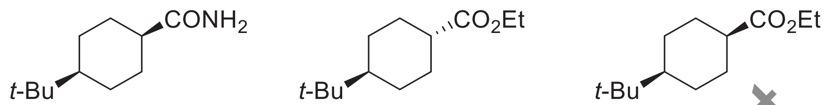
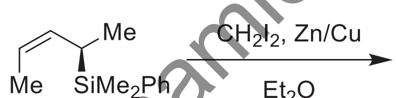
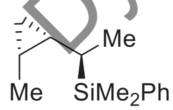
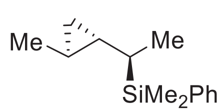
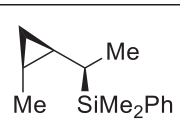
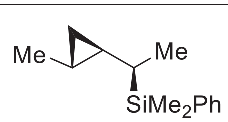
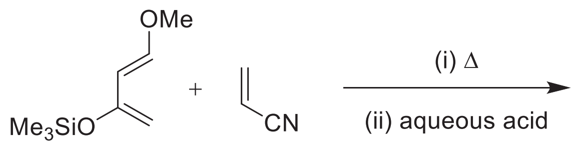
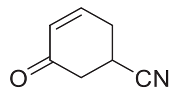
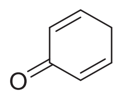
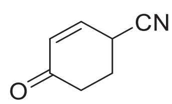
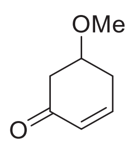
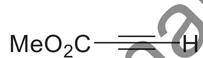
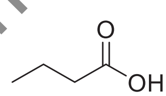
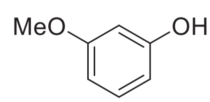
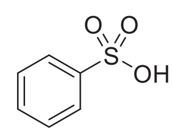
GATE-2021-CY

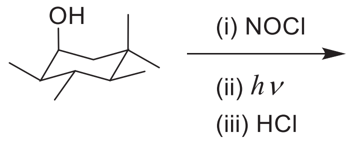
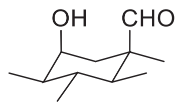
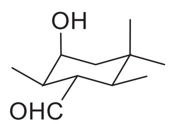
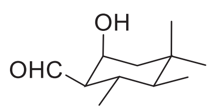
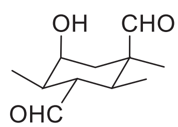
Q.1 – Q.14 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

Q.1	**The rates of alkaline hydrolysis of the compounds shown below**  **I** **II** **III** **follow the order:**
(A)	**I** > **II** > **III**
(B)	**II** > **I** > **III**
(C)	**II** > **III** > **I**
(D)	**III** > **I** > **II**

Q.2	**The major product formed in the following reaction**  **is:**
(A)	
(B)	
(C)	
(D)	

Q.3	**The major product formed in the following reaction**  **is:**
(A)	
(B)	
(C)	
(D)	

Q.4	**The <u>least</u> acidic among the following compounds**  **M**  **N**  **O**  **P** **is:**
(A)	**M**
(B)	**N**
(C)	**O**
(D)	**P**

Q.5	**The major product formed in the following reaction**  **is:**
(A)	
(B)	
(C)	
(D)	

Q.6	**The reagent(s) required for the conversion of hex-3-yne to (*E*)-hex-3-ene is/are:**
(A)	H_2, $Pd/BaSO_4$
(B)	Bu_3SnH
(C)	Li / liquid NH_3
(D)	$LiAlH_4$

Q.7	**An organic compound exhibits the $[M]^+$, $[M+2]^+$ and $[M+4]^+$ peaks in the intensity ratio 1:2:1 in the mass spectrum, and shows a singlet at δ 7.49 in the ^1H NMR spectrum in $CDCl_3$. The compound is:**
(A)	1,4-dichlorobenzene
(B)	1,4-dibromobenzene
(C)	1,2-dibromobenzene
(D)	1,2-dichlorobenzene

Q.8	**Reaction of $LiAlH_4$ with one equivalent of $Me_3N{\cdot}HCl$ gives a tetrahedral compound, which reacts with another equivalent of $Me_3N{\cdot}HCl$ to give compound N. The compound N and its geometry, respectively, are:**
(A)	$LiAlH_4NMe_3$ and trigonal bipyramidal
(B)	Li_2AlH_4Cl and square pyramidal
(C)	$AlH_3(NMe_3)_2$ and trigonal bipyramidal
(D)	$AlH_3(NMe_3)_2$ and pentagonal

Q.9	**Which one of the following is a non-heme protein?**
(A)	hemoglobin
(B)	hemocyanin
(C)	myoglobin
(D)	cytochrome P-450

Q.10	**A correct example of a nucleotide is:**
(A)	adenosine monophosphate (AMP)
(B)	RNA
(C)	uridine
(D)	DNA

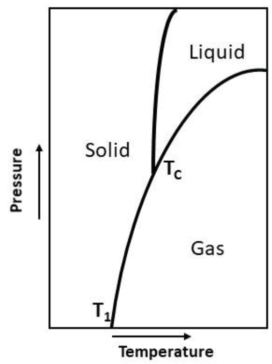
Q.11	**The equilibrium constant for the reaction** **$3\ NO\ (g) \rightleftharpoons N_2O\ (g) + NO_2\ (g)$** **at 25 °C is closest to:** **[$\Delta G^\circ = -104.18$ kJ; $R = 8.314$ J mol^{-1} K^{-1}]**
(A)	1.043
(B)	1.8×10^{18}
(C)	1.651
(D)	5.7×10^{-19}

Q.12	**The reaction of $NiBr_2$ with two equivalents of PPh_3 in CS_2 at –78 °C gives a red-colored diamagnetic complex, $[NiBr_2(PPh_3)_2]$. This transforms to a green-colored paramagnetic complex with the same molecular formula at 25 °C. The geometry and the number of unpaired electrons in the green-colored complex, respectively, are:**
(A)	tetrahedral and 1
(B)	tetrahedral and 2
(C)	square planar and 2
(D)	square planar and 4

Q.13	**The rate of the substitution reaction of $[Co(CN)_5Cl]^{3-}$ with OH^- to give $[Co(CN)_5(OH)]^{3-}$**
(A)	depends on the concentrations of both $[Co(CN)_5Cl]^{3-}$ and OH^-
(B)	depends on the concentration of $[Co(CN)_5Cl]^{3-}$ only
(C)	is directly proportional to the concentration of OH^- only
(D)	is inversely proportional to the concentration of OH^-

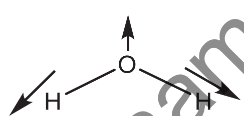
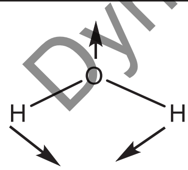
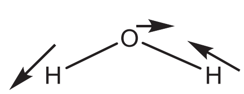
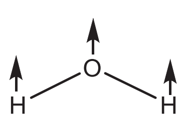
Q.14	**The Δ_o of $[Cr(H_2O)_6]^{3+}$, $[CrF_6]^{3-}$ and $[Cr(CN)_6]^{3-}$ follows the order:**
(A)	$[Cr(H_2O)_6]^{3+} > [CrF_6]^{3-} > [Cr(CN)_6]^{3-}$
(B)	$[CrF_6]^{3-} > [Cr(H_2O)_6]^{3+} > [Cr(CN)_6]^{3-}$
(C)	$[Cr(CN)_6]^{3-} > [Cr(H_2O)_6]^{3+} > [CrF_6]^{3-}$
(D)	$[CrF_6]^{3-} > [Cr(CN)_6]^{3-} > [Cr(H_2O)_6]^{3+}$

Q.15 – Q.18 Multiple Select Question (MSQ), carry ONE mark each (no negative marks).

Q.15	**The phase diagram of CO_2 is shown below:**  **The correct statement(s) about CO_2 is/are:**
(A)	Below T_c, it does not exist in liquid state.
(B)	Above T_c, it does not exist in liquid state.
(C)	At T_c, it can exist in all three phases.
(D)	Above T_1, it does not exist in solid state.

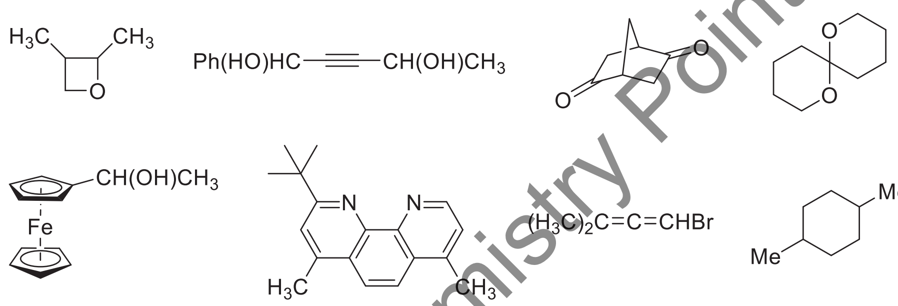
Q.16	**Acceptable wavefunctions for a quantum particle must be:**
(A)	odd
(B)	even
(C)	single-valued
(D)	continuous

Q. 17	**The characters of *E*, C_2, σ_v, and σ'_v symmetry operations, in this order, for valid irreducible representation(s) of the C_{2v} point group is/are:**
(A)	1, 1, 1, 1
(B)	–1, 1, 1, –1
(C)	1, –1, 1, –1
(D)	1, –1, –1, –1

Q. 18	**The normal mode(s) of vibration of H_2O is/are:**
(A)	
(B)	
(C)	
(D)	

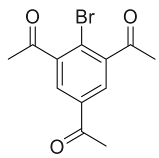
Q.19 – Q.25 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).

Q. 19	**A reversible heat engine absorbs 20 kJ of heat from a source at 500 K and dissipates it to the reservoir at 400 K. The efficiency of the heat engine is _______%.**

Q. 20	**Among the following eight compounds,**  **the number of compound(s) which can exhibit stereoisomerism is _______.**

Q. 21	**The Mo–Mo bond order in $[(\eta^5\text{-}C_5H_5)Mo(CO)_2]_2$ which obeys the 18-electron rule is _______.**

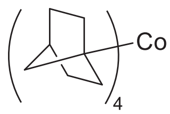
Q. 22	**The change in enthalpy (ΔH) for the reaction** **2 P (s) + 3 Br_2 (l) → 2 PBr_3 (l)** **is –243 kJ. In this reaction, if the amount of phosphorus consumed is 3.1 g, the change in enthalpy (rounded off to two decimal places) is ______ kJ.** **[Atomic Wt. of P = 31]**

Q. 23	**The number of signal(s) in the ^{1}H NMR spectrum of the following compound**  **recorded at 25 °C in $CDCl_3$ is ___________.**

Q. 24	**A 5 V battery delivers a steady current of 1.5 A for a period of 2 h. The total charge that has passed through the circuit is ______ Coulombs.**

Q. 25	**The spin-only magnetic moment of $[Co(H_2O)_6]^{2+}$ (rounded off to one decimal place) is _______ BM.**

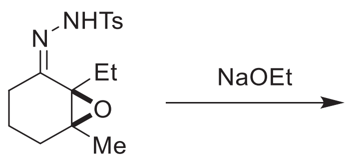
Q.26 – Q.42 Multiple Choice Question (MCQ), carry TWO mark each (for each wrong answer: – 2/3).

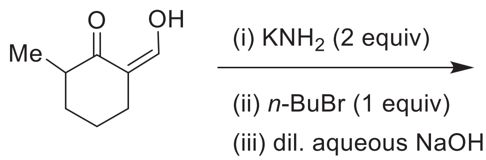
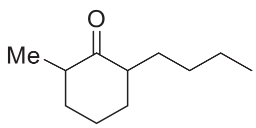
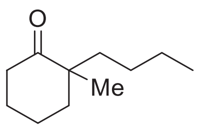
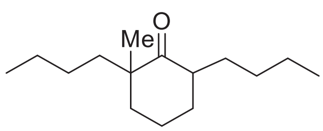
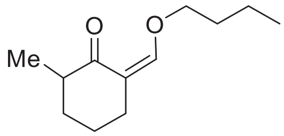
Q.26	**The geometry and the number of unpaired electrons in tetrakis(1-norbornyl)Co**  **respectively, are:**
(A)	tetrahedral and one
(B)	tetrahedral and five
(C)	square planar and one
(D)	square planar and three

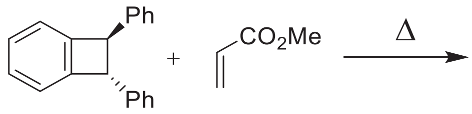
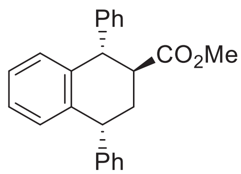
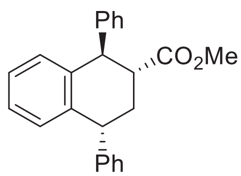
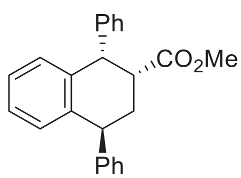
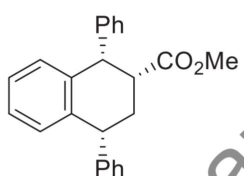
Q.27	**The yellow color of an aqueous solution of K_2CrO_4 changes to red-orange upon the addition of a few drops of HCl. The red-orange complex, the oxidation state of its central element(s), and the origin of its color, respectively, are:**
(A)	chromium chloride, +3, d-d transition
(B)	dichromate ion, +6 and +6, charge transfer
(C)	perchlorate ion, +7, charge transfer
(D)	chromic acid, +6, charge transfer

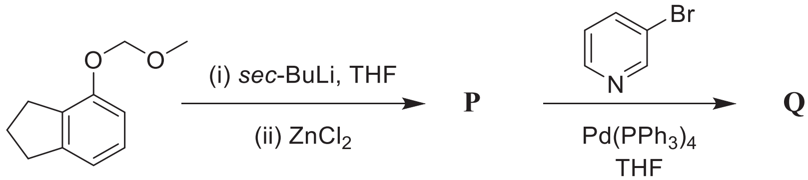
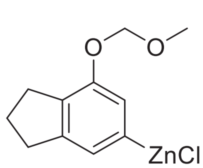
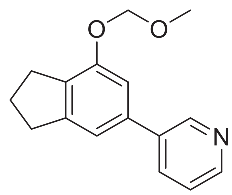
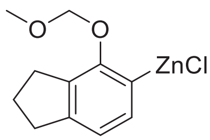
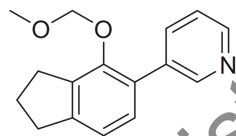
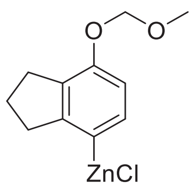
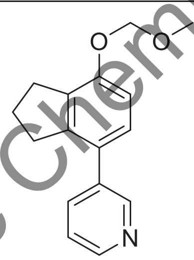
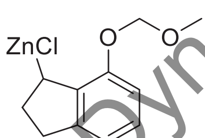
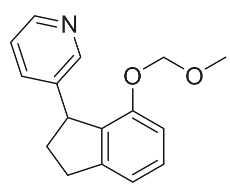
Q.28	**The shapes of the compounds** **ClF_3, $XeOF_2$, N_3^- and XeO_3F_2** **respectively, are:**
(A)	T-shape, T-shape, linear and trigonal bipyramidal
(B)	trigonal planar, T-shape, V-shape and square pyramidal
(C)	T-shape, trigonal planar, linear and square pyramidal
(D)	trigonal planar, trigonal planar, V-shape and trigonal bipyramidal

Q.29	**The metal borides that contain isolated boron atoms are:**
(A)	Tc_7B_3 and Re_7B_3
(B)	Cr_5B_3 and V_3B_2
(C)	Ti_4B_4 and V_3B_4
(D)	TiB and HfB

Q.30	**The major product formed in the following reaction**  **is:**
(A)	non-6-yn-2-one
(B)	non-3-yn-8-one
(C)	non-2-yn-6-one
(D)	non-3-en-8-one

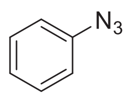
Q.31	**The major product formed in the following reaction**  **is:**
(A)	
(B)	
(C)	
(D)	

Q.32	**The major product formed in the following reaction**  **is:**
(A)	
(B)	
(C)	
(D)	

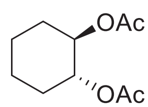
Q.33	**In the following reaction sequence**  **the major products P and Q, respectively, are:**
(A)	 and 
(B)	 and 
(C)	 and 
(D)	 and 

Q.34	**In an electrochemical cell, Ag^{+} ions in $AgNO_3$ are reduced to Ag metal at the cathode and Cu is oxidized to Cu^{2+} at the anode. A current of 0.7 A is passed through the cell for 10 min. The mass (in grams) of silver deposited and copper dissolved, respectively, are:** **[Faraday Constant = 96,485 C mol^{-1}, Atomic Weight of Ag = 107.9, Atomic Weight of Cu = 63.55]**
(A)	0.469 and 0.138
(B)	0.235 and 0.138
(C)	0.469 and 0.069
(D)	0.235 and 0.069

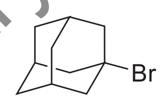
Q.35 **Among the following**



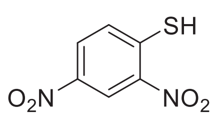
I



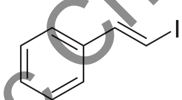
II



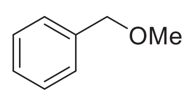
III



IV



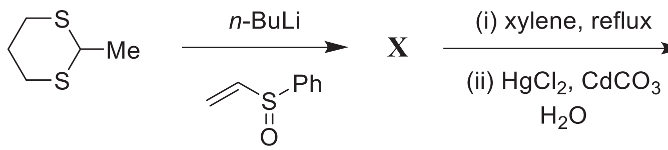
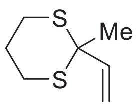
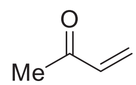
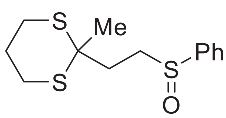
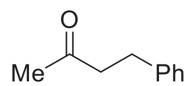
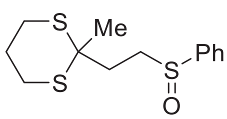
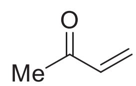
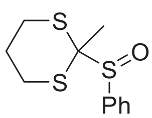
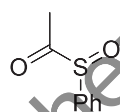
V

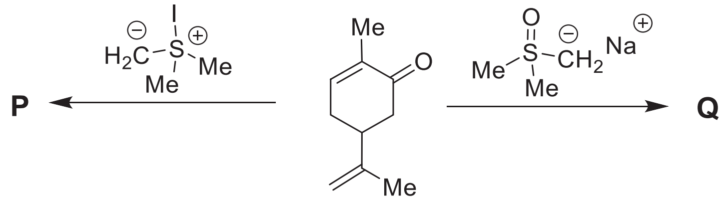
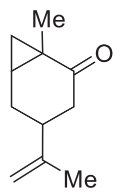
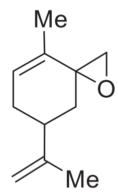
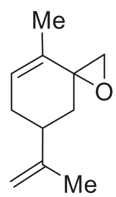
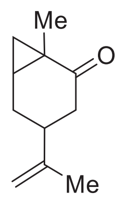
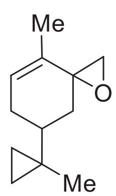
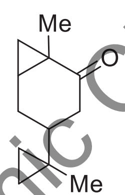
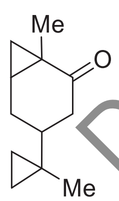
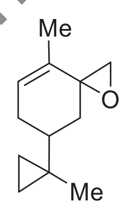


VI

the compounds which can be prepared by nucleophilic substitution reaction are:

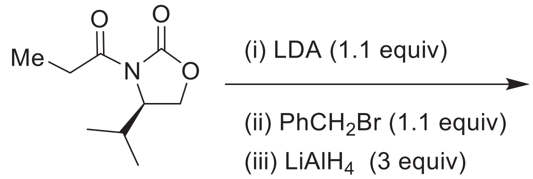
(A)	**III**, **IV**, and **V**
(B)	**I**, **II**, and **VI**
(C)	**II**, **IV**, and **VI**
(D)	**I**, **III**, and **V**

Q.36	**In the following reaction**  **the major products X and Y, respectively, are:**
(A)	 and 
(B)	 and 
(C)	 and 
(D)	 and 

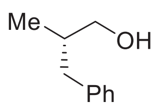
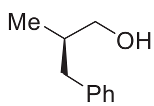
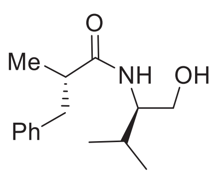
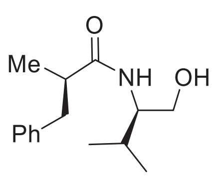
Q.37	**The major products P and Q formed in the following reactions**  **respectively, are:**
(A)	 and 
(B)	 and 
(C)	 and 
(D)	 and 

Q.38	**The major product formed in the reaction of (2*R*,3*R*)-2-bromo-3-methylpentane with NaOMe is:**
(A)	(*Z*)-3-methylpent-2-ene
(B)	(*E*)-3-methylpent-2-ene
(C)	(2*R*,3*R*)-2-methoxy-3-methylpentane
(D)	(2*S*,3*R*)-2-methoxy-3-methylpentane

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



is:

(A)	
(B)	
(C)	
(D)	

Q.40	**Hexane and heptane are completely miscible. At 25 °C, the vapor pressures of hexane and heptane are 0.198 atm and 0.06 atm, respectively. The mole fractions of hexane and heptane in the vapor phase for a solution containing 4 M hexane and 6 M heptane, respectively, are:**
(A)	0.688 and 0.312
(B)	0.400 and 0.600
(C)	0.312 and 0.688
(D)	0.600 and 0.400

Q.41	**The correct order of Lewis acid strengths of BF_2Cl, BFClBr, BF_2Br and $BFBr_2$ is:**
(A)	BF_2Cl > BFClBr > BF_2Br > $BFBr_2$
(B)	$BFBr_2$ > BFClBr > BF_2Br > BF_2Cl
(C)	BF_2Cl > BF_2Br > BFClBr > $BFBr_2$
(D)	BFClBr > $BFBr_2$> BF_2Cl > BF_2Br

Q.42	**The correct order of increasing intensity (molar absorptivity) of the UV-visible absorption bands for the ions $[Ti(H_2O)_6]^{3+}$, $[Mn(H_2O)_6]^{2+}$, $[CrO_4]^{2-}$, and $[NiCl_4]^{2-}$ is:**
(A)	$[Ti(H_2O)_6]^{3+} < [Mn(H_2O)_6]^{2+} < [CrO_4]^{2-} < [NiCl_4]^{2-}$
(B)	$[Mn(H_2O)_6]^{2+} < [Ti(H_2O)_6]^{3+} < [NiCl_4]^{2-} < [CrO_4]^{2-}$
(C)	$[NiCl_4]^{2-} < [Ti(H_2O)_6]^{3+} < [Mn(H_2O)_6]^{2+} < [CrO_4]^{2-}$
(D)	$[Ti(H_2O)_6]^{3+} < [NiCl_4]^{2-} < [CrO_4]^{2-} < [Mn(H_2O)_6]^{2+}$

Q.43 – Q.44 Multiple Select Question (MSQ), carry TWO mark each (no negative marks).

Q.43	**The correct statement(s) about the concentration of Na^+ and K^+ ions in animal cells is/are:**
(A)	$[K^+]$ inside the cell > $[K^+]$ outside the cell
(B)	$[Na^+]$ inside the cell > $[Na^+]$ outside the cell
(C)	$[Na^+]$ inside the cell < $[Na^+]$ outside the cell
(D)	$[K^+]$ inside the cell < $[K^+]$ outside the cell

Q.44	**The correct statement(s) about actinides is/are:**
(A)	The 5f electrons of actinides are bound less tightly than the 4f electrons.
(B)	The trans uranium elements are prepared artificially.
(C)	All the actinides are radioactive.
(D)	Actinides do not exhibit actinide contraction.

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

Q.45	**The number of photons emitted per nanosecond by a deuterium lamp (400 nm) having a power of 1 microwatt (rounded off to the nearest integer) is ______.** **[$h = 6.626 \times 10^{-34}$ kg m^2 s^{-1}; $c = 3.0 \times 10^8$ m s^{-1}]**

Q.46	**Given the initial weight of 1 mg of radioactive $^{60}_{27}Co$ (half-life = 5.27 years), the amount disintegrated in 1 year (rounded off to two decimal places) is _______mg.**

Q.47	**The de Broglie wavelength of an argon atom (mass = 40 amu) traveling at a speed of 250 m s^{-1} (rounded off to one decimal place) is __________ picometers.** **[$N = 6.022 \times 10^{23}$; $h = 6.626 \times 10^{-34}$ kg m^2 s^{-1}]**

Q.48	**The molar absorption coefficient of a substance dissolved in cyclohexane is 1710 L mol^{-1} cm^{-1} at 500 nm. The reduction in intensity of light of the same wavelength that passes through a cell of 1 mm path length containing a 2 mmol L^{-1} solution (rounded off to one decimal place) is ___________%.**

Q.49	**The fundamental vibrational frequency of $^1H^{127}I$ is 2309 cm^{-1}. The force constant for this molecule (rounded off to the nearest integer) is _____N m^{-1}.** **[$N = 6.022 \times 10^{23}$, $c = 3.0 \times 10^8$ m s^{-1}]**

Q.50	**A laser Raman spectrometer operating at 532 nm is used to record the vibrational spectrum of Cl_2 having its fundamental vibration at 560 cm^{-1}. The Stokes line corresponding to this vibration will be observed at _______ cm^{-1}. (Rounded off to the nearest integer)**

Q.51	**The vapor pressure of toluene (Mol. Wt. = 92) is 0.13 atm at 25 °C. If 6 g of a hydrocarbon is dissolved in 92 g of toluene, the vapor pressure drops to 0.12 atm. The molar mass of the hydrocarbon (rounded off to the nearest integer) is _______.**

Q.52	**The reaction** **$CO\,(g) + Cl_2\,(g) \rightleftharpoons COCl_2\,(g)$** **at 500 °C, with initial pressures of 0.7 bar of CO and 1.0 bar of Cl_2, is allowed to reach equilibrium. The partial pressure of $COCl_2$ (g) at equilibrium is 0.15 bar. The equilibrium constant for this reaction at 500 °C (rounded off to two decimal places) is _____________.**

Q.53	**The rate constants for the decomposition of a molecule in the presence of oxygen are 0.237×10^{-4} L mol^{-1} s^{-1} at 0 °C and 2.64×10^{-4} L mol^{-1} s^{-1} at 25 °C** **(R = 8.314 J mol^{-1} K^{-1}).** **The activation energy for this reaction (rounded off to one decimal place) is ___________ kJ mol^{-1}.**

Q.54	**2 L of a gas at 1 atm pressure is reversibly heated to reach a final volume of 3.5 L. The absolute value of the work done on the gas (rounded off to the nearest integer) is _______ Joules.**

Q.55	**The quantity of the cobalt ore $[Co_3(AsO_4)_2 \cdot H_2O]$ required to obtain 1 kg of cobalt (rounded off to two decimal places) is _________ kg.** **[Atomic Wt. of Co = 59, As = 75, O = 16, H = 1]**