GATE – 2021 – Chemistry
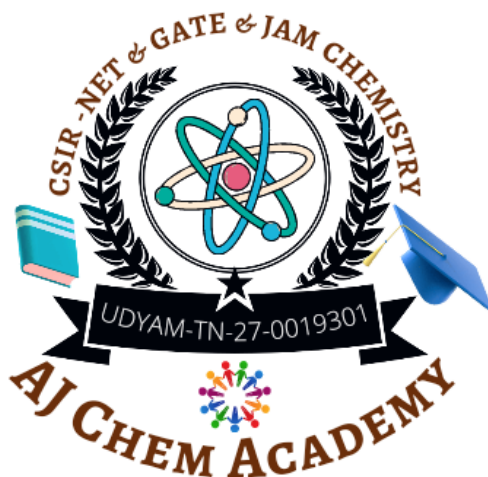

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Q.1 – Q.14 Multiple Choice Question (MCQ), carry ONE mark each (for each wrong answer: – 1/3).

1. The **rates of alkaline hydrolysis** of the compounds shown below, follow the order:
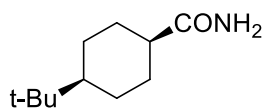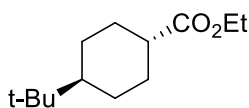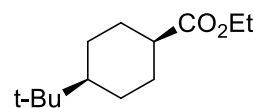
| I | II | III |

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

2. The **major product** formed in the following reaction is:

$$\xrightarrow[\text{Et}_2\text{O}]{\text{CH}_2\text{I}_2,\ \text{Zn/Cu}}$$

(a)   (b)

(c)   (d)
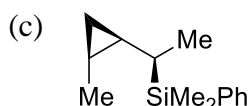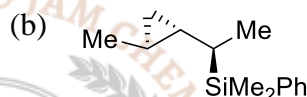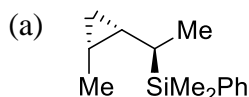
3. The **major product** formed in the following reaction is:

$$\xrightarrow[\text{(ii) aqueous acid}]{\text{(i) }\Delta}$$

(a)   (b)   (c)   (d)
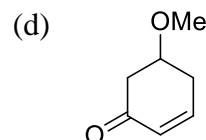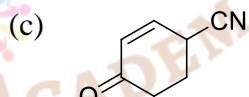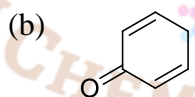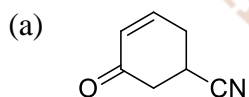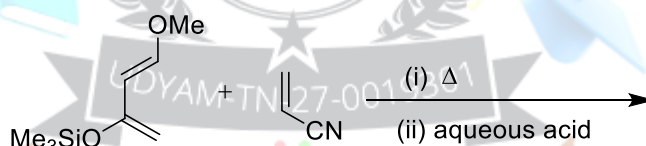
4. The **least acidic** among the following compounds is:

(a) $\text{MeO}_2\text{C}-\!\!\equiv\!\!-\text{H}$ (b)   (c)   (d)

5. The **major product** formed in the following reaction is:

(i) NOCl

(ii) hν

(iii) HCl

(a) OH CHO (b) OH / OHC (c) OH / OHC (d) OH CHO / OHC
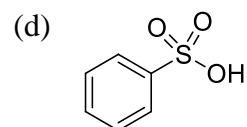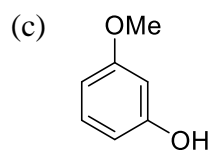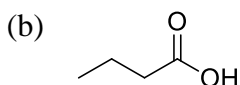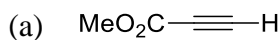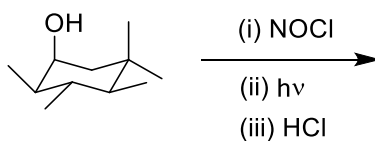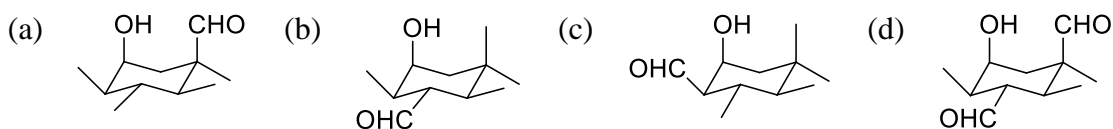
6. The **reagent(s) required for the conversion** of **hex-3-yne to (E)-hex-3-ene** is/are:

(a) $H_2, Pd/BaSO_4$ (b) Bu_3SnH (c) $Li/liquid\ NH_3$ (d) $LiAlH_4$

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 $\delta\ 7.49$ in the** ^{1}**H-NMR** spectrum in $CDCl_3$. The compound is:

(a) 1,4-dichlorobenzene   (b) 1,4-dibromobenzene

(c) 1,2-dibromobenzene   (d) 1,2-dichlorobenzene

8. Reaction of $LiAlH_4$ with **one equivalent** of $Me_3N.HCl$ gives a **tetrahedral compound**, which reacts with **another equivalent** of $Me_3N.HCl$ to **give compound X**. The **compound X** 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

9. Which one of the following is a **non-heme protein**?

(a) haemoglobin   (b) hemocyanin   (c) myoglobin   (d) cytochrome P-450

10. A correct example of a **nucleotide** is:

(a) adenosine monophosphate (AMP)   (b) RNA   (c) uridine   (d) DNA

11. The **equilibrium constant** for the reaction $3NO_{(g)} \rightleftharpoons N_2O_{(g)} + NO_{2(g)}$ at $25\ ^\circ C$ is closest to_____ $[\Delta G^0 = -104.18\ kJ; R = 8.314\ Jmol^{-1}K^{-1}]$

(a) 1.043   (b) 1.8×10^{18} (c) 1.651   (d) 5.7×10^{-19}

**12.** The reaction of $NiBr_2$ with **two equivalents** of PPh_3 in CS_2 at $-78\ ^\circ C$ gives a **red-coloured diamagnetic complex,** $[NiBr_2(PPh_3)_2]$. This transforms to a **green-coloured paramagnetic complex** with the **same molecular formula** at $25\ ^\circ C$. 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

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 concentrations 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^-

14. The Δ_0 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).**

15. The **phase diagram of CO_2** is shown below:
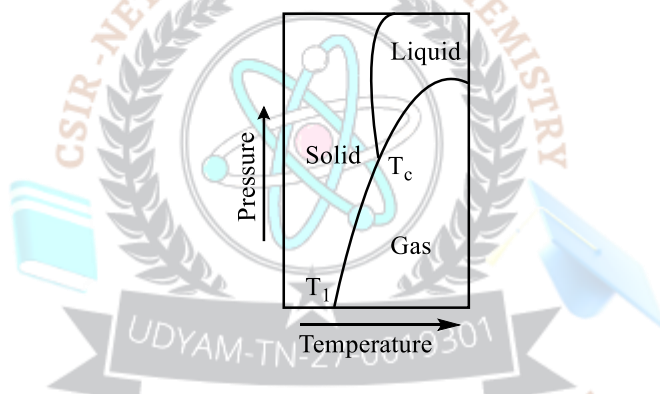
   The **correct statement(s) about CO_2** is/are:

   (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

16. **Acceptable wavefunctions** for a quantum particle must be:

   (a) odd   (b) even   (c) single-valued   (d) continuous

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) $1, -1, -1, -1$

18. The **normal mode(s) of vibration** of H_2O is/are:
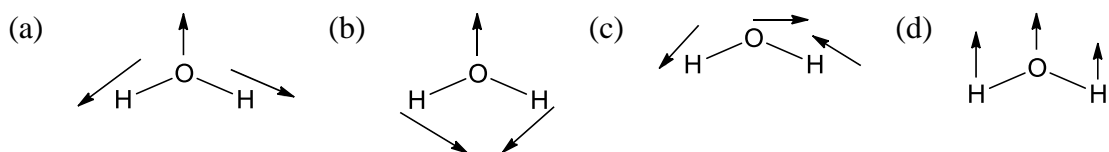
> **Q.19 – Q.25 Numerical Answer Type (NAT), carry ONE mark each (no negative marks).**

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 _____%.

20. Among the following eight compounds, the number of compound(s) which can exhibit stereoisomerism is _____.
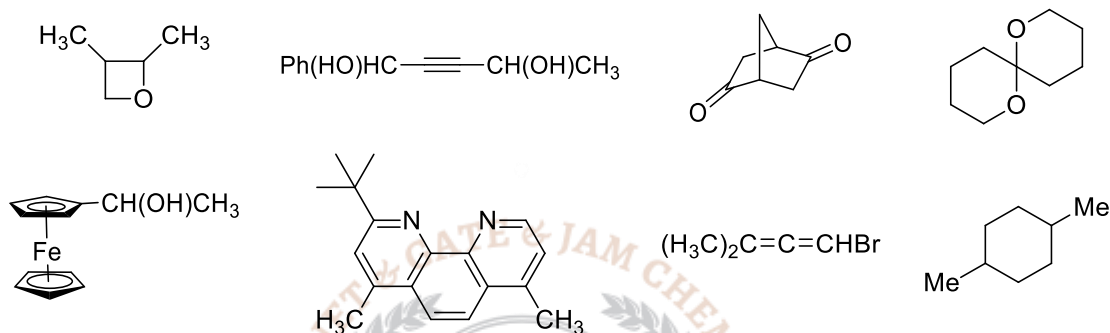
21. The Mo−Mo bond order in $[(\eta^5\text{-}C_5H_5)Mo(CO)_2]_2$ which obeys the 18-electron rule is _____

22. The change in enthalpy(ΔH) for the reaction $2P_{(s)} + 3Br_{2(l)} \longrightarrow 2PBr_{3(l)}$ is -243 kJ. In this reaction, if the amount of phosphorus consumed is 3.1 g, the change in enthalpy is _____ kJ. **(rounded off to two decimal places)**
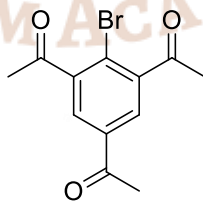
[Atomic Wt. of P $= 31$]

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

24. A 5V 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.

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

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

26. The **geometry** and the **number of unpaired electrons** in the given **tetrakis(1-norbornyl)Co Complex** respectively, are:
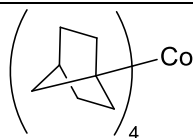
(a) tetrahedral and one

(b) tetrahedral and five

(c) square planar and one

(d) square planar and three

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:

	Red-Orange complex		Oxidation state		Origin of its color
(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

28. The **shapes** of the compounds $ClF_3, XeOF_2, N_3^-$ and XeO_3F_2 respectively, are:

	ClF_3,		$XeOF_2$		N_3^-		XeO_3F_2
(a)	T-shape	;	T-shape	;	linear	;	trigonal bipyramidal
(b)	trigonal planar	;	T-shape	;	V-shape	;	square pyramidal
(c)	T-shape	;	trigonal planar	;	linear	;	square pyramidal
(d)	trigonal planar	;	trigonal planar	;	V-shape	;	trigonal bipyramidal

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

30. The **major product** formed in the following reaction is:
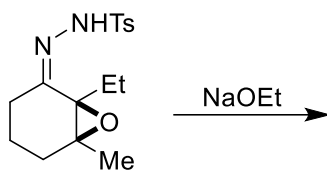
(a) non-6-yn-2-one   (b) non-3-yn-8-one   (c) non-2-yn-6-one   (d) non-3-en-8-one

31. The **major product** formed in the following reaction is:

(a)

(b)

(c)

(d)
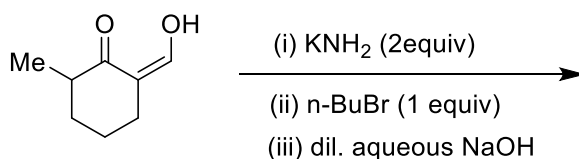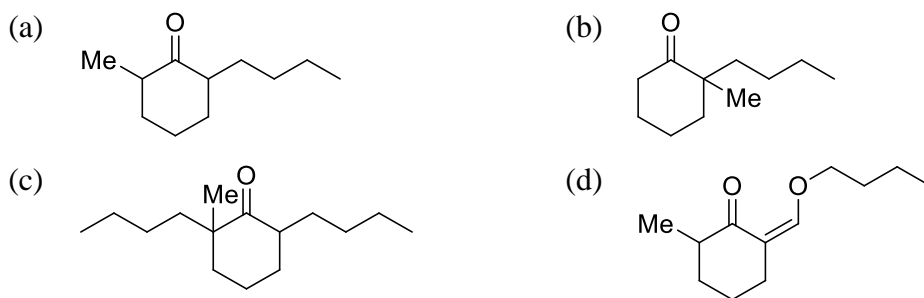
32. The **major product** formed in the following reaction is:

(a)

(b)

(c)

(d)

33. In the following reaction sequence, the **major products P** and **Q**, respectively, are:

(a) P = and Q =

(b) P = and Q =

(c)   P   =   and   Q   =

(d)   P   =   and   Q   =
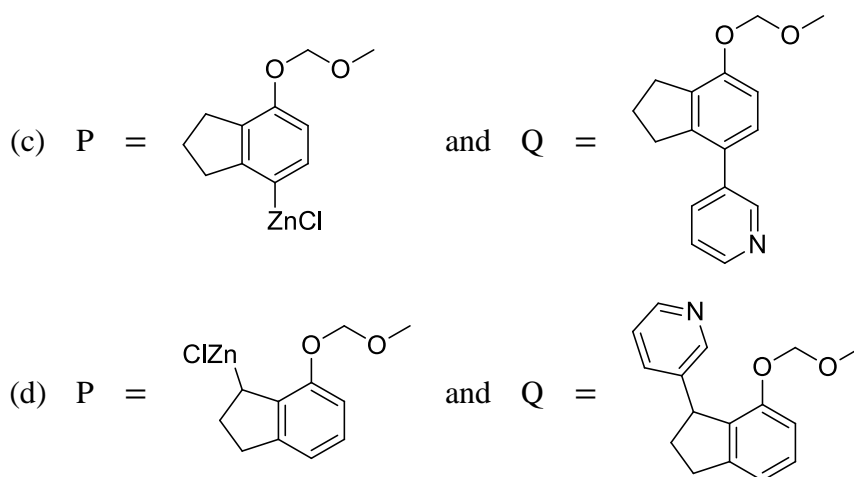
34. In an **electrochemical cell**, Ag^+ ions in $AgNO_3$ are reduced to Ag metal at the cathode and **Cu is oxidized to Cu^{2+}** at the anode. A current of $0.7\ A$ is passed through the cell for **10 min. The mass (in grams)** of silver deposited and copper dissolved, respectively, are:

[Faraday Constant $= 96,485\ C\ mol^{-1}$, Atomic Weight of Ag $= 107.9$, Atomic Weight of Cu $= 63.55$]
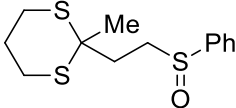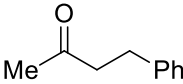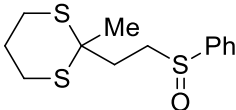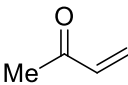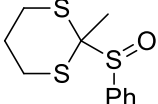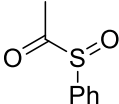
(a) 0.469 and 0.138   (b) 0.235 and 0.138   (c) 0.469 and 0.069   (d) 0.235 and 0.069

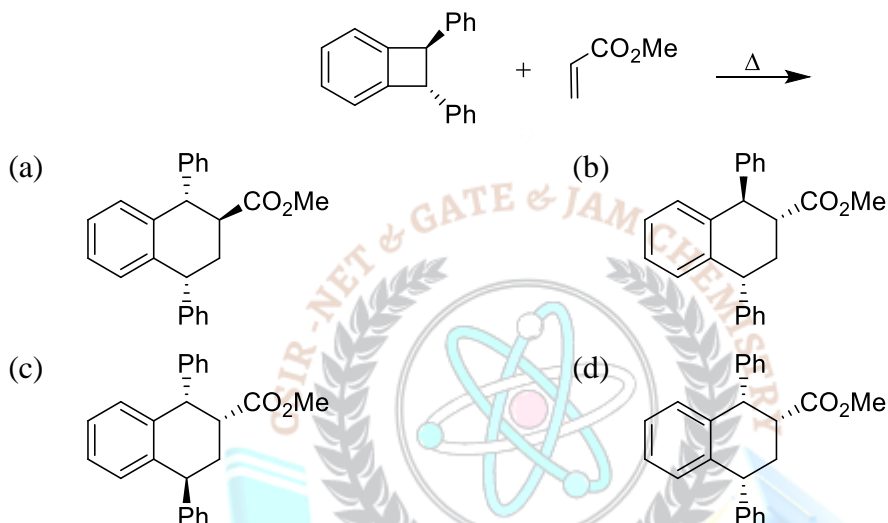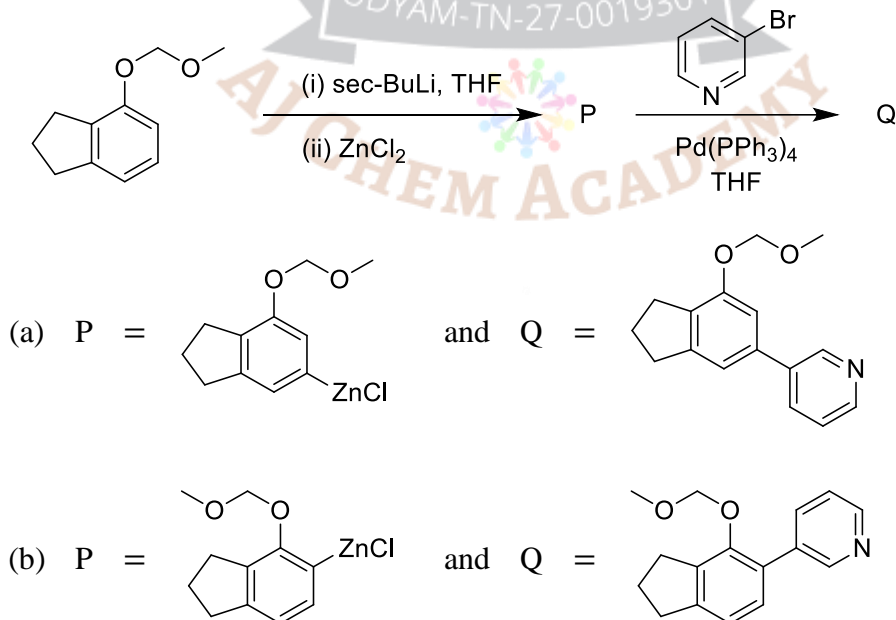**35.** Among the following

I   **II**   **III**

IV   **V**   **VI**
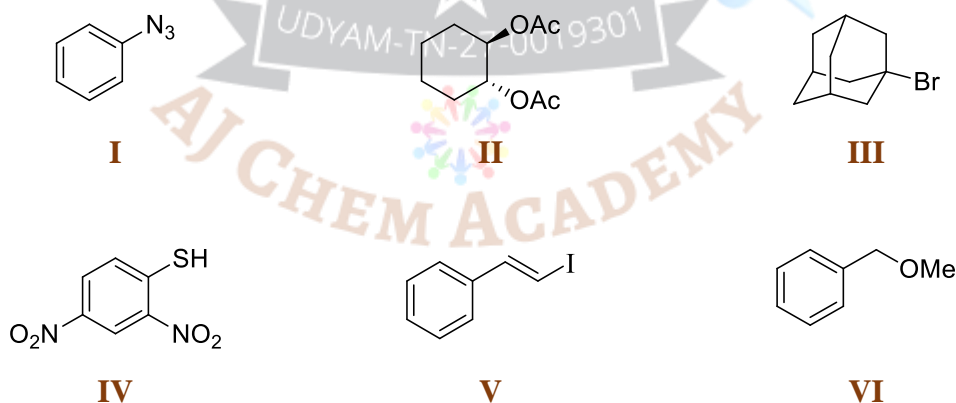
the compounds which can be prepared by **nucleophilic substitution reaction** are:

(a) III, IV, and V   (b) I, II, and VI   (c) II, IV, and VI   (d) I, III, and V

36. In the following reaction, the **major products X and Y**, respectively, are:

(a)   X   =   and   Y   =

(b) X = [structure: 1,3-dithiane with Me and CH₂CH₂-S(=O)-Ph group] and Y = [structure: Me-C(=O)-CH₂-CH₂-Ph]

(c) X = [structure: 1,3-dithiane with Me and CH₂CH₂-S(=O)-Ph group] and Y = [structure: Me-C(=O)-CH=CH₂]

(d) X = [structure: 1,3-dithiane with Me and S(=O)-Ph substituent] and Y = [structure: O=C(Me)-S(=O)-Ph]
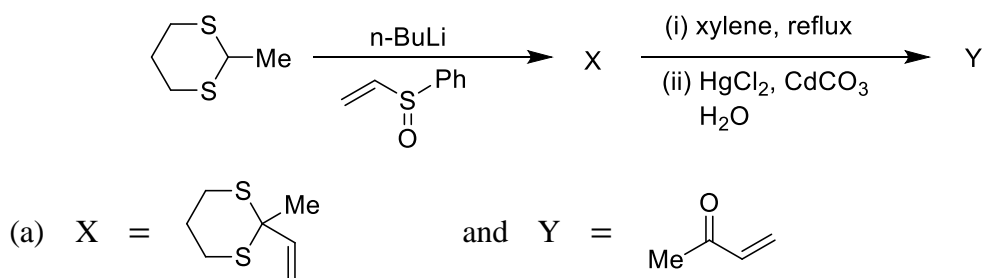
37. The **major products P** and **Q** formed in the following reactions respectively, are:

(a) P = [structure with Me, spiro cyclopropane, ketone O, isopropenyl Me] and Q = [structure with Me, epoxide O, isopropenyl Me]

(b) P = [structure with Me, epoxide O, isopropenyl Me] and Q = [structure with Me, ketone O, isopropenyl Me]

(c) P = [structure with Me, epoxide O, cyclopropyl Me] and Q = [structure with Me, spiro cyclopropane, ketone O, cyclopropyl Me]

(d) P = [structure with Me, spiro cyclopropane, ketone O, cyclopropyl Me] and Q = [structure with Me, epoxide O, cyclopropyl Me]

38. The major product formed in the reaction of **(2R,3R)-2-bromo-3-methylpentane** with **NaOMe** is:

(a) (Z)-3-methylpent-2-ene

(b) (E)-3-methylpent-2-ene

(c) (2R,3R)-2-methoxy-3-methylpentane

(d) (2S,3R)-2-methoxy-3-methylpentane

39. The **major product** formed in the following reaction is:

(i) LDA (1.1 equiv)

(ii) PhCH$_2$Br (1.1 equiv)

(iii) LiAlH$_4$ (3 equiv)

(a)

(b)

(c)

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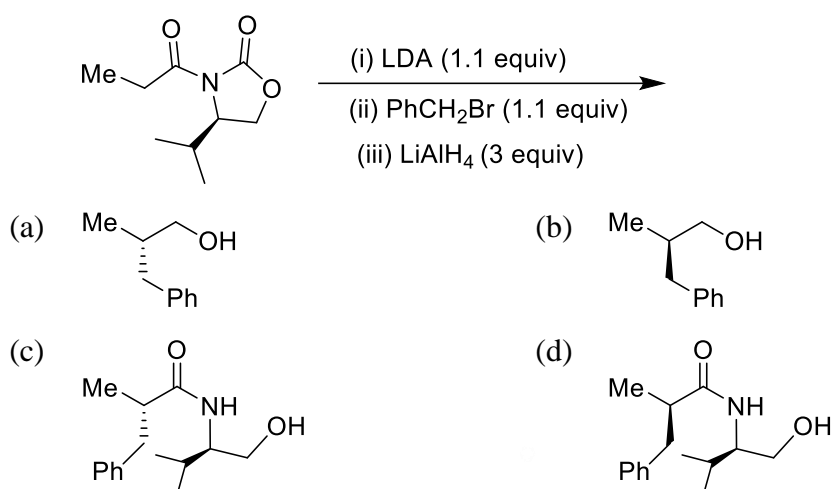
40. **Hexane** and **heptane** are completely miscible. At **25 °C**, the vapor pressures of hexane and heptane are **0.198 atm** and **0.06 atm**, respectively. The **mole fractions of hexane** and **heptane** in the vapor phase for a solution containing 4 M hexane and 6 M heptane, respectively, are:

(a) 0.688 and 0.312   (b) 0.400 and 0.600   (c) 0.312 and 0.688   (d) 0.600 and 0.400

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) $BFClBr > BFBr_2 > BF_2Cl > BF_2Br$

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).

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

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).

45. The **number of photons emitted per nano-second by a deuterium lamp ($400\ nm$)** having a power of 1 microwatt is _____. (rounded off to the nearest integer)

$$[h = 6.626 \times 10^{-34}\ kg\ m^2\ s^{-1}\ ;\ c = 3.0 \times 10^8\ m\ s^{-1}]$$

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

47. The **de Broglie wavelength of an argon atom ($mass = 40\ amu$) traveling at a speed of $250\ m\ s^{-1}$** is _____ picometers. (rounded off to one decimal place)

$$[N = 6.022 \times 10^{23};\ h = 6.626 \times 10^{-34}\ kg\ m^2\ s^{-1}]$$

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 $2\ m\ mol\ L^{-1}$ solution is _____%. (rounded off to one decimal place)

49. The fundamental vibrational frequency of $^1H^{127}I$ is $2309\ cm^{-1}$. The force constant for this molecule is _____ N m^{-1}. (rounded off to the nearest integer)

$$[N = 6.022 \times 10^{23},\ c = 3.0 \times 10^8\ m\ s^{-1}]$$

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)

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 is _____. (rounded off to the nearest integer)

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 $500\,°C$ is _____. (rounded off to two decimal places)

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

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 is _____Joules. (rounded off to the nearest integer)

55. The quantity of the cobalt ore $[Co_3(AsO_4)_2.H_2O]$ required to obtain 1 kg of cobalt is _____kg. (rounded off to two decimal places)

$$[Atomic\ Wt.\ of\ Co = 59, As = 75, O = 16, H = 1]$$

Answer Key

Q.No	Ans		Q.No	Ans		Q.No	Ans
1.	c		21.	3		41.	b
2.	a		22.	−12.16 to − 12.14		42.	b
3.	c		23.	3		43.	a & c
4.	a		24.	10800		44.	a & b & c
5.	a		25.	3.8 to 4.0		45.	2000 to 2020
6.	c		26.	a		46.	0.11 to 0.13
7.	b		27.	b		47.	39.5 to 40.5
8.	c		28.	a		48.	54 to 55
9.	b		29.	a		49.	309 to 315
10.	a		30.	a		50.	18225 to 18245
11.	b		31.	b		51.	71 to 73
12.	b		32.	d		52.	0.30 to 0.34
13.	b		33.	b		53.	65 to 66
14.	c		34.	a		54.	151 to 153

15.	a & c		35.	c		55.	2.50 to 2.80
16.	c & d		36.	c			
17.	a & c		37.	b			
18.	a & b & c		38.	b			
19.	20		39.	a			
20.	6		40.	a			

Q. 1 – 14	1 Mark (MCQ)		Q. 15 – 18	1 Mark (MSQ)		Q. 19 – 25	1 Mark (NAT)
Q. 26 – 42	2 Mark (MCQ)		Q. 43 – 44	2 Mark (MSQ)		Q. 45 – 55	2 Mark (NAT)