# GATE – 2020 – Chemistry

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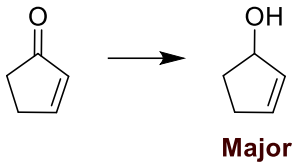
# GATE – 2020 – CY

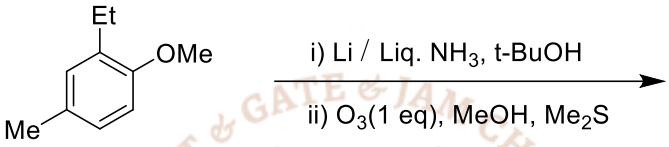
**Q.1 – Q.15 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).**

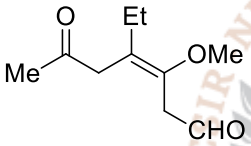
**1. Among the following, the suitable reagents for the given transformation is:**

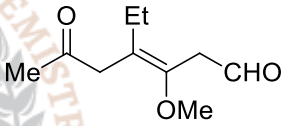


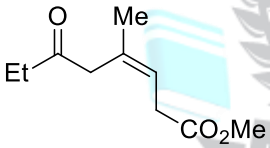

(a) $H_2, Pd/C$ (b) $H_2N\text{-}NH_2/KOH, \Delta$ (c) $NaBH_4/CeCl_3.7H_2O$ (d) $Li/Liq.NH_3$

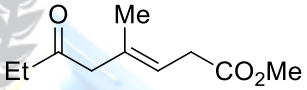
**2. Major product formed in the following reaction sequences is:**



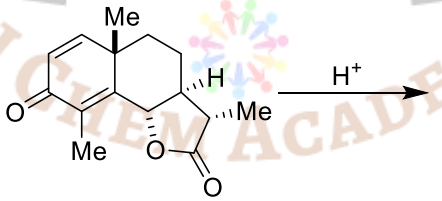

(a) 

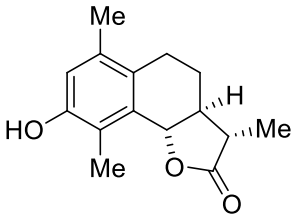

(b) 

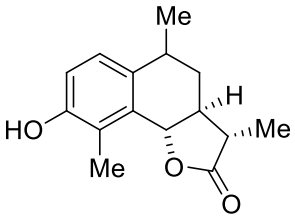

(c) 

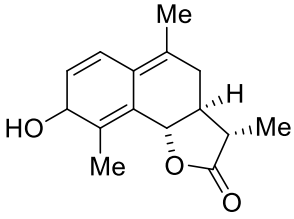

(d) 

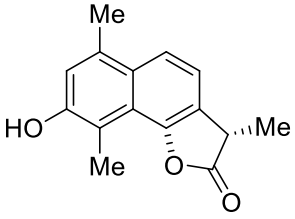

**3. Major product formed in the following sequences is:**



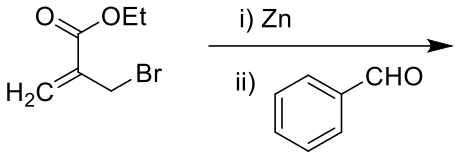

(a) 

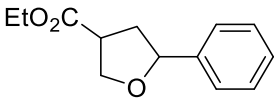

(b) 

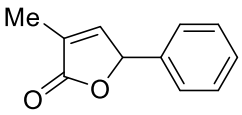

(c) 

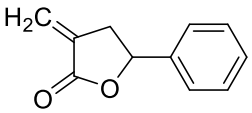

(d) 

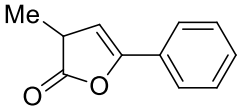

**4. Major product formed in the following transformation is:**



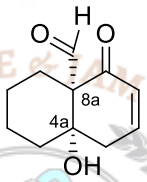

(a) 


(b) 


(c) 

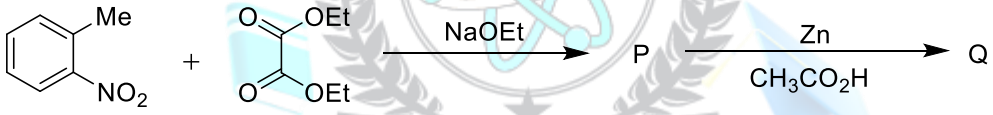

(d) 

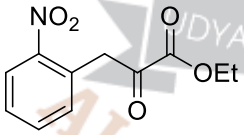

**5. Absolute stereochemistry of the given compound is:**

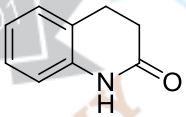


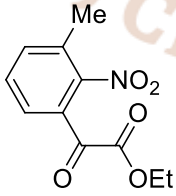

(a) 4aR, 8aS (b) 4aR, 8aR (c) 4aS, 8aS (d) 4aS, 8aR

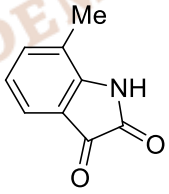
**6. In the following reaction sequences, the major products P and Q are:**

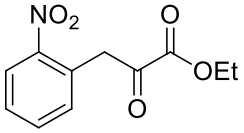


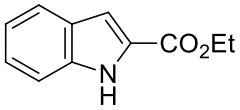

(a) P = 

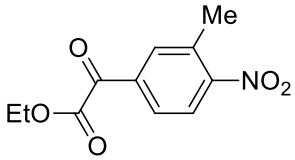
and Q = 

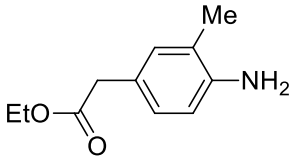

(b) P = 

and Q = 

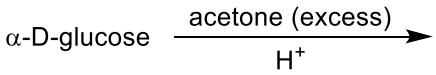

(c) P = 

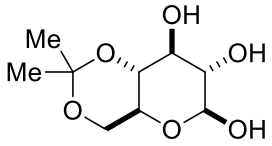
and Q = 

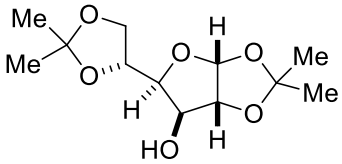

(d) P = 

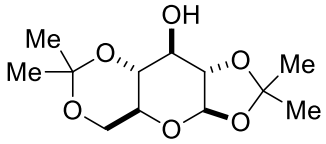
and Q = 

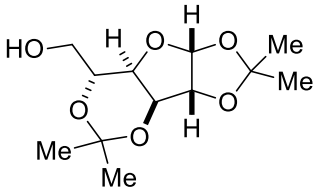

**7. Major product formed in the given reaction is:**



(a) 

(b) 

(c) 

(d) 

8. **The CORRECT statement regarding the substitution of coordinated ligands in $Ni(CO)_4$ and $Co(NO)(CO)_3$ is:**

**(Given: Co−N−O bond is nearly linear; atomic numbers of Co and Ni are 27 and 28, respectively)**

(a) $Ni(CO)_4$ and $Co(NO)(CO)_3$ follow associative and dissociative pathways

(b) $Ni(CO)_4$ and $Co(NO)(CO)_3$ follow dissociative and associative pathways

(c) Both $Ni(CO)_4$ and $Co(NO)(CO)_3$ follow associative pathway

(d) Both $Ni(CO)_4$ and $Co(NO)(CO)_3$ follow dissociative pathways

9. **The CORRECT statement about hexagonal boron nitride is:**

(a) It is a good electrical conductor

(b) It has same layer stacking as that of graphite

(c) It is reactive towards fluorine

(d) It has lower thermal stability in air compound to that of graphite

10. **In oxyhemocyanin, the coordination number, mode of oxygen binding, color and the net magnetic behaviour of copper ions, respectively are:**

(a) Four, $\mu\text{-}\eta^1\text{:}\eta^1\text{-}O_2^-$, colorless and paramagnetic

(b) Five, $\mu\text{-}\eta^2\text{:}\eta^2\text{-}O_2^-$, colorless and paramagnetic

(c) Five, $\mu\text{-}\eta^2\text{:}\eta^2\text{-}O_2^{2-}$, blue and diamagnetic

(d) Four, $\mu\text{-}\eta^1\text{:}\eta^1\text{-}O_2^{2-}$, blue and diamagnetic

11. **Among the following species, the one that has pentagonal shape is:**

**(Given : atomic number of O, F, S, I and Xe are 8, 9, 16, 53 and 54, respectively)**

(a) $XeOF_4$ (b) $IF_5$ (c) $[SF_5]^-$ (d) $[XeF_5]^-$

12. **A solution containing a metal complex absorbs at 480 nm with molar extinction coefficient of $15,000\ L\ mol^{-1}cm^{-1}$. If the path length of the cell is 1.0 cm and transmittance is 20.5%, the concentration (in mol $L^{-1}$) of the metal complex is:**

(a) $1.37 \times 10^{-5}$ (b) $2.29 \times 10^{-5}$ (c) $4.59 \times 10^{-5}$ (d) $8.75 \times 10^{-5}$

13. **Among the following linear combination of atomic orbitals, the CORRECT representation of the lowest unoccupied π-molecular orbital of butadiene is:**

(a) $\varphi = -0.372\,\phi_1 + 0.602\,\phi_2 - 0.602\,\phi_3 + 0.372\,\phi_4$

(b) $\varphi = 0.602\,\phi_1 - 0.372\,\phi_2 - 0.372\,\phi_3 + 0.602\,\phi_4$

(c) $\varphi = 0.602\,\phi_1 + 0.372\,\phi_2 - 0.372\,\phi_3 - 0.602\,\phi_4$

(d) $\varphi = 0.372\,\phi_1 + 0.602\,\phi_2 + 0.602\,\phi_3 + 0.372\,\phi_4$

14. **The activity of 'm' molal $CuSO_4$ solution can be expressed in terms of its mean activity coefficient ($\gamma_\pm$) as:**

(a) $m^2\gamma_\pm^2$ (b) $4\,m^3\gamma_\pm^3$ (c) $16\,m^4\gamma_\pm^4$ (d) $108\,m^5\gamma_\pm^5$

15. **The character table for a pyramidal $AB_3$ molecule of $C_{3v}$ point group is given below:**

| $C_{3v}$ | E | $2C_3$ | $3\sigma_v$ | | |
|---|---|---|---|---|---|
| $A_1$ | 1 | 1 | 1 | z | $x^2+y^2, z^2$ |
| $A_2$ | 1 | 1 | −1 | $R_z$ | |
| E | 2 | −1 | 0 | $(x, y)\ (R_x, R_y)$ | $(x^2-y^2, xy)\ (xz, yz)$ |

**The reducible representation of pyramidal $AB_3$ is**

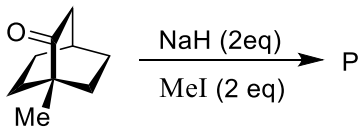
| $C_{3v}$ | E | $2C_3$ | $3\sigma_v$ |
|---|---|---|---|
| Γ | 12 | 0 | 2 |

**The CORRECT option representing all the normal Raman active modes of pyramidal $AB_3$ is**

(a) $A_1 + A_2 + 2E$ (b) $3E$ (c) $3A_1 + A_2 + E$ (d) $2A_1 + 2E$

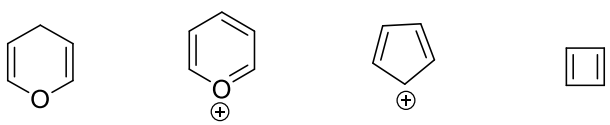
**Q.16 – Q.25 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).**

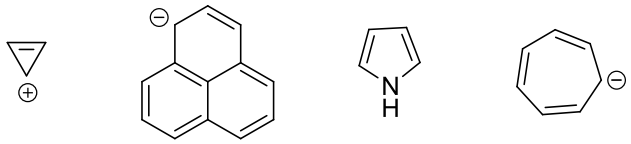
16. **In the following reaction,**




**The number of peaks exhibited by the major product-P in its broadband proton decoupled $^{13}$C-NMR spectrum is _____**

17. **Among the following, the total number of aromatic species is_____**





18. The maximum number of microstates for $d^2$ electronic configuration is _____

19. In a uranium recovery process, an aqueous solution of uranyl ion is evaporated, dried in air at 400 °C and subsequently reduced with hydrogen at 700 °C to obtain a uranium compound (X). The oxidation state of uranium in X is _____
(Given: atomic number of U is 92)

20. For a cubic crystal system, the powder X-ray diffraction pattern recorded using Cu $K_\alpha$ source ($\lambda = 1.54$ Å) shows a peak at $33.60^o$ ($2\theta$) for (111) plane. The lattice parameter 'a' (in Å, rounded off to two decimal places) is _____

21. In an NMR spectrometer operating at a magnetic field strength of 16.45 T, the resonance frequency (in MHz, rounded off to one decimal places) of $^{19}F$ nucleus is _____(g factor of $^{19}F = 5.255$; $\beta_N = 5.05 \times 10^{-27}$ J $T^{-1}$; $h = 6.626 \times 10^{-34}$ J s)

22. When three moles of helium is mixed with one mole of neon at constant temperature and pressure (25 °C, 1 atm), the entropy of mixing (in J $K^{-1}$, rounded off to two decimal places) is _____ (Given: $R = 8.314$ $JK^{-1}mol^{-1}$)

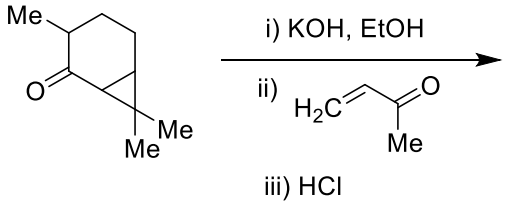
23. At 25 °C, the emf (in volts, rounded off to three decimal places) of the cell, $Ag|AgBr(s)|Br^-(a = 0.20), Cu^{2+}(a = 0.48), Cu^+(a = 0.24)|Pt$ is _____
(standard emf of the cell is 0.082 V; $R = 8.314$ $JK^{-1}mol^{-1}$; $F = 96500$ C $mol^{-1}$)

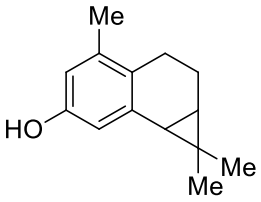
24. For an enzyme catalysed reaction, the plot of inverse of initial rate against inverse of initial substrate concentration is linear with slope 0.16 s and intercept 2.12 $mol^{-1}$ L s. The estimated value of Michaelis constant (in mol $L^{-1}$, rounded off to two decimal places) is _____

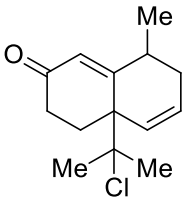
25. Fluorescence quantum yield and fluorescence lifetime of molecules are 0.4 and $5 \times 10^{-9}$s, respectively. If the fluorescence decay rate constant is $Y \times 10^7 s^{-1}$, the value of Y (rounded off to nearest integer) is _____

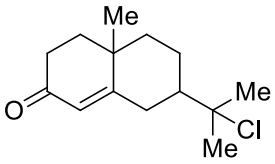
**Q.26 – Q.43 Multiple Choice Question (MCQ), carry TWO mark each (for each wrong answer: – 2/3).**

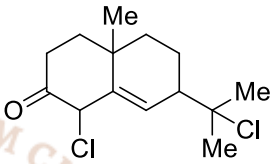
26. Major product formed in the following reaction sequences is:



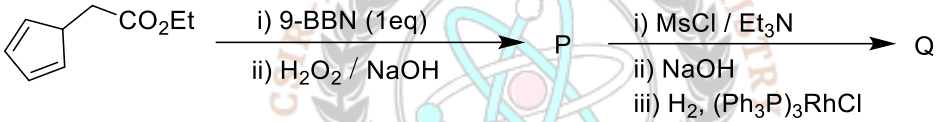

(a) 

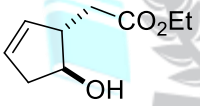

(b) 

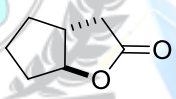

(c) 

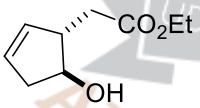

(d) 

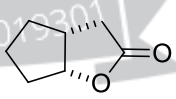

**27. Major product P and Q, in the given reaction sequences, are:**

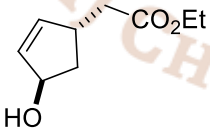


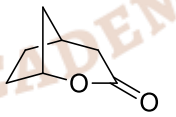

(a) P = 

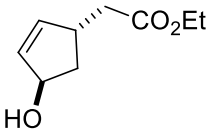
and Q = 

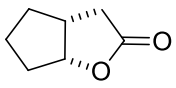

(b) P = 

and Q = 

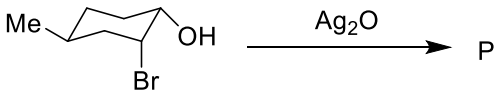

(c) P = 

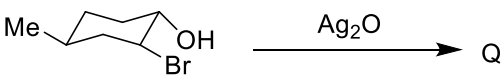
and Q = 

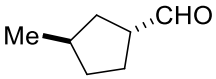

(d) P = 

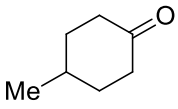
and Q = 

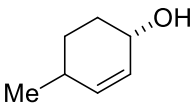
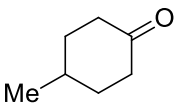

**28. Major product P and Q, formed in the reactions given below, are:**

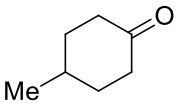
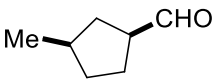


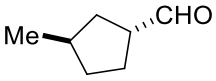
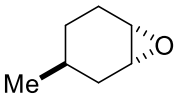




(a) P = 

and Q = 

(b) P =  and Q = 

(c) P =  and Q = 

(d) P =  and Q = 

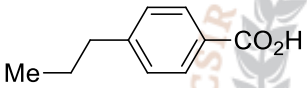
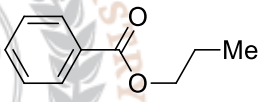
**29. A compound with molecular formula $C_{10}H_{12}O_2$ showed the following signals**

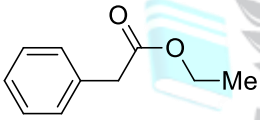
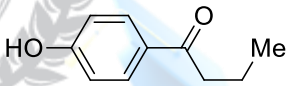
**IR : strong band at ~1720 $cm^{-1}$**

**EI Mass : m/z 122**

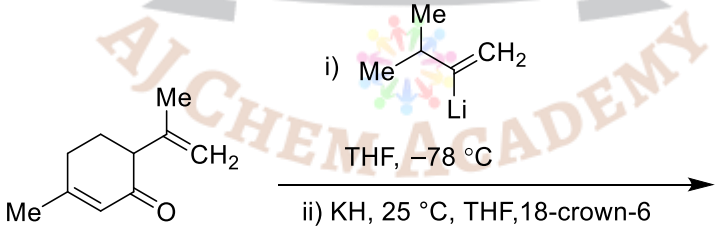
**$^1$H-NMR : δ 8.1 - 8.0 (2H, m), 7.6 - 7.5(1H, m), 7.5 - 7.3(2H, m), 4.3 (2H, t), 1.8 (2H, sextet) and 1.0 (3H, t)**

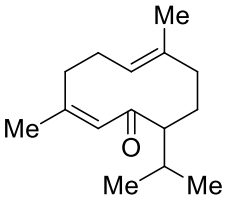
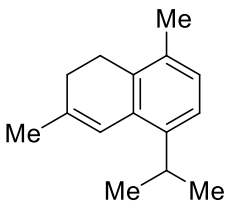
**The Structure of the compound is:**

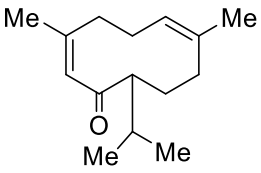
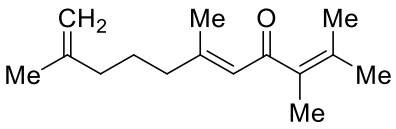
(a)  (b) 

(c)  (d) 

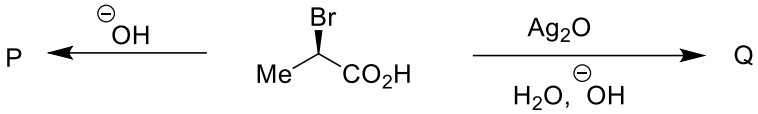
**30. Major product formed in the following synthetic sequences, is:**




(a)  (b) 

(c)  (d) 

**31. The CORRECT statements with respect to the stereochemistry of α-hydroxy acids P and Q formed in the following reaction is:**



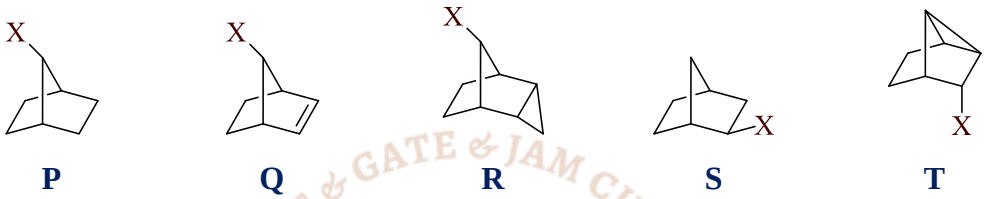

(a) Both P and Q are formed with retention of configuration

(b) Both P and Q are formed with inversion of configuration

(c) P is formed with retention of configuration and Q with inversion of configuration

(d) P is formed with inversion of configuration and Q with retention of configuration

**32. The rate of solvolysis of the given compounds is in the order:**



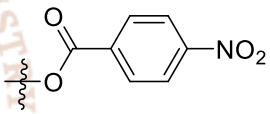

**P** **Q** **R** **S** **T**

(a) T > R > Q > S > P

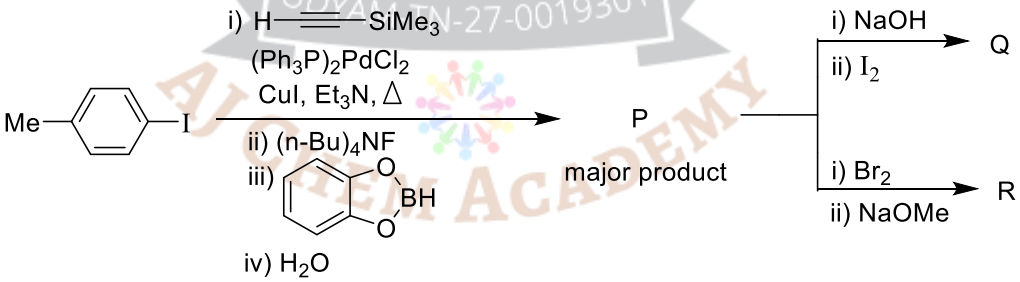
(b) Q > T > R > P > S

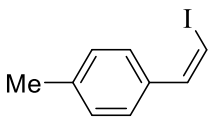
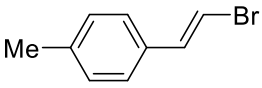
(c) R > T > Q > S > P

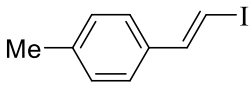
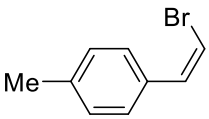
(d) T > Q > R > P > S

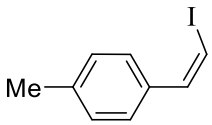
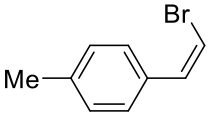


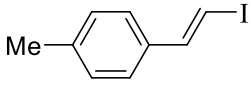
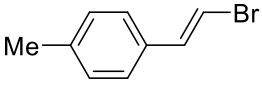

**33. In the following reaction sequences, the major products Q and R are:**




(a) Q =  and R = 

(b) Q =  and R = 

(c) Q =  and R = 

(d) Q =  and R = 

**34.** In the electronic absorption spectrum of an aqueous solution of $[Ni(NH_3)_6]^{2+}$, a very weak band is observed between the bands due to the transitions $^3A_{2g} \longrightarrow {}^3T_{2g}$ and $^3A_{2g} \longrightarrow {}^3T_{1g}(F)$. The transition responsible for the very weak band is

(Given: atomic number of Ni is 28)

(a) $^3A_{2g} \longrightarrow {}^1T_{1g}$ (b) $^3A_{2g} \longrightarrow {}^1T_{2g}$ (c) $^3A_{2g} \longrightarrow {}^1E_g$ (d) $^3A_{2g} \longrightarrow {}^1A_{2g}$

**35.** The experimental magnetic moment (3.4 BM) of a hydrated salt of $Eu^{3+}$ at 27 °C is significantly different from the calculated value. The difference is due to

(Given: atomic number of Eu is 63)

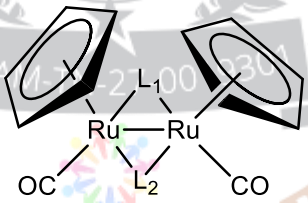
(a) population of electrons at higher J level(s) via thermal excitation

(b) strong ligand field splitting of f-orbitals

(c) strong spin-orbit coupling

(d) pairing of electrons in f-orbitals

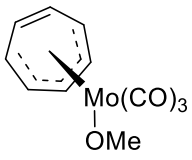
**36.** The CORRECT combination of $L_1$ and $L_2$ among $H^-$, $NO^-$, $MeCH^{2-}$ and CO, that will satisfy the 18 electron rule for both metal centres in the following neutral molecules, is (Given: atomic number of Ru is 44)

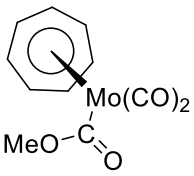


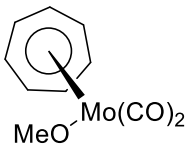

(a) $H^-, NO^-$ (b) $MeCH^{2-}, NO^-$ (c) $MeCH^{2-}, CO$ (d) $H^-, CO$

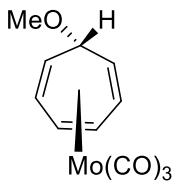
**37.** In the following reaction sequences, the structure of B is


(Given: atomic number of Mo is 42)

(a) 


(b) 


(c) 


(d) 


**38.** The following table lists the reaction/ conversion catalysed by metalloenzymes.

| | Reaction / conversion | | Metalloenzymes. |
|---|---|---|---|
| P. | $R-H + O_2 + 2H^+ + 2e^- \longrightarrow R-OH + H_2O$ | I. | Coenzyme $B_{12}$ |
| Q. | $O_2 + 4e^- + 8H^+ \longrightarrow 2H_2O + 4H^+$ | II. | Cytochrome P-450 |

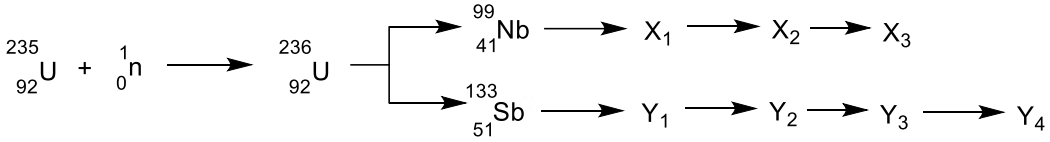
| | | | |
|---|---|---|---|
| **R.** | $2H_2O_2 \rightarrow 2H_2O + O_2$ | **III.** | **Cytochrome *c* oxidase** |
| **S.** | $NH_2\text{-}CH_2\text{-}CO_2H \rightarrow NH_2\text{-}CH(CH_2OH)\text{-}CO_2H$ | **IV.** | **Catalase** |

**The CORRECT combination is**

| | P | Q | R | S |
|---|---|---|---|---|
| (a) | II | I | III | IV |
| (c) | II | III | IV | I |

| | P | Q | R | S |
|---|---|---|---|---|
| (b) | IV | III | II | I |
| (d) | I | IV | III | II |

**39.** **The fission reaction of $^{235}_{92}U$ with thermal neutron is represented below.**

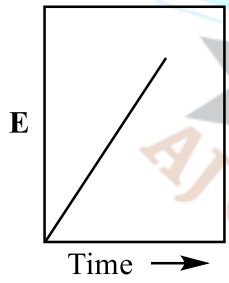



**$^{99}_{41}Nb$ and $^{133}_{51}Sb$ are the primary fission fragment pair, which undergo series of radioactive decay to form stable nuclei $X_3$ and $Y_4$ (chain enders). The $X_3$ and $Y_4$, respectively are:**

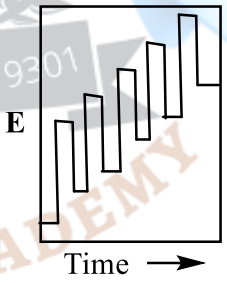
(a) $^{99}_{41}Nb$ and $^{130}_{51}Sb$ (b) $^{99}_{44}Ru$ and $^{133}_{55}Cs$ (c) $^{93}_{38}Sr$ and $^{127}_{35}Ag$ (d) $^{87}_{35}Br$ and $^{124}_{43}Tc$

**40.** **The CORRECT 'voltage (E) versus time' excitation signal used in cyclic voltammetry is**

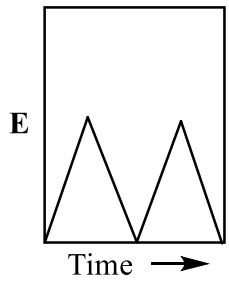
(a)



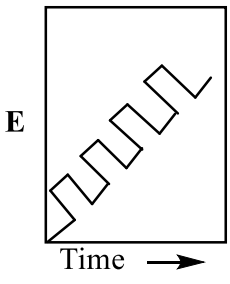

(b)




(c)




(d)




**41.** **The hydrogen-like radial wave function of the 3s orbital is given as**

$R_{3,0} = \frac{1}{9\sqrt{3}}\left(\frac{Z}{a_0}\right)^{3/2}\left(6 - 2\rho + \frac{\rho^2}{9}\right)e^{-\rho/6}$. **Where,** $\rho = \frac{2Zr}{a_0}$; $Z = atomic\ number$; $r = distance\ from\ the\ nucleus\ and\ a_0 = Bohr\ radius.$

**Positions of the radial nodes (in units of $a_0$) of the 3s orbital are at**

(a) $\frac{3+\sqrt{3}}{2Z}, \frac{3-\sqrt{3}}{2Z}$ (b) $\frac{6+3\sqrt{3}}{2Z}, \frac{6-3\sqrt{3}}{2Z}$ (c) $\frac{9+3\sqrt{3}}{2Z}, \frac{9-3\sqrt{3}}{2Z}$ (d) $\frac{3+3\sqrt{3}}{2Z}, \frac{3-3\sqrt{3}}{2Z}$

**42.** $\Delta G_f^0$ and $\Delta H_f^0$ for $Fe_{(g)}$ are $370.7\ kJ\ mol^{-1}$ and $416.3\ kJ\ mol^{-1}$ at 298 K, respectively. Assuming $\Delta H_f^0$ is constant in the interval 250 K to 375 K, $\Delta G_f^0$ (rounded off to the nearest integer) for $Fe_{(g)}$ at 375 K is:

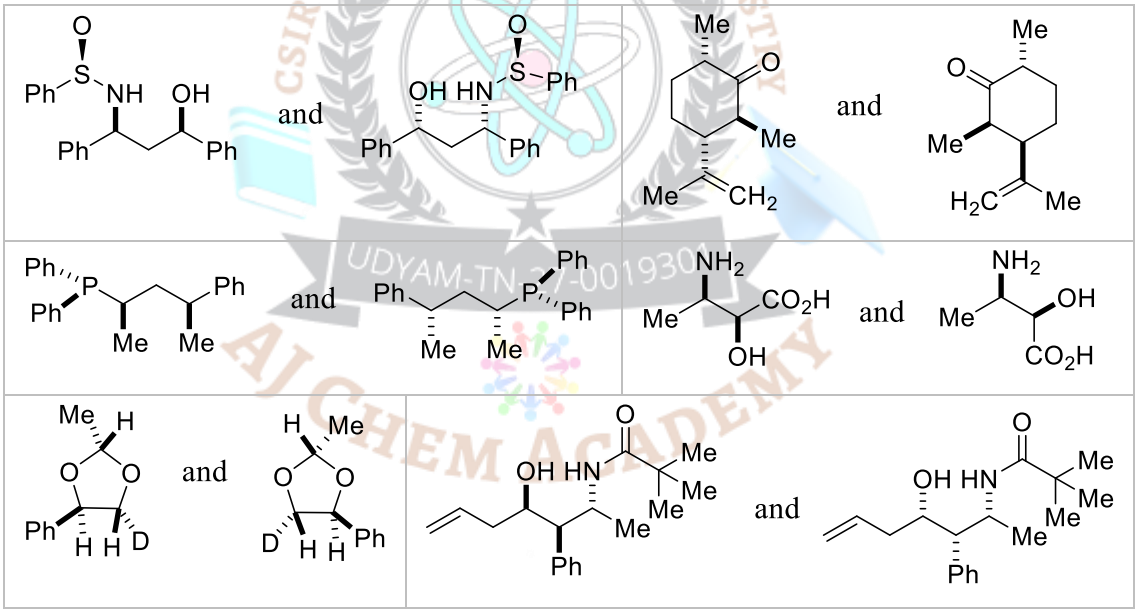
(a) 359 kJ $mol^{-1}$ (b) 338 kJ $mol^{-1}$ (c) 325 kJ $mol^{-1}$ (d) 310 kJ $mol^{-1}$

**43.** Adsorption of $N_2$ on $TiO_2$ was carried out at 75 K. A plot of $\frac{z}{(1-z)V}$ versus z ($z = p/p^0$) gives a straight line with an intercept, $4.0 \times 10^{-6}\ mm^{-3}$ and slope, $1.0 \times 10^{-3}\ mm^{-3}$. The volume (rounded off to the nearest integer) corresponding to the monolayer coverage is:

(a) 996 $mm^3$ (b) 785 $mm^3$ (c) 690 $mm^3$ (d) 555 $mm^3$

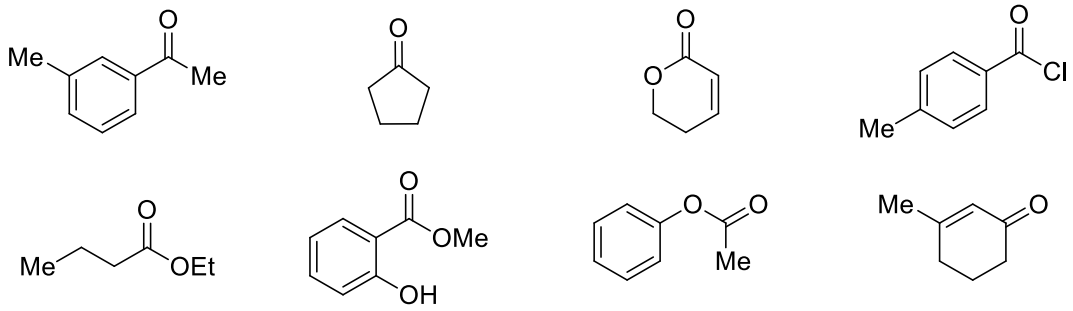
**Q.44 – Q.55 Numerical Answer Type (NAT), carry TWO marks each (no negative marks).**

**44.** Among the following sets,




the total number of set(s) of diastereomeric pair(s) is _____

**45.** Among the following,



the total number of compounds showing characteristics carbonyl stretching

frequency less than $1700\ cm^{-1}$ in their IR spectra is_____

46. Consider that AgX crystallizes in rock salt structure. The density of AgX is $6477\ kg/m^3$ and unit cell length is $577.5\ pm$. Atomic weight of Ag is $107.87\ g\ mol^{-1}$. Atomic weight of X (in $g\ mol^{-1}$, rounded off to two decimal places) is _____

47. The total number of $g_{\|}$ lines expected in the EPR spectrum of a solution of bis(salicylaldimine)copper(II) having pure $^{63}Cu$ and $^{14}N$ at 77 K is_____

(Given: I value of $^{63}Cu$, $^{14}N$ and $^{1}H$ are $3/2$, 1 and $1/2$, respectively)

48. Among the following,

$[B_{12}H_{12}]^{2-}$, $[Ni_5(CO)_{12}]^{2-}$, $[C_2B_9H_{11}]^{2-}$, $Rh_6(CO)_{16}$, $Os_6(CO)_{20}$, $B_5H_{11}$, $B_6H_{10}$

the total number of species having nido structure is_____

(atomic numbers of H, B, C, O, Ni, Rh and Os are 1, 5, 6, 8, 28, 45 and 76)

49. The frequency (in $cm^{-1}$, rounded off to two decimal places) for pure rotational line in the spectrum of NO molecule due to change in the quantum number from $J = 1$ to $J = 2$ is _____ (Moment of inertia of $NO = 1.6427 \times 10^{-46}\ kg\ m^2$; $h = 6.626 \times 10^{-34}\ J\ s$; $c = 3 \times 10^8\ m/s$)

50. The % error (rounded off to two decimal places) in the ground state energy of a particle in a one-dimensional box of length 'a' described by a trial variation function $\varphi = x(a - x)$, where $0 \le x \le a$, is_____

(Given: The true ground state energy of the above system is $h^2/8ma^2$ ; $\int_0^a \Psi^* \Psi\, d\tau = a^5/30$)

51. Assuming no interaction between vibrational and rotational energy levels in HF, the frequency (in $cm^{-1}$, rounded off to the nearest integer) of the R branch line originating from $J = 4$ in its IR spectrum is_____

(Given: Rotational constant for HF $= 19.35\ cm^{-1}$; $\bar{\nu}_0 = 4138.52\ cm^{-1}$)

52. The van der Waals constants a and b for gaseous CO are given as $1.49\ L^2\ atm\ mol^{-2}$ and $0.0399\ L\ mol^{-1}$, respectively. The fugacity (in atm, rounded off to two decimal places) of CO at 35 °C and 95 atm is _____

(Given: $R = 0.082\ L\ atm\ K^{-1}mol^{-1}$)

53. At 30 °C, the vapor pressure and density of a 1.0 M aqueous solution of sucrose are 31.207 mm Hg and 1.1256 g/mL, respectively. If the vapor pressure of pure water at 30 °C is 31.824 mm Hg, the activity coefficient (rounded off to three

decimal places) of water in the given solution is _____

(Given: The molar mass of sucrose $= 342.3\ g\ mol^{-1}$)

54. For the ring opening reaction of cyclopropane to propene at 25 °C, the pre-exponential factor is $4.3 \times 10^{15}\ s^{-1}$. The entropy of activation (in $J\ K^{-1}mol^{-1}$) is _____ (rounded off to two decimal places)

($h = 6.626 \times 10^{-34}\ J\ s$; $k_B = 1.38 \times 10^{-23} J\ K^{-1}$; $R = 8.314\ JK^{-1}mol^{-1}$)

55. In a reaction, reactant X is converted to products Y and Z consecutively with rate constants $6.0 \times 10^{-2}\ min^{-1}$ and $9.0 \times 10^{-3}\ min^{-1}$, respectively. If the initial amount of X is 12.5 moles, the number of moles of Y formed after 10 minutes is _____ (rounded off to one decimal place)

## Answer Key

| Q.No | Ans | | Q.No | Ans | | Q.No | Ans |
|---|---|---|---|---|---|---|---|
| 1. | c | | 21. | 658 to 659 | | 41. | c |
| 2. | c | | 22. | 18.60 to 18.80 | | 42. | a |
| 3. | a | | 23. | 0.058 to 0.060 | | 43. | a |
| 4. | c | | 24. | 0.07 to 0.08 | | 44. | 4.0 |
| 5. | d | | 25. | 8 | | 45. | 3.0 |
| 6. | c | | 26. | c | | 46. | 79 to 81 |
| 7. | b | | 27. | b | | 47. | 60 |
| 8. | b | | 28. | c | | 48. | 3.0 |
| 9. | c | | 29. | b | | 49. | 6.80 to 6.82 |
| 10. | c | | 30. | a | | 50. | 1.22 to 1.44 |
| 11. | d | | 31. | d | | 51. | 4332 |
| 12. | c | | 32. | a | | 52. | 88.11 to 88.60 |
| 13. | b | | 33. | b | | 53. | 1.002 to 1.004 |
| 14. | a | | 34. | c | | 54. | 46 to 46.10 |
| 15. | d | | 35. | a | | 55. | 5.3 to 5.5 |
| 16. | 8.0 | | 36. | c | | | |
| 17. | 4.0 | | 37. | d | | | |
| 18. | 45.0 | | 38. | c | | | |
| 19. | 4.0 | | 39. | b | | | |
| 20. | 4.60 to 4.64 | | 40. | c | | | |