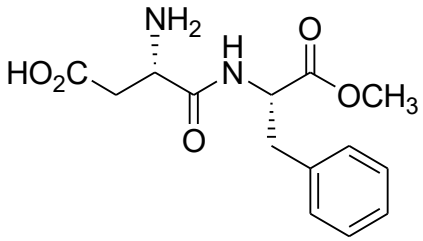
Section A: Q.1 – Q.10 Carry ONE mark each (Multiple Choice Questions)

Q.1 The following dipeptide derivative is used as an artificial sweetener:



The constituent α-amino acids of this dipeptide are

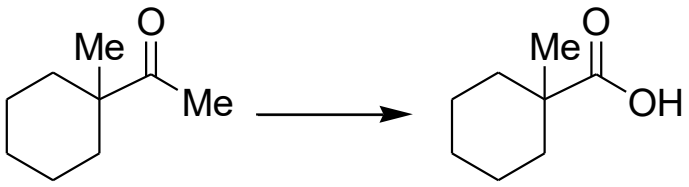
(A) phenylalanine and glutamic acid.

(B) phenylalanine and aspartic acid.

(C) tyrosine and aspartic acid.

(D) tyrosine and glutamic acid.

Q.2 The suitable reagent combination for the following transformation



is

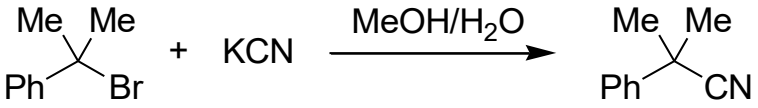
(A) (i) *meta*-chloroperbenzoic acid (*m*-CPBA); (ii) NaOH; (iii) aq. HCl

(B) (i) OsO_4; (ii) aq. HCl

(C) (i) I_2/NaOH; (ii) aq. HCl

(D) (i) dimethyldioxirane (DMDO); (ii) aq. HCl

Q.3 For the reaction



if the concentration of KCN is increased four times, then the rate of the reaction would be

(A) unaffected.

(B) increased by two times.

(C) decreased by four times.

(D) increased by four times.

Q.4 Consider the wavefunction $\psi(x) = N[\exp(ikx) + \exp(-ikx)]$. The complex conjugate $\psi^*(x)$ is

[Given: N is the normalization constant; $i = \sqrt{-1}$]

(A) $N[\exp(-ikx) - \exp(ikx)]$

(B) $N^*[\exp(-ikx) - \exp(ikx)]$

(C) $N^*[\exp(ikx) + \exp(-ikx)]$

(D) $2N[\sin(kx)]$

Q.5 Wavelength of X-rays used in a diffraction experiment is 1.54 Å. X-rays are diffracted from a set of planes with an interplanar spacing of 1.54 Å. Then the angle θ (in degrees) corresponding to the first-order Bragg diffraction is

(A) 30º

(B) 15º

(C) 45º

(D) 90º

Q.6 Identify the reaction for which, at equilibrium, a change in the volume of the closed reaction vessel at a constant temperature will not affect the extent of the reaction.

(A) $\mathrm{CaCO_3}(s) \rightleftharpoons \mathrm{CaO}(s) + \mathrm{CO_2}(g)$

(B) $\mathrm{H_2}(g) + \mathrm{I_2}(g) \rightleftharpoons 2\mathrm{HI}(g)$

(C) $2\mathrm{NO_2}(g) \rightleftharpoons \mathrm{N_2O_4}(g)$

(D) $\mathrm{CO_2}(s) \rightleftharpoons \mathrm{CO_2}(g)$

Q.7 Among $[Ti(H_2O)_6]^{3+}$, $[NiCl_4]^{2-}$, $[CrO_4]^{2-}$, and $[Mn(H_2O)_6]^{2+}$, the complex that exhibits the largest molar absorptivity in the visible region of the electronic absorption spectrum is

(A) $[Ti(H_2O)_6]^{3+}$

(B) $[NiCl_4]^{2-}$

(C) $[CrO_4]^{2-}$

(D) $[Mn(H_2O)_6]^{2+}$

Q.8 $[Co(NH_3)_5(SO_4)]Br$ and $[Co(NH_3)_5Br]SO_4$ are examples of

(A) ionization isomers.

(B) linkage isomers.

(C) optical isomers.

(D) coordination isomers.

Q.9 The pair of proteins having heme core is

(A) hemoglobin and myoglobin.

(B) hemerythrin and myoglobin.

(C) hemoglobin and hemocyanin.

(D) hemocyanin and hemerythrin.

Q.10 The shape of SCN^- is

(A) linear.

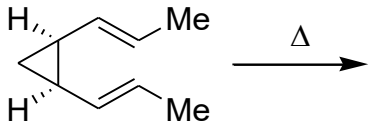
(B) bent.

(C) pyramidal.

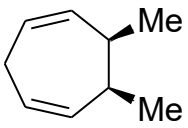
(D) trigonal planar.

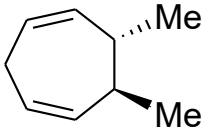
Section A: Q.11 – Q.30 Carry TWO marks each. (Multiple Choice Questions)

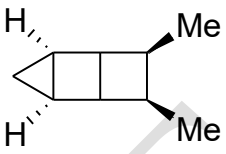
Q.11 The major product formed in the following reaction

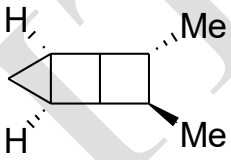


is

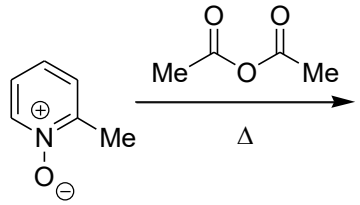
(A) 

(B) 

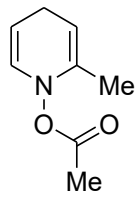
(C) 

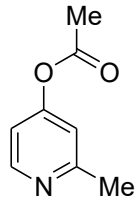
(D) 

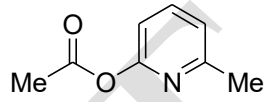
Q.12 The major product formed in the following reaction

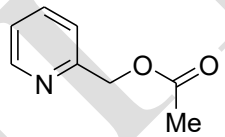


is

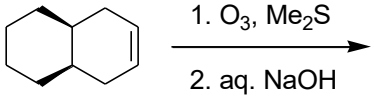
(A) 

(B) 

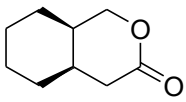
(C) 

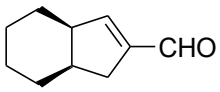
(D) 

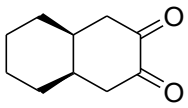
Q.13 The major product formed in the following reaction

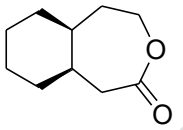


is

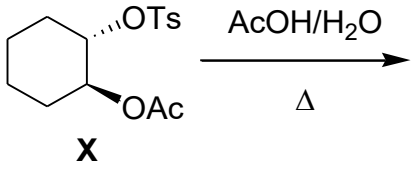
(A) 

(B) 

(C) 

(D) 

Q.14 In the following reaction



X

optically pure ester **X** formed product that did not exhibit optical rotation ($[\alpha]_D = 0$) due to the formation of

(Note: Ts = *para*-toluenesulfonyl; Ac = acetyl)

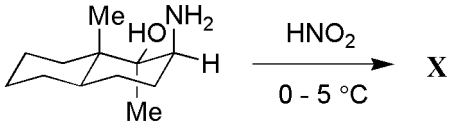
(A) *cis*-1,2-diacetoxycyclohexane.

(B) a racemic mixture of *trans*-1,2-diacetoxycyclohexane.

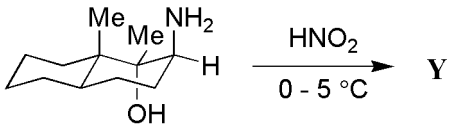
(C) cyclohexene.

(D) cyclohexene oxide.

Q.15 The major products **X** and **Y** in the following reactions

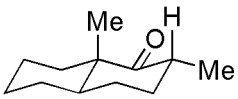


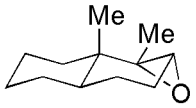
X

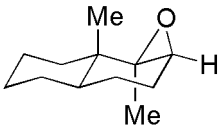


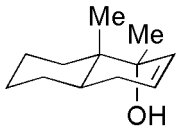
Y

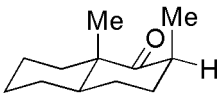
respectively, are

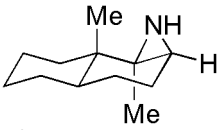
(A) 

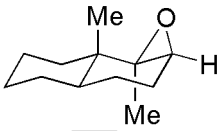
and 

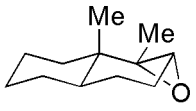
(B) 

and 

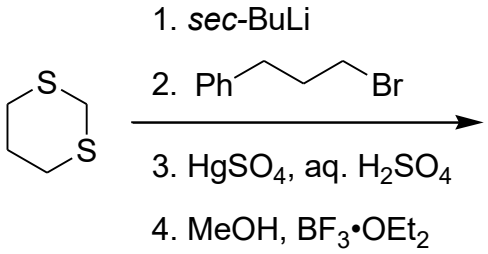
(C) 

and 

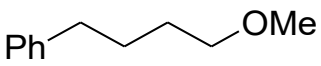
(D) 

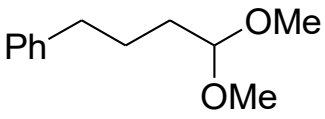
and 

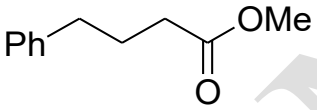
Q.16 The major product formed in the following reaction

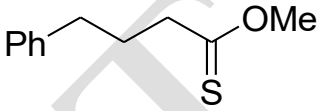


is

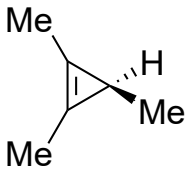
(A) 

(B) 

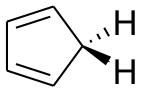
(C) 

(D) 

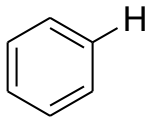
Q.17 The acidity of the compounds shown below



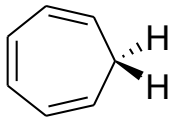
I



II



III



IV

follows the order

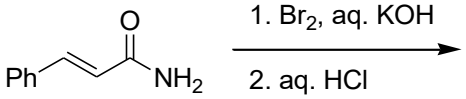
(A) **II** > **I** > **III** > **IV**

(B) **II** > **IV** > **III** > **I**

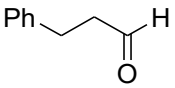
(C) **I** > **II** > **IV** > **III**

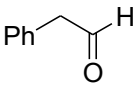
(D) **III** > **IV** > **II** > **I**

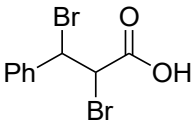
Q.18 The major product formed in the following reaction

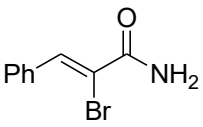


is

(A) 

(B) 

(C) 

(D) 

Q.19 The ratio of osmotic pressures of aqueous solutions of 0.01 M $BaCl_2$ to 0.005 M NaCl is

[Given: Both compounds dissociate completely in water]

(A) 3:1

(B) 1:4

(C) 1:1

(D) 3:2

Q.20 In the cell reaction

$$P^{+}(aq) + Q(s) \rightarrow P(s) + Q^{+}(aq)$$

the EMF of the cell, E_{cell} is zero. The standard EMF of the cell, E^{o}_{cell} is

[Given:
Activities of all solids are unity.
Activity of $P^{+}(aq)$ is 2 M. Activity of $Q^{+}(aq)$ is 1 M.
R = universal gas constant; T = temperature; F = Faraday constant]

(A) $\frac{RT}{F}$

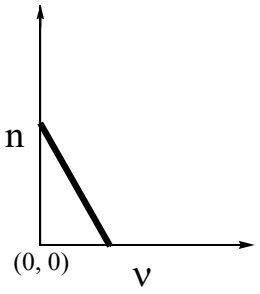
(B) $\frac{RT}{2F}$

(C) $-\frac{RT}{F}\ln(2)$

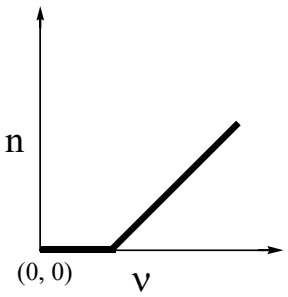
(D) $\frac{RT}{F}\ln(2)$

Q.21 Consider photoelectric effect. The number of incident photons is the same for all frequencies. The plot that best describes the dependence of the number of photoelectrons (n) emitted as a function of the incident light frequency (ν) is

(A)



(B)



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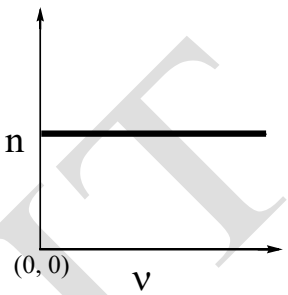
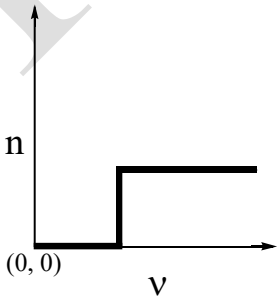


(D)



Q.22 If nitrogen and oxygen gases are at the same temperature, the correct statement according to the kinetic theory of gases is

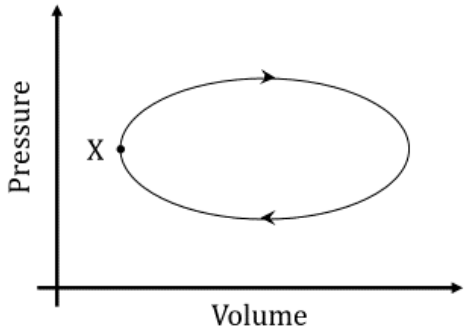
(A) Average kinetic energy of nitrogen and oxygen molecules is inversely proportional to temperature.

(B) For nitrogen and oxygen molecules, the root mean square speed is equal to the most probable speed.

(C) Average speed of nitrogen molecules is less than the average speed of oxygen molecules.

(D) Average kinetic energies of nitrogen and oxygen molecules are equal.

Q.23 A system undergoes one clockwise cycle from point X back to point X as shown in the figure below:



The correct statement about this process is

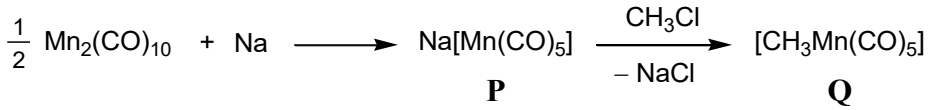
(A) Internal energy of the system decreases at the end of the cycle.

(B) Entropy of the system increases at the end of the cycle.

(C) System performs work on the surroundings during the cycle.

(D) Heat exchanged between system and surroundings is zero during the cycle.

Q.24 For the reaction shown below



the oxidation states of Mn in **P** and **Q**, respectively, are

(A) +1 and +1

(B) –1 and +1

(C) –1 and –1

(D) +1 and –1

Q.25 The number and nature of *d*–*d* transition(s) in the case of Sc^{2+} in an octahedral crystal field, respectively, are

[Ignore spin-orbit coupling and Jahn-Teller distortion.]

(A) 1 and spin allowed.

(B) 3 and spin allowed.

(C) 1 and Laporte allowed.

(D) 3 and Laporte allowed.

Q.26 The *d*-*d* transitions in $[Mn(H_2O)_6]^{2+}$ and $[Ti(H_2O)_4]^{3+}$, respectively, are

[Ignore spin-orbit coupling and Jahn-Teller distortion.]

(A) symmetry allowed and symmetry forbidden.

(B) symmetry forbidden and symmetry allowed.

(C) symmetry allowed and symmetry allowed.

(D) symmetry forbidden and symmetry forbidden.

Q.27 A pair of isosteric compounds is

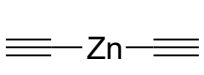
(A) H_2NBH_2 and C_2H_6

(B) $H_3N{\cdot}BH_3$ and C_2H_6

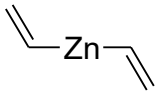
(C) B_2H_6 and C_2H_6

(D) $H_3N{\cdot}BH_3$ and B_2H_6

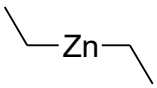
Q.28 Zn–C bond polarity in the compounds below



I



II



III

follows the order

(A) **I** > **II** > **III**

(B) **III** > **II** > **I**

(C) **II** > **III** > **I**

(D) **II** > **I** > **III**

Q.29 B_2 and C_2, respectively, are

(A) paramagnetic and diamagnetic.

(B) diamagnetic and paramagnetic.

(C) paramagnetic and paramagnetic.

(D) diamagnetic and diamagnetic.

Q.30 Mobility of ions

Li^+, Na^+, K^+, Ag^+

in water at 298 K follows the order

(A) $K^+ < Ag^+ < Na^+ < Li^+$

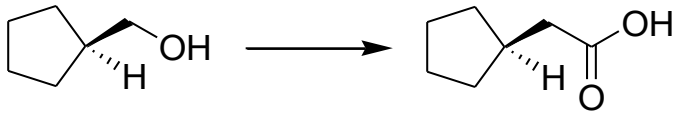
(B) $Li^+ < K^+ < Na^+ < Ag^+$

(C) $Ag^+ < Li^+ < K^+ < Na^+$

(D) $Li^+ < Na^+ < Ag^+ < K^+$

Section B: Q.31 – Q.40 Carry TWO marks each. (Multiple Select Questions)

Q.31 The suitable synthetic route(s) for the following transformation



is/are

(A) (i) *para*-toluenesulfonyl chloride (TsCl), pyridine; (ii) KI; (iii) Mg/Et_2O; (iv) CO_2; (v) aq. HCl

(B) (i) *para*-toluenesulfonyl chloride (TsCl), pyridine; (ii) KCN; (iii) conc. aq. NaOH, reflux; (iv) aq. HCl

(C) (i) CrO_3, H_2SO_4; (ii) $SOCl_2$; (iii) CH_2N_2; (iv) Ag_2O, H_2O

(D) (i) CrO_3, H_2SO_4; (ii) CH_2N_2

Q.32 The compound(s) which on reaction with CH_3MgBr followed by treatment with aqueous NH_4Cl would produce 1-methyl-1-phenylethanol as the major product is/are

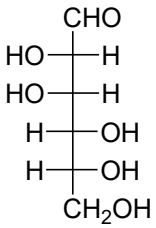
(A) methyl benzoate.

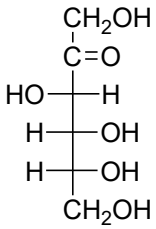
(B) phenyl acetate.

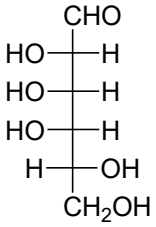
(C) acetaldehyde.

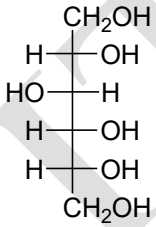
(D) acetophenone.

Q.33 Among the following, the compound(s) which produce the same osazone as that obtained from D-glucose, when reacted with phenylhydrazine, is/are

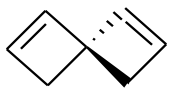
(A) 

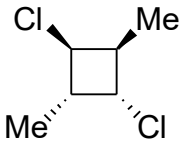
(B) 

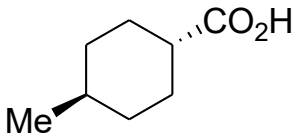
(C) 

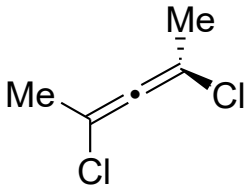
(D) 

Q.34 Among the following, the chiral molecule(s) is/are

(A) 

(B) 

(C) 

(D) 

Q.35 The correct assumption(s) required to derive Langmuir adsorption isotherm is/are

(A) Adsorption is limited to a monolayer on adsorbing surface.

(B) All binding sites on adsorbing surface are identical.

(C) Adsorption of a molecule on a site enhances binding of other molecules on neighboring sites.

(D) Rate of adsorption and rate of desorption are equal at equilibrium.

Q.36 For one mole of an ideal gas, the correct statement(s) is/are

[U = internal energy; V = volume; T = temperature; P = pressure]

(A) $\left(\frac{\partial U}{\partial V}\right)_T = 0$

(B) $\left(\frac{\partial U}{\partial T}\right)_V > 0$

(C) $\left(\frac{\partial P}{\partial T}\right)_V > 0$

(D) $\left(\frac{\partial V}{\partial P}\right)_T > 0$

Q.37 Consider the exothermic chemical reaction $O_2(g) + 2H_2(g) \rightleftharpoons 2H_2O(g)$ at equilibrium in a closed container. The correct statement(s) is/are

(A) At equilibrium, introduction of catalyst increases product formation.

(B) Equilibrium constant decreases with increase in temperature.

(C) The equilibrium constant K_P increases with pressure.

(D) Decrease in volume of reaction vessel increases product formation.

Q.38 Elements and their processes of extraction/purification are given.
The correct pair(s) is/are

(A) Na; Downs process

(B) Ni; Mond process

(C) B; Frasch process

(D) Al; Bayer process

Q.39 The correct statement(s) about the ligand substitution/exchange reaction is/are

(A) The rate is faster in the case of SF_6 than in $[AlF_6]^{3-}$.

(B) The rate is faster in the case of $[Mg(H_2O)_6]^{2+}$ than in $[Sr(H_2O)_6]^{2+}$.

(C) The rate of water exchange is faster in the case of $[Ni(H_2O)_6]^{2+}$ than in $[Co(NH_3)_5(H_2O)]^{3+}$.

(D) The rate is faster in case of $[Cr(H_2O)_6]^{2+}$ than in $[Cr(H_2O)_6]^{3+}$.

Q.40 The stretching frequency of CO in $H_3B{\cdot}CO$ is

(A) greater than the stretching frequency in free CO.

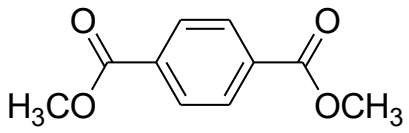
(B) lesser than the stretching frequency in free CO.

(C) lesser than the stretching frequency of CO in $Fe(CO)_5$.

(D) greater than the stretching frequency of CO in $Fe(CO)_5$.

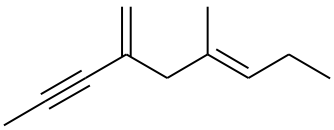
Section C: Q.41 – Q.50 Carry ONE mark each. (Numerical Answer Type)

Q.41 For the following compound



the number of signals expected in the ^{1}H NMR spectrum is _____.

Q.42 Exhaustive hydrogenation of the following compound



under Pd/C generates a saturated hydrocarbon as the product.
The number of stereoisomers possible for this product is _____.

Q.43 For a zero-order reaction P → Q, the concentration of P becomes half of its initial concentration in 30 minutes after starting the reaction.

The concentration of P becomes zero at _____ minutes.
(*rounded off to the nearest integer*)

Q.44 The magnitude of energy difference between the energy levels $n = 3$ and $n = 2$ of a quantum particle of mass m in a box of length L is $\frac{Xh^2}{8m\mathrm{L}^2}$.

Then X = _____.

(*rounded off to the nearest integer*)

[Given: h is Planck's constant and n denotes the quantum number]

Q.45 The function $\exp(-2(x-1)^2)$ attains a maximum at $x =$ _____.
(*rounded off to the nearest integer*)

Q.46 0.1 M aqueous solution of a weak monobasic acid has pH 2.0. The pK_a of the monobasic acid is _____. (*rounded off to one decimal place*)

Q.47 The enthalpy change for the reaction

$C(g) + \frac{1}{2}O_2(g) \rightarrow CO(g)$ is _____ kJ per mole of $CO(g)$ produced.

(*rounded off to one decimal place*)

[Given:

$C(g) + O_2(g) \rightarrow CO_2(g)$, $\Delta H_{rxn} = -393.5$ kJ per mole of $CO_2(g)$ produced

$CO_2(g) \rightarrow CO(g) + \frac{1}{2}O_2(g)$, $\Delta H_{rxn} = 283.0$ kJ per mole of $CO(g)$ produced]

Q.48 The N–O bond order in $[NO]^-$ is _____.

Q.49 The bond length of CO is 113 pm and its dipole moment ($\vec{\mu}$) is 0.1 D. The charge (in units of electronic charge) on carbon in the CO molecule *including its sign* is _____. (*rounded off to three decimal places*)

[Given: charge of electron = 1.602×10^{-19} C; 1 D = 3.336×10^{-30} C m]

Q.50 The magnetic moment of O_3 molecule is _____ Bohr magneton (B.M.).

(*rounded off to the nearest integer*)

Section C: Q.51 – Q.60 Carry TWO marks each. (Numerical Answer Type)

Q.51 A reaction of 10.50 g of 1,2-diphenylethane-1,2-dione with conc. NaOH followed by aqueous acidic work-up furnished 8.55 g of a carboxylic acid. The yield of the carboxylic acid in this reaction is _____ %.

(*rounded off to the nearest integer*)

Q.52 The specific rotation of an optically pure compound is +75.3 (*c* 1.0 in $CHCl_3$) at 20 °C. A synthetic sample of the same compound showed a specific rotation of +66.3 (*c* 1.0 in $CHCl_3$) at 20 °C. The enantiomeric excess (*ee*) of the synthetic sample is _____ %.
(*rounded off to the nearest integer*)

Q.53 A salt QCl of a certain metal Q is electrolyzed to its elements. 40 g of metal Q is formed at an electrode. The volume of Cl_2 formed at the other electrode at 1 atm pressure and 298 K is _____ litres. (*rounded off to one decimal place*)

[Given: The gas constant $R = 0.082$ L atm mol^{-1} K^{-1}, the molar mass of Q is 40 g mol^{-1} and Cl_2 is assumed to be an ideal gas]

Q.54 If 1 M of a dye in water transmits 50% of incident light at 400 nm, then 2 M of the dye in water transmits _____ % of the incident light at 400 nm.
(*rounded off to the nearest integer*)

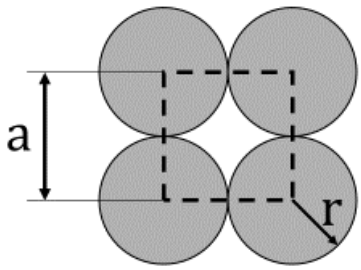
[Given: Both experiments are performed in the same spectrophotometric cell.]

Q.55 A 1.0 L solution is prepared by dissolving 2.0 g of benzoic acid and 4.0 g of sodium benzoate in water. The pH of the resulting solution is _____.
(*rounded off to one decimal place*)

Given:
Molar mass of benzoic acid is $122\ \text{g mol}^{-1}$
Molar mass of sodium benzoate is $144\ \text{g mol}^{-1}$
pK_a of benzoic acid is 4.2

Q.56 The total vapour pressure of an ideal binary liquid mixture of benzene and toluene is 0.3 bar. The vapour pressure of pure benzene is 0.5 bar and that of toluene is 0.2 bar. The mole fraction of benzene in this mixture is _____.
(*rounded off to two decimal places*)

Q.57 The unit cell of a two-dimensional square lattice with lattice parameter a is indicated by the dashed lines as shown below:



The percentage (%) area occupied by the grey circles (of radius r) inside the unit cell is _____. (*rounded off to the nearest integer*)

Q.58 In the oxidation of phosphorus with oxygen, 0.2 mol of P_4 produces _____ g of P_4O_{10}.
(*rounded off to one decimal place*)

[Given: Atomic weight of P = 31; Atomic weight of O = 16]

Q.59 An element E has three isotopes:

$^{28}_{14}$E (abundance 92.21%, atomic mass: 27.977 a.m.u.),

$^{29}_{14}$E (abundance 4.70%, atomic mass: 28.976 a.m.u.), and

$^{30}_{14}$E (abundance 3.09%, atomic mass: 29.974 a.m.u).

The atomic mass of E is _____ a.m.u.

(*rounded off to three decimal places*)

Q.60 The wavelength of the γ-ray emitted in

$^{137m}_{56}$Ba ⇝ $^{137}_{56}$Ba + γ-ray (0.66 MeV)

is _____ Å. (*rounded off to three decimal places*)

[Given: $h = 6.626 \times 10^{-34}$ J s; $c = 2.998 \times 10^{8}$ m s^{-1}; 1 MeV = 1.602×10^{-13} J]