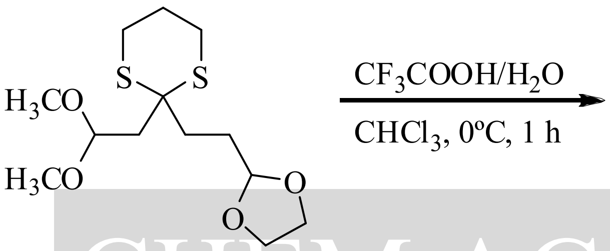
IIT JAM (2021)

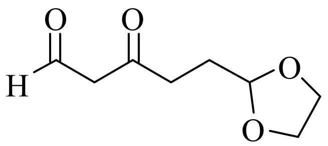
Section - A

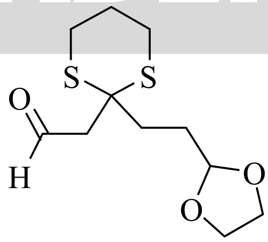
1. Spin-only magnetic moments (in BM) of $[NiCl_2(PPh_3)_2]$ and $[Mn(NCS)_6]^{4-}$, respectively, are

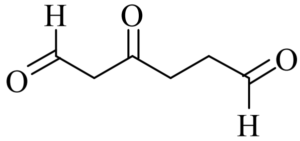
(a) 2.83 and 5.92 (b) 0.00 and 5.92 (c) 2.83 and 1.89 (d) 0.00 and 1.89

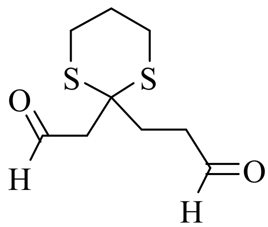
2. The major product formed in the following reaction is



(a) 

(b) 

(c) 

(d) 

3. 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) $Na^+ > F^- > Mg^{2+} > Al^{3+}$
(d) $F^- > Na^+ > Mg^{2+} > Al^{3+}$

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

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

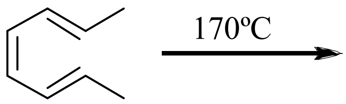
(a) I > III > II > IV (b) IV > II > III > I (c) IV > III > II > I (d) I > II > III > IV

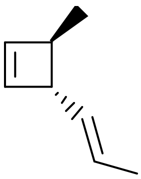
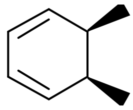
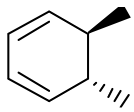
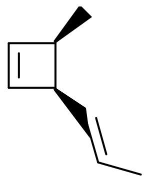
5. Among the following, the matrices with non-zero determinant are

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

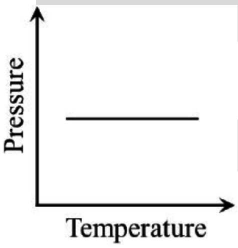
(a) P, Q and R (b) P, Q and S (c) P, R and S (d) Q, R and S

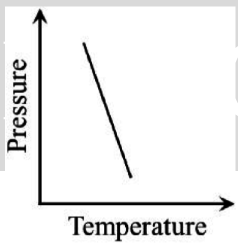
6. The major product formed in the following reaction is

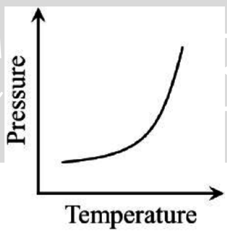


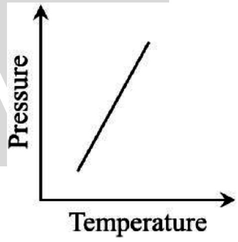
(a)  (b)  (c)  (d) 

7. 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) 

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

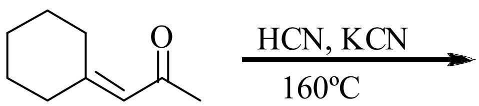
(a) $n = 3; l = 2; m_l = 0$ and $n = 2; l = 1; m_l = 0$

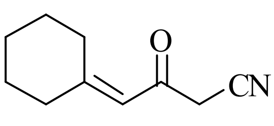
(b) $n = 3; l = 0; m_l = 0$ and $n = 2; l = 0; m_l = 0$

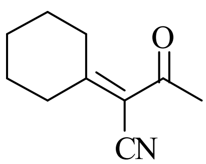
(c) $n = 3; l = 1; m_l = 1$ and $n = 2; l = 1; m_l = 0$

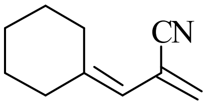
(d) $n = 3; l = 1; m_l = -1$ and $n = 2; l = 1; m_l = 0$

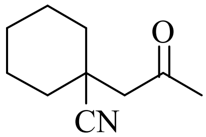
9. The major product formed in the following reaction is



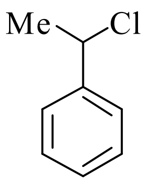
(a) 

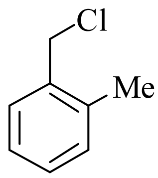
(b) 

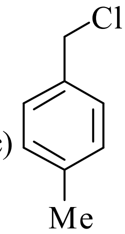
(c) 

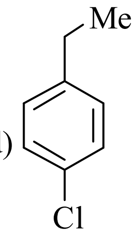
(d) 

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) 

11. For the consecutive reaction,

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

C_o 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) $\dfrac{k_X C_X}{k_Y - k_X}\left(e^{-k_X t} - e^{-k_Y t}\right)$ (b) $\dfrac{k_X C_X}{k_Y - k_X}\left(e^{-k_Y t} - e^{-k_X t}\right)$

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

12. Half-life ($t_{1/2}$) of a chemical reaction varies with the initial concentration of reactant (A_0) as given belwo:

$A_0\left(\text{mol L}^{-1}\right)$	5×10^{-2}	4×10^{-2}	3×10^{-2}
$t_{1/2}(s)$	360	450	600

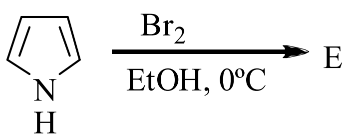
The order of the reaction is

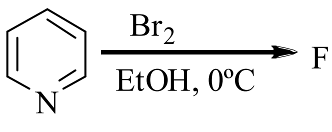
(a) 1 (b) 3 (c) 2 (d) 0

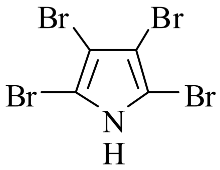
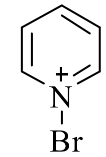
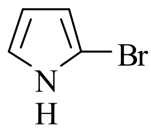
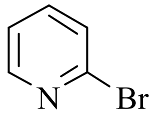
13. For α > 0, the value of the integral $\int_{-\infty}^{+\infty} xe^{-\alpha x^2}dx$ is

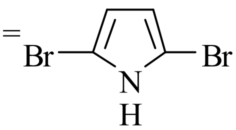
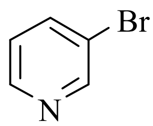
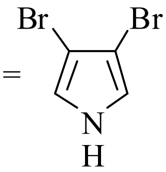
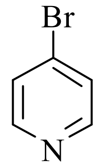
(a) 0 (b) 1 (c) $\sqrt{\dfrac{\pi}{\alpha}}$ (d) ∞

14. 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 = 

15. 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 $[BClNH]_3$

16. According to the crystal field theory, d–d transition observed in $[Ti(H_2O)_6]^{3+}$ is

(a) Laporte forbidden and spin allowed (b) Laporte allowed and spin forbidden

(c) Laporte forbidden and spin forbidden (d) Laporte allowed and spin allowed

17. 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) $2H_2O_2 \rightarrow 2H_2O + O_2$
(ii) Catalase	(L) $R–CH_2OH + O_2 \rightarrow R–CHO + H_2O_2$ (R = alkyl or aryl)
(iii) Galactose oxidase	(M) $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$
(iv) Cytochrome c oxidase	(N) $R–H + O_2 + 2e^- + 2H^+ \rightarrow R–OH + H_2O$ (R = alkyl or aryl)

(a) (i)–(M); (ii)–(K); (iii)–(L); (iv)–(N) (b) (i)–(N); (ii)–(K); (iii)–(L); (iv)–(M)

(c) (i)–(M); (ii)–(N); (iii)–(K); (iv)–(L) (d) (i)–(N); (ii)–(L); (iii)–(K); (iv)–(M)

18. The CORRECT statement regarding the molecules BF_3 and CH_4 is

(a) CH_4 is microwave active and infrared inactive

(b) Both BF_3 and CH_4 are infrared active

(c) BF_3 is microwave active and infrared active

(d) Both BF_3 and CH_4 are microwave active

19. Monochromatic X-rays having energy 2.8×10^{-15} J diffracted (first order) from (200) plane of a cubic crystal at an angle 8.5º. The length of unit cell in Å of the crystal (rounded off to one decimal place) is (Given: Planck's constant, $h = 6.626 \times 10^{-34}$ J s; $c = 3.0 \times 10^8$ m s^{-1})

(a) 9.8 (b) 4.8 (c) 2.4 (d) 3.4

20. Hybridization of the central atoms in I_3^-, ClF_3 and SF_4, respectively, are

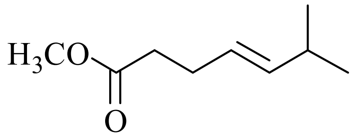
(a) sp^3d, sp^2 and dsp^2 (b) sp, sp^2 and sp^3d (c) sp, sp^3d and dsp^2 (d) sp^3d, sp^3d and sp^3d

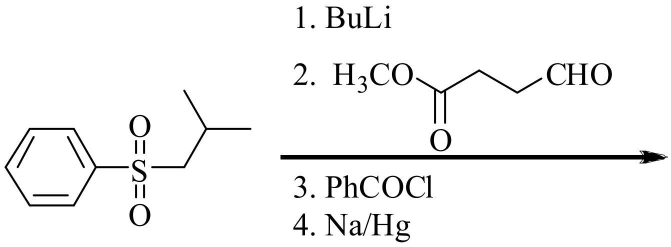
21. Reaction of $[Ni(CN)_4]^{2-}$ with metallic potassium in liquid ammonia at –33ºC yields complex E. The geometry and magnetic behavior of E, respectively, are

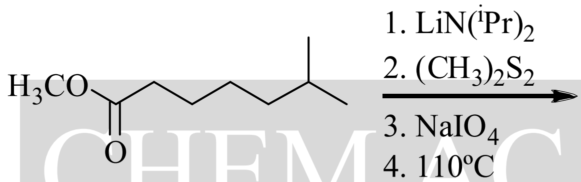
(a) Octahedral and paramagnetic (b) Tetrahedral and diamagnetic

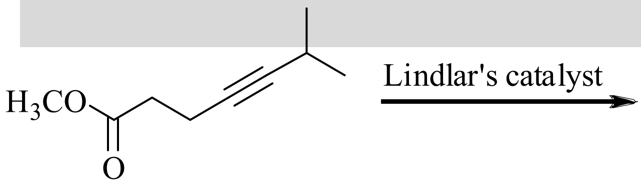
(c) Square pyramidal and paramagnetic (d) Square planar and diamagnetic

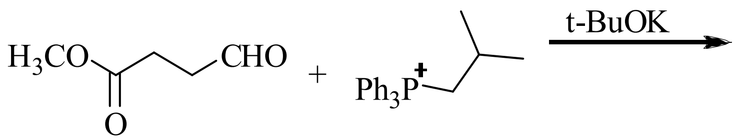
22. The reaction that produces the following as a major product is



(a) 

(b) 

(c) 

(d) 

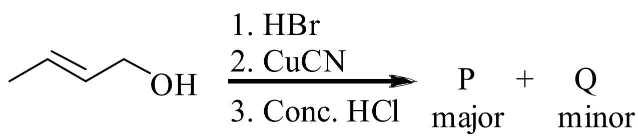
23. The complex that does NOT obey the 18-electron rule is

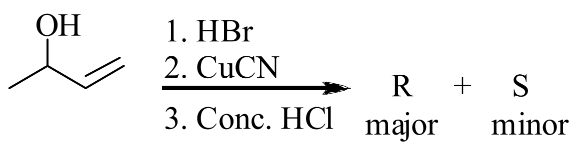
(Given: Atomic numbers of Ti, Mn, Ta and Ir are 22, 25, 73 and 77, respectively)

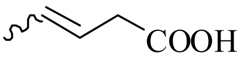
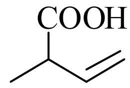
(a) $[(\eta^5\text{-}C_5H_5)Ti(CO)_4]^-$ (b) $[TaCl_3(PEt_3)_2(CHCMe_3)]$

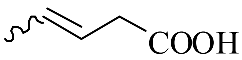
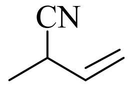
(c) $[Mn(SnPh_3)_2(CO)_4]^-$ (d) $[(\eta^5\text{-}C_5H_5)Ir(CH_2)(PMe_3)]$

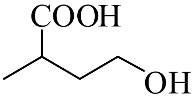
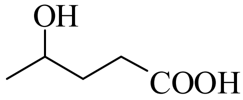
24. The products P, Q, R and S formed in the following reactions are

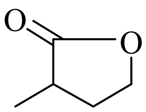
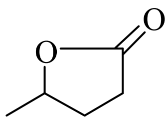




(a) P = R =  and Q = S = 

(b) P = R =  and Q = S = 

(c) P = S =  and Q = R = 

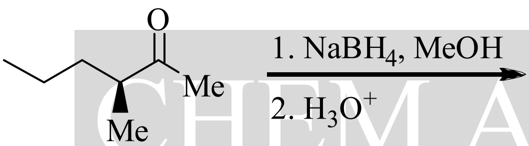
(d) P = S =  and Q = R = 

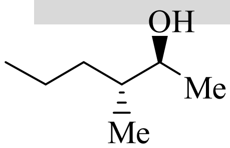
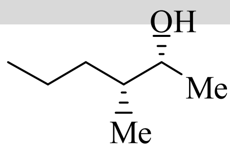
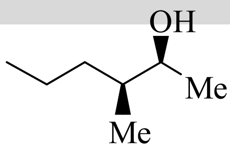
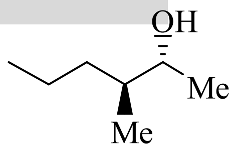
25. The decreasing order of C=C bound length in the following complexes is

$[Cl_3Pt(CH_2{=}CH_2)]^-$	$[Cl_3Pt(C(CN)_2{=}C(CN)_2)]^-$	$[Cl_3Pt(CF_2{=}CH_2)]^-$	$[Cl_3Pt(CF_2{=}CF_2)]^-$
I	II	III	IV

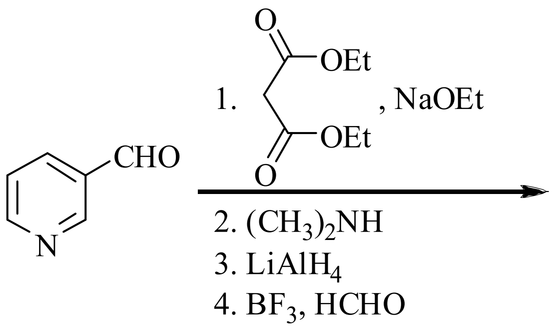
(a) II > III > IV > I (b) IV > II > III > I (c) II > IV > III > I (d) IV > II > I > III

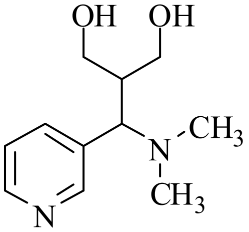
26. The major product formed in the following reaction is

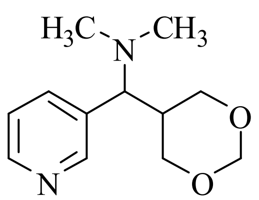


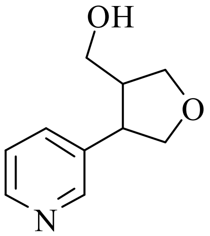
(a)  (b)  (c)  (d) 

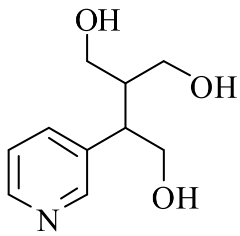
27. The major product formed in the following reaction sequence is



(a) 

(b) 

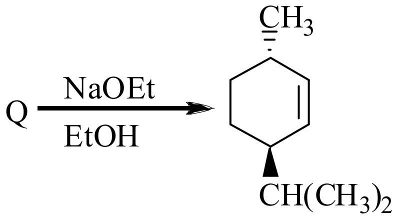
(c) 

(d) 

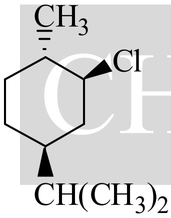
28. The volume correction factor for a non-ideal gas in terms of critical pressure (p_c), critical molar volume (V_c), critical temperature (T_c) and gas constant (R) is

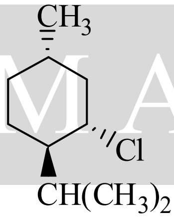
(a) $\frac{8p_cV_c}{3T_c}$ (b) $\frac{RT_c}{8p_c}$ (c) $3p_cV_c^2$ (d) $\frac{27R^2T_c^2}{64p_c}$

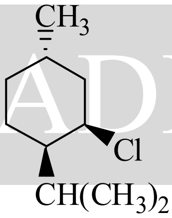
29. In the following reaction, comlpound Q is

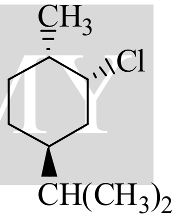


(only product)

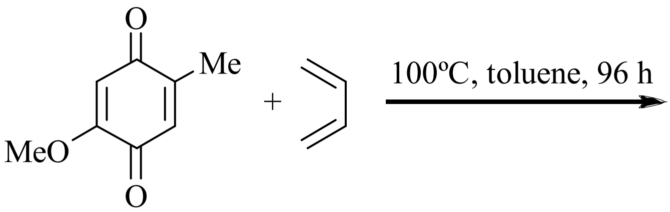
(a) 

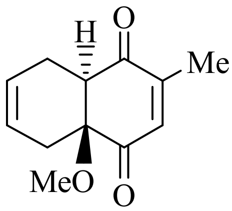
(b) 

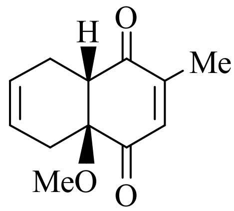
(c) 

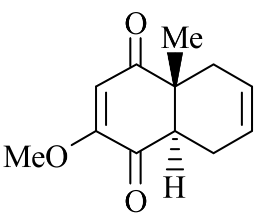
(d) 

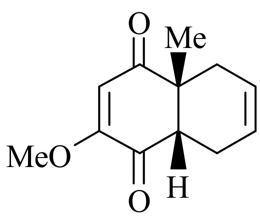
30. The major product formed in the following reaction is



(a) 

(b) 

(c) 

(d) 

Section - B

1. The functional group (s) in reducing sugar that tests positive with Tollen's reagent is (are)

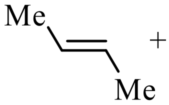
(a) Aldehyde (b) Ketone (c) Acetal (d) Hemi – acetal

2. Hantzsch pyridine synthesis involves several steps. Some of those are

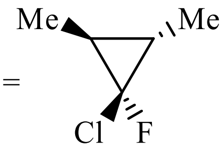
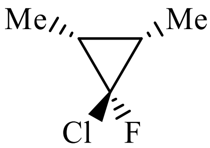
(a) Mannich reaction (b) Michael addition

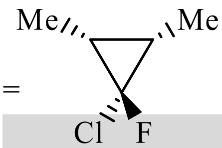
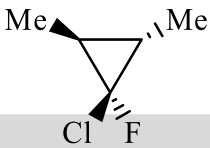
(c) Darzens reaction (d) Aldol reaction

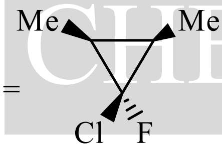
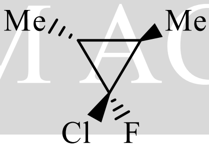
3. The product P and Q formed in the reaction are

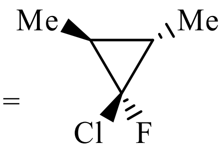
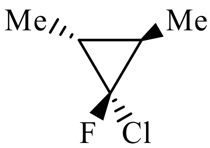


+ :CFCl (singlet state) $\longrightarrow$ P + Q + minor product(s)

(a) P =  Q = 

(b) P =  Q = 

(c) P =  Q = 

(d) P =  Q = 

4. The CORRECT statement(s) about the species is (are)

(a) $CpMo(CO)_3$ and $CpW(CO)_3$ are isoelectronic (wher Cp is cyclopentadienyl)

(b) BH and CH are isolobal and isoelectronic

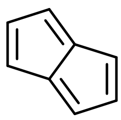
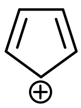
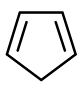
(c) CH_3 and $Mn(CO)_5$ are isolobal

(d) CH_2^- and NH_2 are isolobal and isoelectronic

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

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

6. Among the following, the anti – aromatic compound(s) is (are)

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

7. The CORRECT statement(s) about sodium nitroprusside is(are)

(a) It contains nitrosyl ligand as NO^+

(b) It is a paramagnetic complex

(c) It is used for the detection of S^{2-} in aqueous solution

(d) Nitroprusside ion is formed in the brown ring test for nitrates

8. The complex (es) that show (s) Jahn – Teller distortion is(are)

(a) $[Co(CN)_5(H_2O)]^{3-}$ (b) $[NiF_6]^{2-}$ (c) $[Co(en)_2F_2]^+$ (d) $[Mn(CNMe)_6]^{2+}$

9. The pigment responisble for red color in tomato has one functional group. The CORRECT statement(s) about this functinal group is(are)

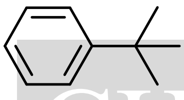
(a) It gives positive silver mirror test

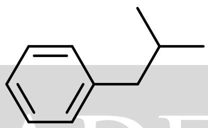
(b) It gets cleaved on reaction with ozone

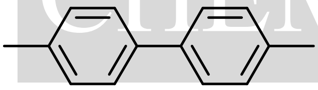
(c) It gives hydrazone derviative on reaction with 2, 4– dinitrophenylhydrazine

(d) It decolorizes bromine water

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

(a) 

(b) 

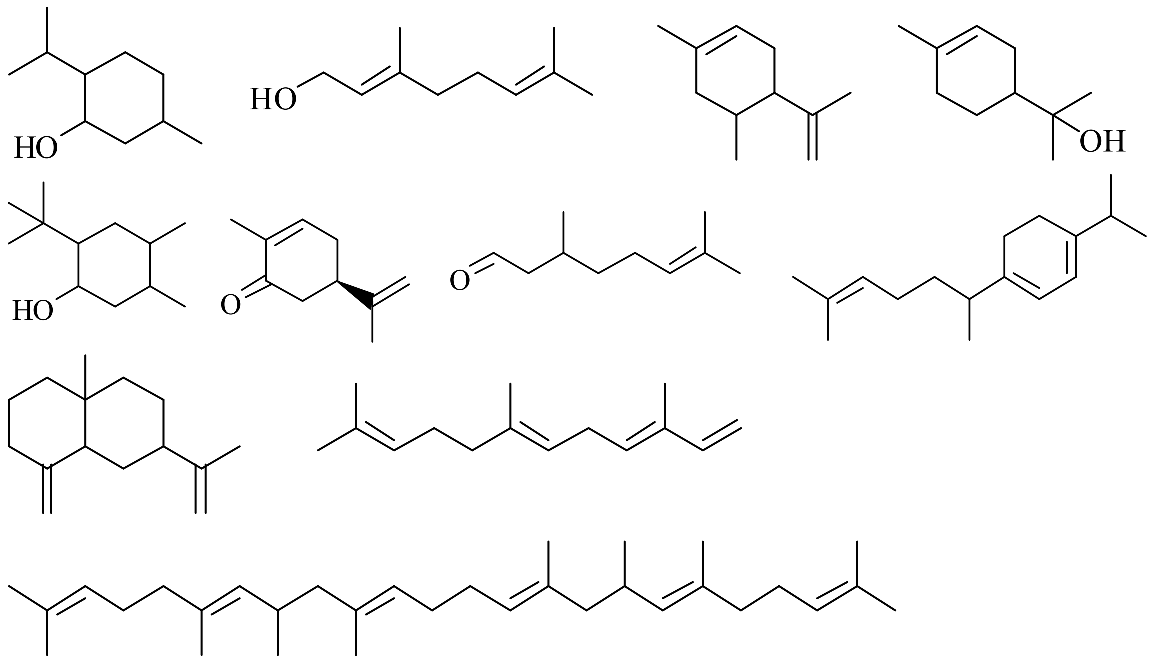
(c) 

(d) 

Section - C

1. The total number of microstates possible for a d^8 electronic configuration is_______.

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



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

4. For the following fusion reaction,

$$4\ {}^{1}H \rightarrow {}^{4}He + 2\beta^{+} + 2\upsilon + \gamma$$

the Q-value (energy of the reaction) in MeV (rounded off to one decimal place) is ______.

(Given: Mass of ^{1}H nucleus is 1.007825 u and mass of ^{4}He nucleus is 4.002604 u)

5. 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 × 10^{-2} mho m^{-1}. The value of n (rounded off to two decimal places) is___________.

6. 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}; $N_A = 6.022 \times 10^{23}$ mol^{-1})

7. 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})

8. 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 J K^{-1} mol^{-1})

9. 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 25ºC, then the pH (rounded off to one decimal place) of the buffer solution at 25ºC is_________.

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

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

11. 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} J s; $N_A = 6.022 \times 10^{23}$ mol^{-1}; atomic mass of C is 12 g mol^{-1}; atomic mass of O is 16 g mol^{-1}; c = 3×10^{8} m s^{-1})

12. A dilute solution prepared by dissolving a nonvolatile 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 waterr, boiling point = 373.15 K; cryoscopic constant = 1.86 K (mol kg^{-1})$^{-1}$; ebullioscopic constant = 0.51 K (mol kg^{-1})$^{-1}$)

13. 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 th 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)

14. For the molecule,

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

the number of all possible stereoisomers is_______.

15. For the reaction,

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

$k_1 = 2.5 \times 10^5$ L mol^{-1} s^{-1}, $k_{-1} = 1.0 \times 10^4$ 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 _______.

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

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

Thermodynamic quantity	$CaCO_3(s)$	CaO(s)	$CO_2(g)$
μ^o (kJ mol^{-1})	–1128.8	–604.0	–394.4
ΔH_f^o (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})

17. The mean ionic activity coefficient of 0.004 molal $CaCl_2$ in water at 298 K (rounded off to thre decimal places) is ___________.

(Given: Debye-Huckel constant for an aqueous solution at 298 K is 0.509 kg$^{1/2}$ mol$^{-1/2}$)

18. 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 ________

19. The surface tension (γ) of a solution, prepared by mixing 0.02 mol of an organic acid in 1 L 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 $n \times 10^{-6}$ mol m^{-2}. The value of n (rounded off to two decimal places) is _____________.

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

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