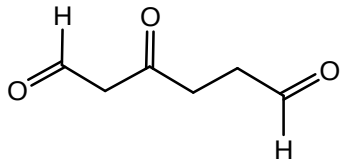


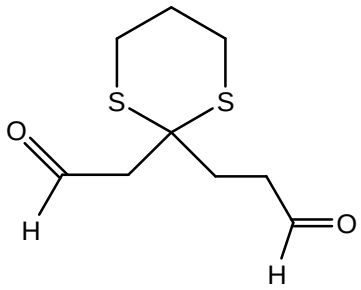
(a)



(b)



(c) 

(d) 

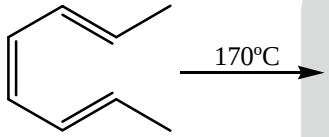
3. Among the following, the matrices with non-zero determinant are

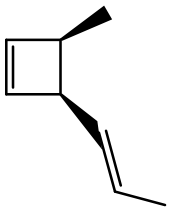
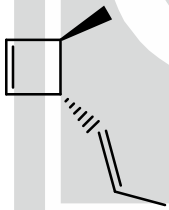
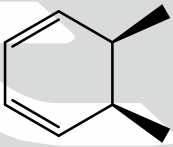
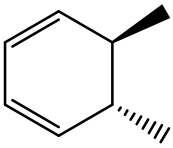
$$\mathbf{P}:\begin{bmatrix}1&0&0&0\\0&1&0&0\\0&0&1&0\\0&0&0&1\end{bmatrix}\quad \mathbf{Q}:\begin{bmatrix}1&0&0&0\\0&2&0&0\\0&0&3&0\\0&0&0&4\end{bmatrix}\quad \mathbf{R}:\begin{bmatrix}1&0&0&0\\2&2&0&0\\3&1&3&0\\4&3&1&4\end{bmatrix}\quad \mathbf{S}:\begin{bmatrix}1&2&3&1\\2&3&4&2\\3&4&1&3\\4&1&2&4\end{bmatrix}$$

(a) P, Q and S (b) P, Q and R (c) P, R and S (d) Q, R and S

4. For Na^+, Mg^{2+}, Al^{3+} and F^-, the **CORRECT** order of ionic radii is
(a) $Al^{3+} > Mg^{2+} > Na^+ > F^-$ (b) $Al^{3+} > Na^+ > Mg^{2+} > F^-$
(c) $F^- > Na^+ > Mg^{2+} > Al^{3+}$ (d) $Na^+ > F^- > Mg^{2+} > Al^{3+}$

5. The major product formed in the following reaction is



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

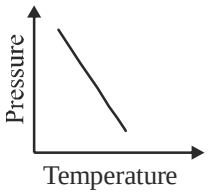
6. The CORRECT order of pK_a for the compound I to IV in water at 298 K is

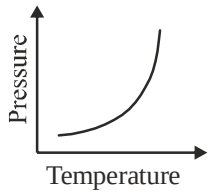
$\underset{(\mathbf{I})}{HCo(CO)_4}$ $\underset{(\mathbf{II})}{HCo(CO)_3(PPh_3)}$ $\underset{(\mathbf{III})}{HCo(CO)_3(P(OPh)_3)}$ $\underset{(\mathbf{IV})}{HCo(CO)_2(PPh_3)_2}$

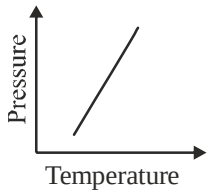
(a) I > II > III > IV (b) IV > III > II > I (c) IV > II > III > I (d) I > III > II > IV

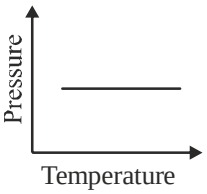
7. Spin-only magnetic moments (in BM) of $\left[NiCl_2(PPh_3)_2\right]$ and $\left[Mn(NCS)_6\right]^{4-}$, respectively
(a) 0.00 and 1.89 (b) 2.83 and 1.89 (c) 2.83 and 5.92 (d) 0.00 and 5.92

8. A pure substance M has lesser density in solid state than in liquid state. The ΔS_{fusion} of M is +25 $J\,K^{-1}\,mol^{-1}$. The CORRECT representative Pressure-Temperature diagram for the fusion of M is

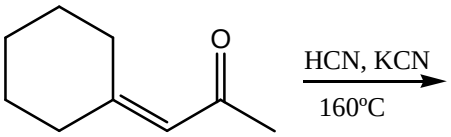
(a) 

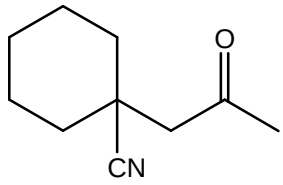
(b) 

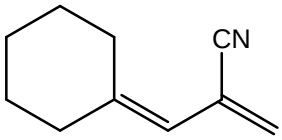
(c) 

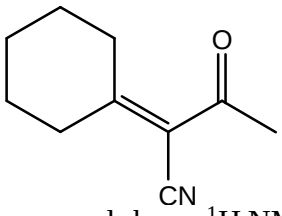
(d) 

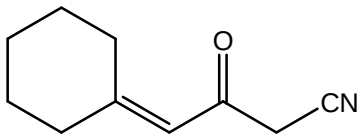
9. The major product formed in the following reaction is



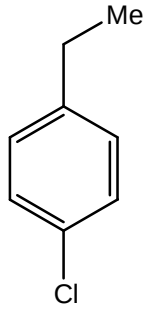
(a) 

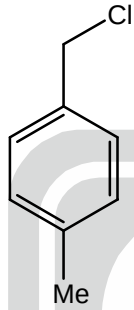
(b) 

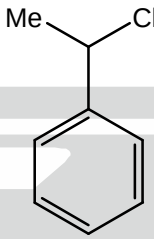
(c) 

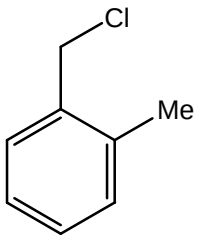
(d) 

10. A compound shows ^{1}H NMR peaks at δ-values (in ppm) 7.31 (2H), 7.21 (2H), 4.5 (2H) and 2.3 (3H). The structure of the compound is

(a) 

(b) 

(c) 

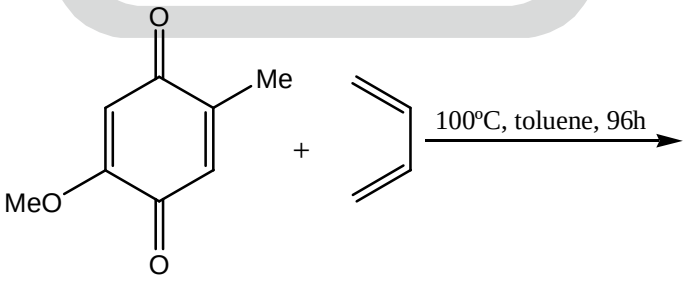
(d) 

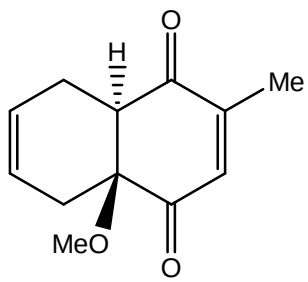
Q.11 – Q.30 carry TWO marks each.

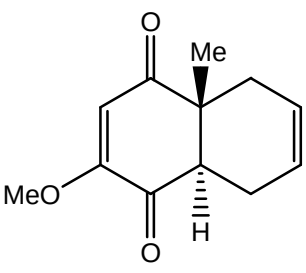
11. For $\alpha > 0$, the value of the integral $\int_{-\infty}^{+\infty} xe^{-\alpha x^2} dx$ is

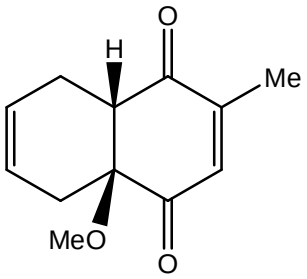
(a) 0 (b) $\sqrt{\frac{\pi}{\alpha}}$ (c) ∞ (d) 1

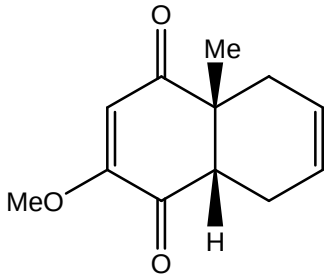
12. The major product formed in the following reaction is



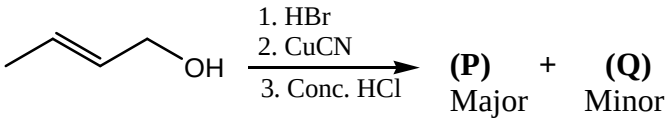
(a) 

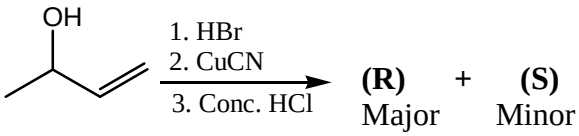
(b) 

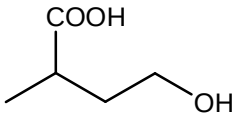
(c) 

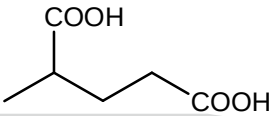
(d) 

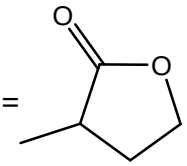
13. The products P, Q, R and S formed in the following reactions are

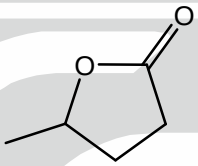


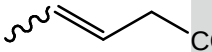


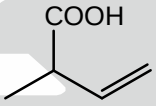
(a) **P** = **S** = 

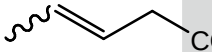
and **Q** = **R** = 

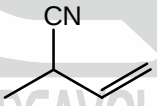
(b) **P** = **S** = 

and **Q** = **R** = 

(c) **P** = **R** = 

and **Q** = **S** = 

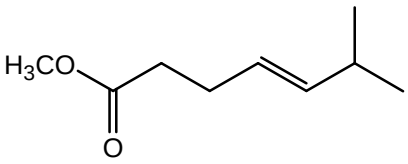
(d) **P** = **R** = 

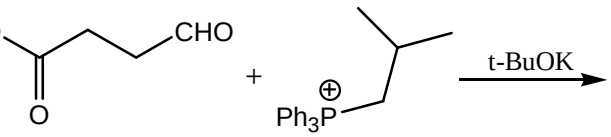
and **Q** = **S** = 

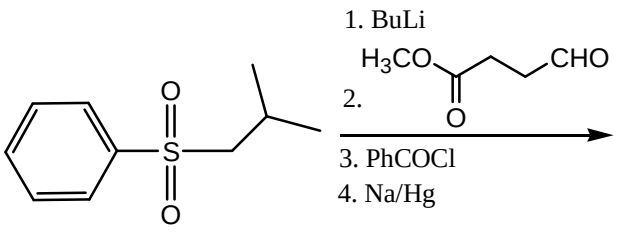
14. Reaction of BCl_3 with NH_4Cl at 140ºC produces compound P. Further, P reacts with $NaBH_4$ to give a colorless liquid Q. The reaction of Q with H_2O at 100ºC produces compound R and a diatomic gas S. Among the following, the CORRECT statement is

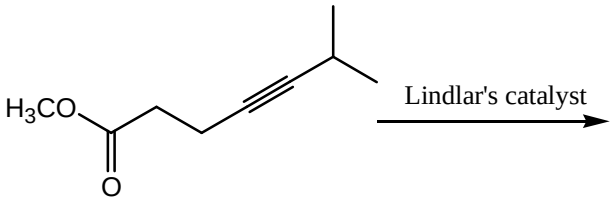
(a) S is Cl_2 (b) P is $B_3N_3H_6$ (c) R is $[B(OH)NH]_3$ (d) Q is $[BClNH]_3$

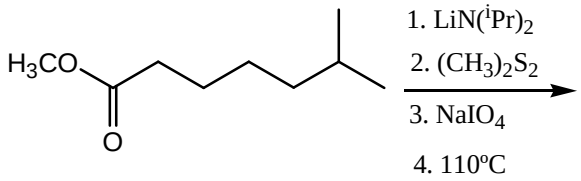
15. The reaction that produces the following as a major product is



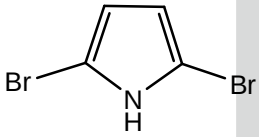
(a) 

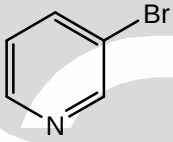
(b) 

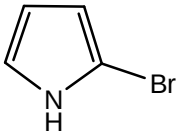
(c) 

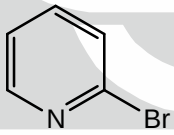
(d) 

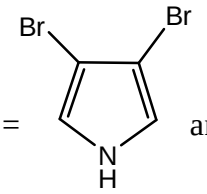
16. The major products **E** and **F** formed in the following reactions are

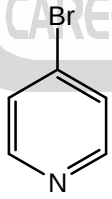
(a) **E** = 

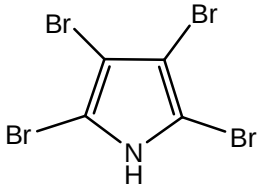
and **F** = 

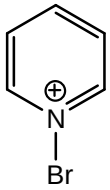
(b) **E** = 

and **F** = 

(c) **E** = 

and **F** = 

(d) **E** = 

and **F** = 

17. For the consecutive reaction,

$$X \xrightarrow{k_X} Y \xrightarrow{k_Y} Z$$

C_0 is the initial concentration of X. The concentrations of X, Y and Z at time t are C_X, C_Y and C_Z, respectively. The expression for the concentration of Y at time t is

(a) $\frac{k_X C_0}{k_Y - k_X}\left(e^{-k_Y t} - e^{-k_X t}\right)$ (b) $\frac{k_X C_X}{k_Y - k_X}\left(e^{-k_X t} - e^{-k_Y t}\right)$

(c) $\frac{k_X C_X}{k_Y - k_X}\left(e^{-k_Y t} - e^{-k_X t}\right)$ (d) $\frac{k_X C_0}{k_Y - k_X}\left(e^{-k_X t} - e^{-k_Y t}\right)$

18. The complex that does **NOT** obey the 18-electron rule is
(Given: Atomic number of Ti, Mn, Ta and Ir are 22, 25, 73 and 77, respectively)

(a) $\left[\left(\eta^5\text{-}C_5H_5\right)Ti(CO)_4\right]^-$ (b) $\left[\left(\eta^5\text{-}C_5H_5\right)Ir(CH_2)(PMe_3)\right]$

(c) $\left[TaCl_3(PEt_3)_2(CHCMe_3)\right]$ (d) $\left[Mn(SnPh_3)_2(CO)_4\right]^-$

19. The CORRECT statement regarding the molecules BF_3 and CH_4 is
(a) Both BF_3 and CH_4 are microwave active
(b) Both BF_3 and CH_4 are infrared active
(c) BF_3 is microwave active and infrared active
(d) CH_4 is microwave active and infrared inactive

20. The decreasing order of C=C bond length in the following complexes is

(I) $\left[Cl_3Pt(CH_2=CH_2)\right]^-$ **(II)** $\left[Cl_3Pt\left(C(CN)_2=C(CN)_2\right)\right]^-$

(III) $\left[Cl_3Pt(CF_2=CH_2)\right]^-$ **(IV)** $\left[Cl_3Pt(CF_2=CF_2)\right]^-$

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

21. The volume correction factor for a non-ideal gas in terms of critical pressure (p_c), critical molar volume (V_c), critical temperature (T_c) and gas constant (R) is

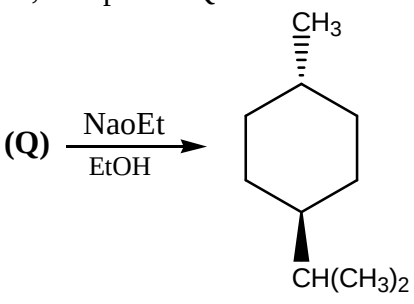
(a) $\frac{8p_cV_c}{3T_c}$ (b) $3p_cV_c^2$ (c) $\frac{27R^2T_c^2}{64p_c}$ (d) $\frac{RT_c}{8p_c}$

22. Half-life ($t_{½}$) of a chemical reaction varies with the initial concentration of reactant (A_o) as given below:

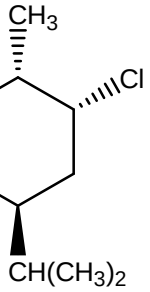
$A_o\left(\text{mol L}^{-1}\right)$	5×10^{-2}	4×10^{-2}	3×10^{-2}
$t_{½}(s)$	360	450	600

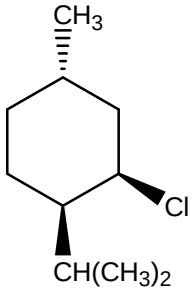
The order of the reaction is
(a) 0 (b) 1 (c) 3 (d) 2

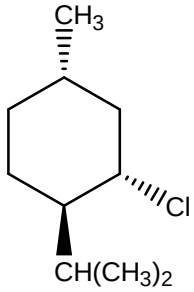
23. In the following reaction, compound Q is

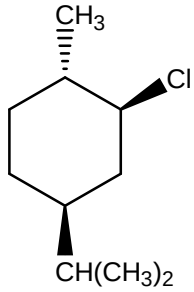


(only product)

(a) 

(b) 

(c) 

(d) 

24. Monochromatic X-rays having energy 2.8×10^{-15} J diffracted (first order) from (200) plane of a cubic crystal at an angle 8.5°. The length of unit cell in Å of the crystal (rounded off to one decimal place) is
(Given: Planck's constant, $h = 6.626\times10^{-34}$ Js, $c = 3.0\times10^{8}$ ms^{-1})
(a) 2.4 (b) 4.8 (c) 9.8 (d) 3.4

25. The CORRECT combination for metalloenzymes given in **Column-I** with their catalytic reactions in **Column-II** is

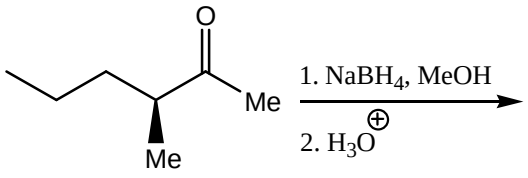
Column-I	**Column-II**
(I) Cytochrome P-450	(K) $2H_2O_2 \longrightarrow 2H_2O + O_2$
(II) Catalase	(L) $R\text{-}CH_2OH + O_2 \longrightarrow R\text{-}CHO + H_2O$ (R=alkyl or aryl)
(III) Galactose oxidase	(M) $O_2 + 4H^+ + 4e^- \longrightarrow 2H_2O$
(IV) Cytochrome c oxidase	(N) $R - H + O_2 + 2e^- + 2H^+ \longrightarrow R - OH + H_2O$ (R = alkyl or aryl)

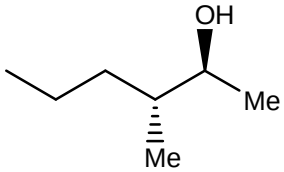
(a) (I)-(N); (II)-(K); (III)-(L); (IV)-(M) (b) (I)-(M); (II)-(N); (III)-(K); (IV)-(L)
(b) (I)-(N); (II)-(L); (III)-(K); (IV)-(M) (d) (I)-(M); (II)-(K); (III)-(L); (IV)-(N)

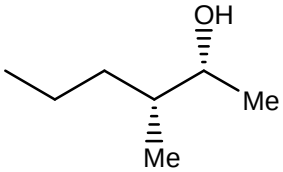
26. Hybridization of central atoms in I_3^-, ClF_3 abd SF_4, respectively, are
(a) sp, sp^3d and dsp^2 (b) sp^3d, sp^3d and sp^3d
(c) sp^3d, sp^2 and dsp^2 (d) sp, sp^2 and sp^3d

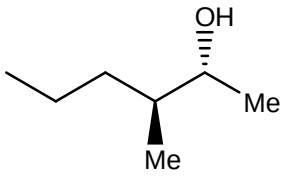
27. According to the crystal field theory, d-d transition observed in $\left[Ti\left(H_2O\right)_6\right]^{3+}$ is
(a) Laporte allowed and spin allowed (b) Laporte forbidden and spin forbidden
(c) Laporte forbidden and spin allowed (d) Laporte allowed and spin forbidden

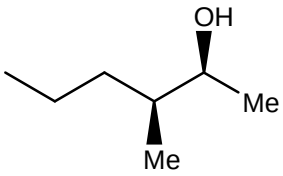
28. The major product formed in the following reaction is



(a) 

(b) 

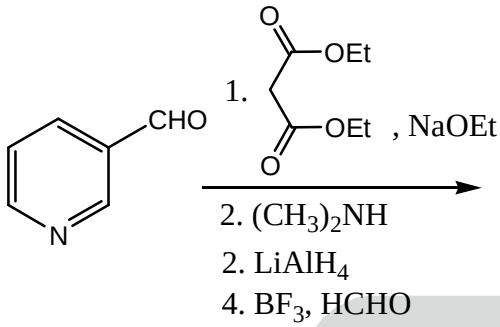
(c) 

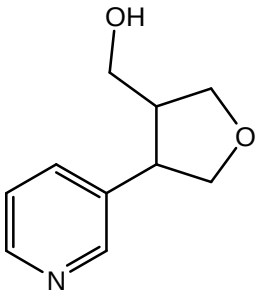
(d) 

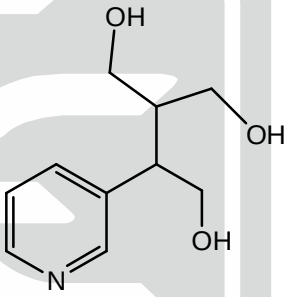
29. Reaction of $\left[Ni(CN)_4\right]^{2-}$ with metallic potassium in liquid ammonia at –33 °C yields complex **E**. The geometry and magnetic behaviour of **E**, respectively, are

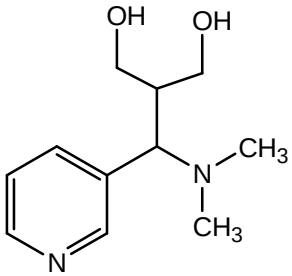
(a) Octahedral and paramagnetic
(b) Tetrahedral and diamagnetic
(c) Square planar and diamagnetic
(d) Square pyramidal and paramagnetic

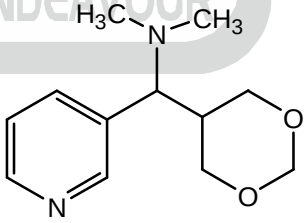
30. The major product formed in the following reaction sequence is



(a) 

(b) 

(c) 

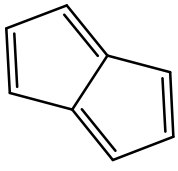
(d) 

SECTION-B

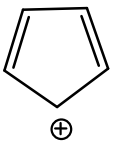
Multiple Select Questions (MSQ)

Q.1 – Q.10 carry TWO marks each.

1. Among the following, the anti-aromatic compound(s) is(are)

(a) 

(b) 

(c) 

(d) 

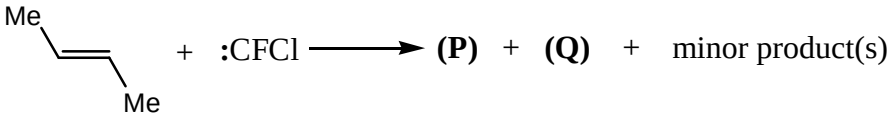
2. The pigment responsible for red color in tomato has one functional group. The CORRECT statement(s) about this functional group is/are
(a) It gives positive silver mirror test
(b) It gives hydrazone derivative on reaction with 2, 4-dinitrophenylhydrazine
(c) It decolorizes bromine water
(d) It gets cleaved on reaction with ozone

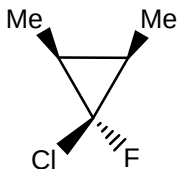
3. Hantzsch pyridine synthesis involves several steps. Some of those are
(a) Michael addition (b) Darzens reaction (c) Mannich reaction (d) Aldol reaction

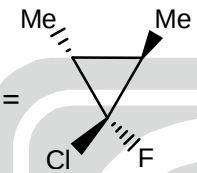
4. The functional group(s) in reducing sugar that tests positive with Tollen's reagent is/are
(a) Aldehyde (b) Ketone (c) Acetal (d) Hemi-acetal

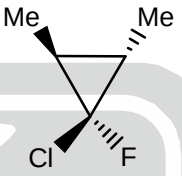
5. The CORRECT statement(s) about sodium nitroprusside is/are
(a) Nitroprusside ion is formed in the brown ring test for nitrates
(b) It is a paramagnetic complex
(c) It is used for the detection of S^{2-} in aqueous solution
(d) It contains nitrosyl ligand as NO^{+}

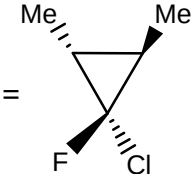
6. The product (P) and (Q) formed in the reaction are

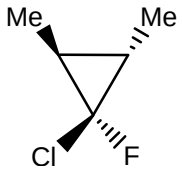


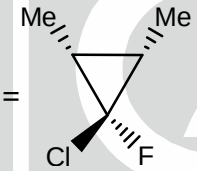
(a) **P** = 

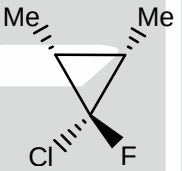
Q = 

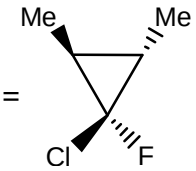
(b) **P** = 

Q = 

(c) **P** = 

Q = 

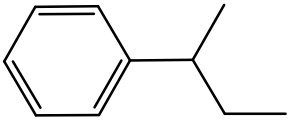
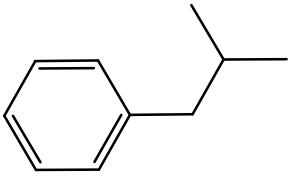
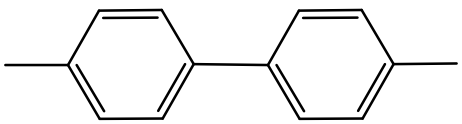
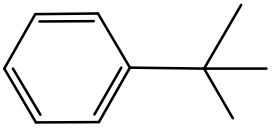
(d) **P** = 

Q = 

7. The complex(es) that show(s) Jahn-Teller distortion is/are
(a) $\left[Co(CN)_5(H_2O)\right]^{3-}$ (b) $\left[NiF_6\right]^{2-}$
(c) $\left[Mn(CNMe)_6\right]^{2+}$ (d) $\left[Co(en)_2F_2\right]^{+}$

8. The CORRECT statement(s) about the species is/are
(a) BH and CH are isolobal and isoelectronic
(b) CH_2^- and NH_2 are isolobal and isoelectronic
(c) CH_3 and $Mn(CO)_5$ are isolobal
(d) $CpMo(CO)_3$ and $CpW(CO)_3$ are isoelectronic (where Cp is cyclopentadienyl)

9. The compound(s), which give(s) benzoic acid on oxidation with $KMnO_4$ is(are)

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

10. The CORRECT Maxwell relation(s) derived from the fundamental equations of thermodynamics is/ are

(a) $\left(\frac{\partial T}{\partial V}\right)_S = \left(\frac{\partial p}{\partial S}\right)_V$ (b) $\left(\frac{\partial S}{\partial V}\right)_T = \left(\frac{\partial p}{\partial T}\right)_V$ (c) $\left(\frac{\partial T}{\partial p}\right)_S = \left(\frac{\partial V}{\partial S}\right)_p$ (d) $\left(\frac{\partial S}{\partial p}\right)_T = -\left(\frac{\partial V}{\partial T}\right)_p$

SECTION-C

Numerical Answer Type (NAT)

Q.1 – Q.10 carry ONE mark each.

1. If the root mean square speed of hydrogen gas at a particular temperature is 1900 m s^{-1}, then the root mean square speed of nitrogen gas at the same temperature, in m s^{-1} (*Rounded off to the nearest integer*), is _____

(**Given:** atomic mass of H is 1 g mol^{-1}, atomic mass of N is 14 g mol^{-1})

2. For the following fusion reaction,

$4\,{}^1H \longrightarrow {}^4He + 2\beta^+ + 2\nu + \gamma$

the Q-value (energy of the reaction) in MeV (Rounded off to one decimal place) is _____
(Given: Mass of ^1H nucleus is 1.007825 u and mass of ^4He nucleus is 4.002604u)

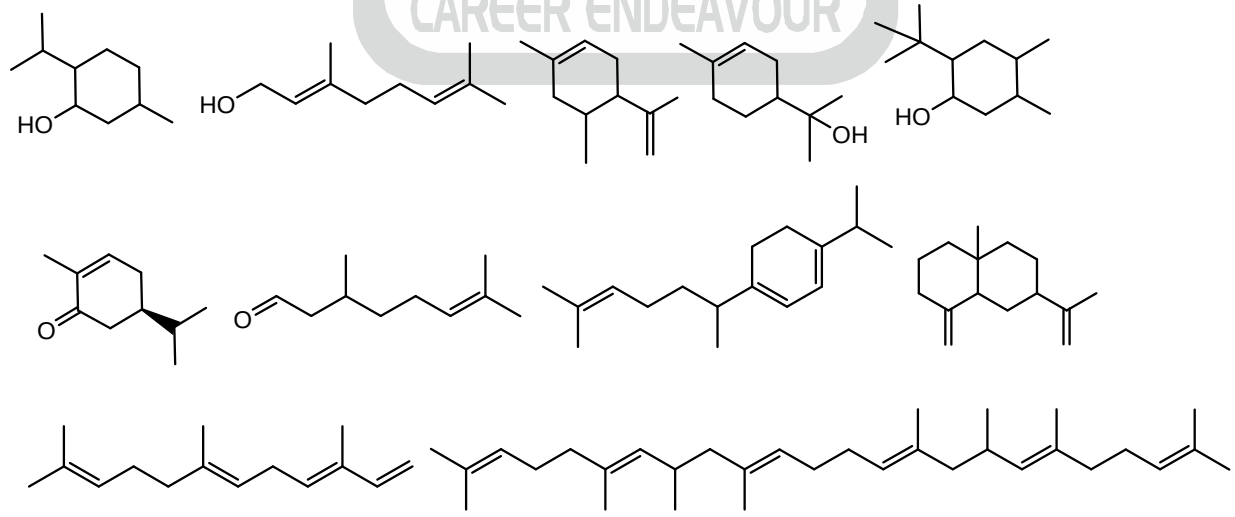
3. Adsorption of a toxic gas on 1.0 g activated charcoal is 0.75 cm^3 both at 2.5 atm, 140 K and at 30.0 atm. 280 K. The isosteric enthalpy for adsorption of the gas in kJ mol^{-1} (Rounded off to two decimal places) is _____

(Given: R = 8.314 JK^{-1} mol^{-1})

4. MgO crystallizes as rock salt structure with unit cell length 2.12 Å. From electrostatic model, the calcualted lattice energy in kJ mol^{-1} (rounded off to the nearest integer) is _____

(Given: $N_A = 6.022\times10^{23}$ mol^{-1}; Madelung constant = 1.748; $\varepsilon_0 = 8.854\times10^{-12}$ $J^{-1}C^2m^{-1}$; Charge of an electron = 1.602×10^{-19} C).

5. Among the following, the total number of terpenes (terpenoids) is



6. The total number of microstates possible for a d^8 electronic configuration is _____

7. The total number of optically active isomers of dichloridobis (glycinato) cobaltate (III) ion is _____

8. The dissociation constant of a weak monoprotic acid is 1.6×10^{-5} and its molar conductance at infinite dilution is 360.5×10^{-4} mho m^2 mol^{-1}. For 0.01 M solution of this acid, the specific conductance is $n\times10^{-2}$ mho m^{-1}. The value of n (rounded off to two decimal places) is _____

9. Calcium crystallizes in *fcc* lattice of unit cell length 5.56 Å and density 1.4848 g cm^{-3}. The percentage of Schottky defects (rounded off to one decimal place) in the crystal is _____

(Given: Atomic mass of Ca is 40 g mol^{-1}; $N_A = 6.022\times10^{23}$ mol^{-1})

10. A buffer solution is prepared by mixing 0.3 M NH_3 and 0.1 M NH_4NO_3. If K_b of NH_3 is 1.6×10^{-5} at 25°C, then the pH (rounded off to one decimal place) of the buffer solution at 25°C is _____

Q.11 – Q.20 carry TWO marks each.

11. A dolute solution prepared by dissolving a non-volatile solute in one liter water shows a depression in freezing point of 0.186 K. This solute neither dissociates nor associates in water. The boiling point of the solution in K (rounded off to three decimal places) is _____
(Given: For pure water, boiling point = 373.15 K; cryoscopic constant = 1.86 K $(mol\ kg^{-1})^{-1}$; ebullioscopic constant = 0.51 K $(mol\ kg^{-1})^{-1}$)

12. The intensity of a monochromatic visible light is reduced by 90 % due to absorption on passing through a 5.0 mM solution of a compound. If the path length is 4 cm, then the molar extinction coefficient of the compound in M^{-1} cm^{-1} is _____

13. The thermodynamic data at 298K for the decomposition reaction of limestone at equilibrium is given below.

$$CaCO_3(s) \rightleftharpoons CaO(s) + CO_2(g)$$

Thermodynamic quantity	$CaCO_3(s)$	$CaO(s)$	$CO_2(g)$
$\mu^0\ (kJ\ mol^{-1})$	−1128.8	−604.0	−394.4
$\Delta H_f^0\ (kJ\ mol^{-1})$	−1206.9	−635.1	−393.5

The partial pressure of CO_2(g) in atm evolved on heating limestone (rounded off to two decimal places) at 1200 K is _____
(Given: R = 8.314 J K^{-1} mol^{-1})

14. For the reaction,

$$Q + R \underset{k_{-1}}{\overset{k_1}{\rightleftharpoons}} X \xrightarrow{k_2} P$$

$k_1 = 2.5\times10^5$ $Lmol^{-1}s^{-1}$, $k_{-1} = 1.0\times10^4$ s^{-1} and $k_2 = 10\ s^{-1}$. Under steady state approximation, the rate constant for the overall reaction in L mol^{-1} s^{-1} (rounded off to the nearest integer) is _____

15. The mean ionic activity coefficient of 0.004 molal $CaCl_2$ in water at 298 K (rounded off to three decimal places) is _____
(Given: Debye-Huckel constant for an aqueous solution at 298 K is 0.509 $kg^{1/2}$ $mol^{-1/2}$)

16. If the crystal field splitting energy of $\left[Co\left(NH_3\right)_4\right]^{2+}$ is 5900 cm^{-1}, then the magnitude of its crystal field stabilization energy, in kJ mol^{-1} (rounded off to one decimal place) is _____

17. A salt mixture (1.0 g) contains 25 wt% of $MgSO_4$ and 75 wt% of M_2SO_4. Aqueous solution of this salt mixture on treating with excess $BaCl_2$ solution results in the precipitation of 1.49 g of $BaSO_4$. The atomic mass of M in g mol^{-1} (rounded off to two decimal places) is _____
(Given: the atomic masses of Mg, S, O, Ba and Cl are 24.31, 32.06, 16.00, 137.33 and 35.45 g mol^{-1}, respectively).

18. The surface tension (γ) of a solution, prepared by mixing 0.02 mol of an organic acid in 1L of pure water, is represented as

$$\gamma^* - \gamma = A\log(1+Bc)$$

γ^* is the surface tension of pure water, A = 0.03 N m^{-1}, B = 50 mol^{-1} L and *c* is concentration in mol L^{-1}. The excess concentration of the organic acid at the surface of the liquid, determined by Gibbs adsorption equation at 300 K is $n\times10^{-6}$ mol m^{-2}. The value of *n* (rounded off to two decimal places) is_____
(Given: R = 8.314 JK^{-1} mol^{-1})

19. The separation of energy levels in the rotational spectrum of CO is 3.8626 cm^{-1}. The bond length (assume it does not change during rotation) of CO in Å (rounded off to two decimal places) is _____
(Given: Planck's constant h = 6.626×10^{-34} Js; N_A = 6.022×10^{23} mol^{-1}; atomic mass of C is 12 g mol^{-1}, atomic mass of O is 16 g mol^{-1}; *c* = 3×10^8 ms^{-1})

20. For the molecule,

$$CH_3-CH=CH-CH(OH)-CH=CH-CH=C(CH_3)_2$$

the number of all possible stereoisomers is _____