Paper Specific Instructions

1. The examination is of 3 hours duration. There are a total of 60 questions carrying 100 marks. The entire paper is divided into three sections, **A**, **B** and **C**. All sections are compulsory. Questions in each section are of different types.

2. **Section – A** contains a total of 30 **Multiple Choice Questions (MCQ).** Each MCQ type question hasfour choices out of which only **one**choice is the correct answer. Questions Q.1 – Q.30 belong to this section and carry a total of 50 marks. Q.1 – Q.10 carry 1 mark each and Questions Q.11 – Q.30 carry 2 marks each.

3. **Section – B** contains a total of 10 **Multiple Select Questions (MSQ).** Each MSQ type question is similar to MCQ but with a difference that there may be **one or more than one** choice(s) that are correct out of the four given choices. The candidate gets full credit if he/she selects all the correct answers only and no wrong answers.Questions Q.31 – Q.40 belong to this section and carry 2 marks each with a total of 20 marks.

4. **Section – C** contains a total of 20 **Numerical Answer Type (NAT)** questions. For these NAT type questions, the answer is a real number which needs to be entered using the virtual keyboard on the monitor. No choices will be shown for these type of questions. Questions Q.41 – Q.60 belong to this section and carry a total of 30 marks. Q.41 – Q.50 carry 1 mark each and Questions Q.51 – Q.60 carry 2 marks each.

5. In all sections, questions not attempted will result in zero mark. In **Section – A** (MCQ), wrong answer will result in **NEGATIVE** marks. For all 1 mark questions, 1/3 marks will be deducted for each wrong answer. For all 2 marks questions, 2/3 marks will be deducted for each wrong answer. In **Section – B** (MSQ), there is **NO NEGATIVE** and **NO PARTIAL** marking provisions. There is **NO NEGATIVE**marking in **Section – C** (NAT) as well.

6. Only Virtual Scientific Calculator is allowed. Charts, graph sheets, tables, cellular phone or otherelectronic gadgets are **NOT** allowed in the examination hall.

7. Paper for rough work will be provided.

## SECTION – A

MULTIPLE CHOICE QUESTIONS (MCQ)

Q. 1 – Q.10 carry one mark each.

Q.1 For a reaction of the type A + B → Products, the unit of the rate constant is mol L^{-1} s^{-1}. The overall order of the reaction is

(A) 0   (B) 1   (C) 2   (D) 3

Q.2 The thermodynamic criterion for spontaneity of a process in a system under constant volume and temperature and in the absence of any work other than expansion work (if any) is

(A) change in entropy is positive
(B) change in enthalpy is negative
(C) change in Helmholtz free energy is negative
(D) change in Gibbs free energy is negative

Q.3 The number of vibrational mode(s) of a carbon dioxide molecule that can be detected using infrared spectroscopy is

(A) 1   (B) 2   (C) 3   (D) 4

Q.4 For three non-coplanar vectors $\mathbf{a}$, $\mathbf{b}$ and $\mathbf{c}$, the expression $\mathbf{a} \cdot (\mathbf{b} \times \mathbf{c})$ can be written as

(A) $(\mathbf{a} \times \mathbf{b}) \cdot \mathbf{c}$ (B) $(\mathbf{a} \times \mathbf{b}) \cdot (\mathbf{a} \times \mathbf{c})$

(C) $(\mathbf{a} \cdot \mathbf{b}) \times (\mathbf{a} \cdot \mathbf{c})$ (D) $(\mathbf{a} \cdot \mathbf{b}) \times \mathbf{c}$

Q.5 Correct trend in the bond order is

(A) $O_2^+ > O_2^{2-} > O_2^-$
(B) $O_2^- > O_2^+ > O_2^{2-}$
(C) $O_2^{2-} > O_2^- > O_2^+$
(D) $O_2^+ > O_2^- > O_2^{2-}$

Q.6 The correct option for the metal ion present in the active site of myoglobin, hemocyanin and vitamin B_{12}, respectively, is

(A) iron, iron and zinc
(B) molybdenum, iron and copper
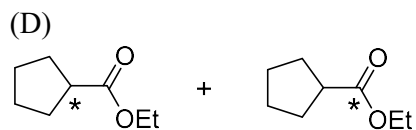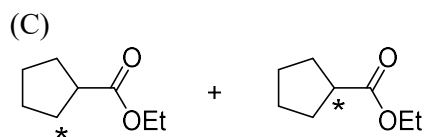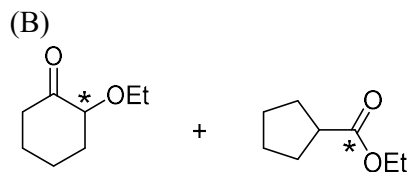(C) iron, copper and cobalt
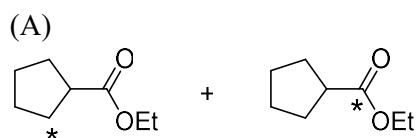(D) molybdenum, copper and cobalt

Q.7   The correct order of wavelength (λ_{max}) of the halide to metal charge-transfer band of
      $[Co(NH_3)_5Cl]^{2+}$ (I), $[Co(NH_3)_5Br]^{2+}$ (II) and $[Co(NH_3)_5I]^{2+}$ (III), is

      (A) III < II < I
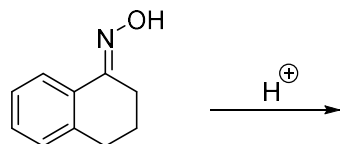   (B) I < II < III
      (C) II < III < I
      (D) I < III < II

Q.8   The correct option for the major products of the following reaction is
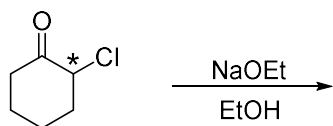
(* represents isotopically
 labelled carbon atom)
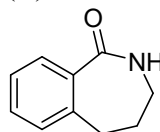
(A)

(B)

(C)

(D)

Q.9   The major product formed in the following reaction is
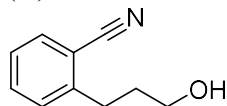
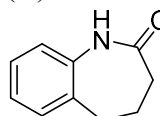(A)   (B)
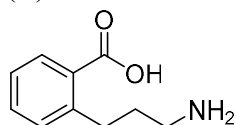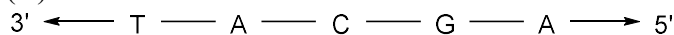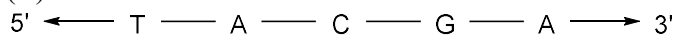

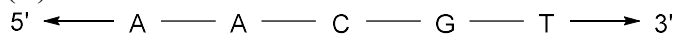(C)   (D)

Q.10   The complementary strand for the following single strand of DNA is

5' ←—— A —— T —— G —— C —— T ——→ 3'

(A)
3' ←—— T —— A —— C —— G —— A ——→ 5'

(B)
3' ←—— A —— T —— G —— C —— T ——→ 5'

(C)
5' ←—— T —— A —— C —— G —— A ——→ 3'

(D)
5' ←—— A —— A —— C —— G —— T ——→ 3'

Q. 11 – Q. 30 carry two marks each.

Q.11   The function $f(x) = x\,e^{-x^2}$ has a minimum at

(A) $x = \sqrt{2}$ (B) $x = -\sqrt{2}$ (C) $x = \frac{1}{\sqrt{2}}$ (D) $x = -\frac{1}{\sqrt{2}}$

Q.12   The correct option for the number of bending modes of vibration in each of H_2O, CS_2 and SO_2 molecules, respectively, is

(A) 1, 2 and 2   (B) 2, 2 and 1
(C) 2, 1, and 2   (D) 1, 2 and 1

Q.13   The total number of degrees of freedom of an HBr molecule that is constrained to translate along a straight line but does not have any constraints for its rotation and vibration is

(A) 6   (B) 5   (C) 4   (D) 3

Q.14   According to the kinetic theory of gases, the ratio of the root mean square velocity of molecular oxygen and molecular hydrogen at 300 K is

(A) $1:1$ (B) $1:2\sqrt{2}$ (C) $1:4$ (D) $1:16$

Q.15   The half-life of the chemical reaction, A $\rightarrow$ Product, for initial reactant concentrations of 0.1 and 0.4 mol L^{-1} are 200 and 50 s, respectively. The order of the reaction is

(A) 0   (B) 1   (C) 2   (D) 3

Q.16   The ratio of the nearest neighbor atomic distances in body-centered cubic (bcc) and face-centered cubic (fcc) crystals with the same unit cell edge length is

(A) $\sqrt{\dfrac{3}{2}}$ (B) $\dfrac{\sqrt{3}}{2}$ (C) $\dfrac{1}{\sqrt{2}}$ (D) $\dfrac{1}{2}$

Q.17   The correct trend in the rate of substitution of Cl$^-$ by pyridine in the following complexes is
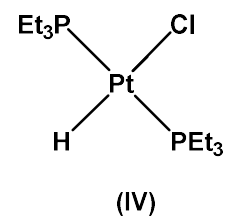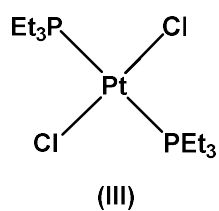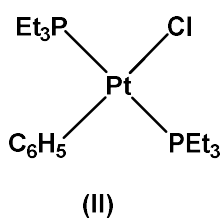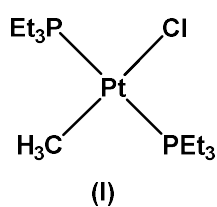

(A) III < II < I < IV
(B) II < III < I < IV
(C) I < II < III < IV
(D) III < II < IV < I

Q.18   In qualitative inorganic analysis of metal ions, the ion which precipitates as sulfide in the presence of H$_2$S in warm dilute HCl is

(A) Cr^{3+} (B) Al^{3+} (C) Co^{2+} (D) Bi^{3+}

Q.19   The correct statement regarding the observed magnetic properties of NO, O_2, B_2, and C_2 in their ground state is

(A) NO, B_2, and C_2 are paramagnetic
(B) B_2, O_2 and NO are paramagnetic
(C) O_2, C_2 and NO are paramagnetic
(D) O_2, B_2 and C_2 are paramagnetic

Q.20   The observed magnetic moments of octahedral Mn^{3+}, Fe^{3+} and Co^{3+} complexes are 4.95, 6.06 and 0.00 BM, respectively. The correct option for the electronic configuration of Mn^{3+}, Fe^{3+} and Co^{3+} metal ions in these complexes, respectively, is

(A) $t_{2g}^4 e_g^0$, $t_{2g}^3 e_g^2$ and $t_{2g}^4 e_g^2$
(B) $t_{2g}^3 e_g^1$, $t_{2g}^5 e_g^0$ and $t_{2g}^6 e_g^0$
(C) $t_{2g}^3 e_g^1$, $t_{2g}^3 e_g^2$ and $t_{2g}^6 e_g^0$
(D) $t_{2g}^3 e_g^1$, $t_{2g}^3 e_g^2$ and $t_{2g}^4 e_g^2$

Q.21   Among the following compounds, the one having the lowest boiling point is

(A) $SnCl_4$ (B) $GeCl_4$ (C) $SiCl_4$ (D) CCl_4

Q.22   The correct option having one complex from each of the following pairs which is more reactive towards the oxidative addition reaction by hydrogen molecule is

Pair 1: $IrCl(PMe_3)_3$ (I) and $IrCl(CO)(PMe_3)_2$ (II)
Pair 2: $IrCl(CO)(PPh_3)_2$ (III) and $IrCl_3(PPh_3)$ (IV)

(A) (I) and (III)   (B) (I) and (IV)   (C) (II) and (III)   (D) (II) and (IV)

Q.23   Among the following, the correct statement is

(A) The density follows the order, Cs > Rb > Li > Na.
(B) The solubility in water follows the order, Cs_2CO_3 > K_2CO_3 > Na_2CO_3 > Li_2CO_3.
(C) The first ionization potential follows the order, Li > K > Na > Cs.
(D) The melting point follows the order, $MgCl_2$ > $BeCl_2$ > $CaCl_2$ > $SrCl_2$.

Q.24   The major product of the following reaction is

$\xrightarrow{\textit{meta}\text{-chloroperbenzoic acid}}$

(A)

(B)

(C)

(D)
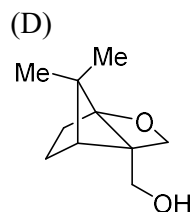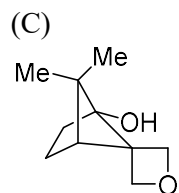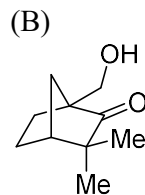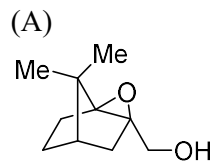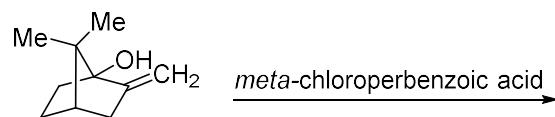
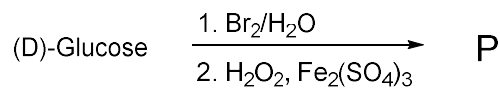
Q.25   In ^{1}H NMR spectrum of the given molecule, the correct order of chemical shifts of the labelled protons (H^X, H^Y, H^Z) is
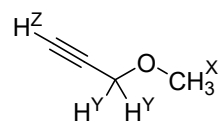
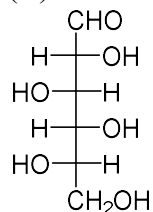(A) $H^Z > H^X > H^Y$
(B) $H^Z > H^Y > H^X$
(C) $H^X > H^Y > H^Z$
(D) $H^Y > H^X > H^Z$

Q.26   In the following reaction of (D)-Glucose, a product P is formed.

(D)-Glucose $\xrightarrow[\text{2. H}_2\text{O}_2, \text{Fe}_2(\text{SO}_4)_3]{\text{1. Br}_2/\text{H}_2\text{O}}$ P

Among the following compounds, the one which will give the same product (P) under identical reaction conditions is

(A)

```
        CHO
   H ——— OH
  HO ——— H
   H ——— OH
  HO ——— H
       CH2OH
```
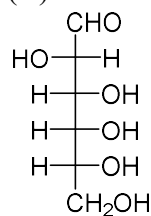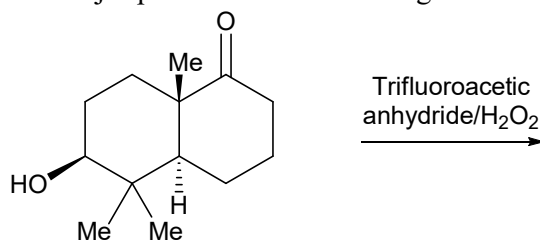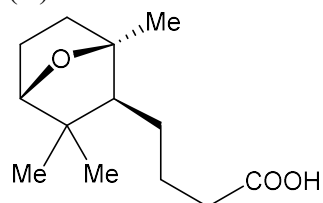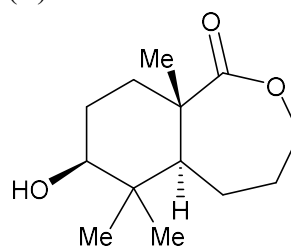
(B)

```
        CHO
  HO ——— H
  HO ——— H
   H ——— OH
   H ——— OH
       CH2OH
```

(C)

```
        CHO
   H ——— OH
   H ——— OH
   H ——— OH
   H ——— OH
       CH2OH
```

(D)

```
        CHO
  HO ——— H
   H ——— OH
   H ——— OH
   H ——— OH
       CH2OH
```

Q.27   The major product of the following reaction is

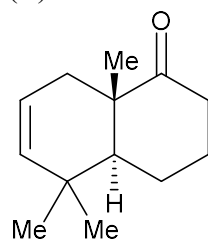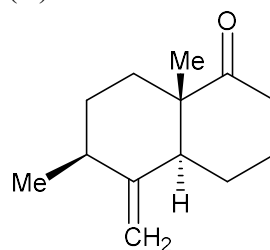Trifluoroacetic anhydride/H$_2$O$_2$
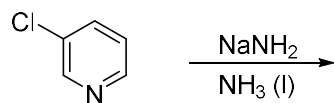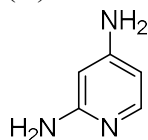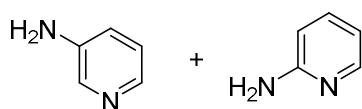
(A)

(B)

(C)

(D)

Q.28   The correct option for the product(s) of the following reaction is
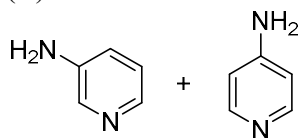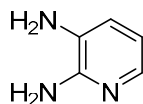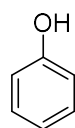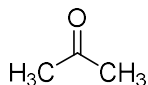

(A)

(B)

(C)

(D)
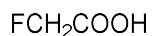

Q.29   The increasing order of acidity of the given molecules in aqueous media is

OH			
I	II	III	IV

I   II   III   IV

(A)
IV < I < II < III

(B)
II < I < IV < III

(C)
II < IV < I < III

(D)
IV < II < I < III
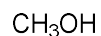
Q.30   The compound formed upon subjecting an aliphatic amine to Lassaigne's test is

(A) $NaNH_2$ (B) $NaNO_2$ (C) NaCN   (D) NaN_3

SECTION - B

MULTIPLE SELECT QUESTIONS (MSQ)

Q. 31 – Q. 40 carry two marks each.

Q.31   The eigenvalue(s) of the matrix $\begin{bmatrix} 1 & 2 \\ 2 & 1 \end{bmatrix}$ is/are
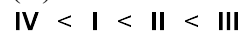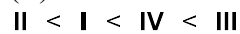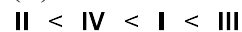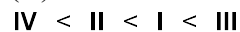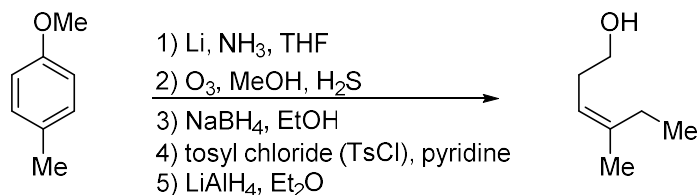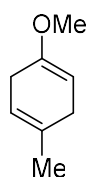
(A) –1   (B) 1   (C) 2   (D) 3

Q.32   The unit of the constant 'a' in van der Waals equation of state of a real gas can be expressed as

(A) $m^6 \, Pa \, mol^{-2}$ (B) $m^6 \, J \, mol^{-2}$
(C) $m^3 \, Pa \, mol^{-2}$ (D) $m^3 \, J \, mol^{-2}$

Q.33   Among the following, microwave active molecule(s) is/are

(A) *trans*-dichloroethene
(B) 1,2-dinitrobenzene
(C) 3-methylphenol
(D) *para*-aminophenol

Q.34   The true statement(s) regarding the brown ring test carried out in the laboratory for the detection of NO_3^- is/are

(A) Brown ring is due to the formation of the iron nitrosyl complex.
(B) Concentrated nitric acid is used for the test.
(C) The complex formed in the reaction is $[Fe(CN)_5NO]^{2-}$.
(D) The brown colored complex is paramagnetic in nature.

Q.35   The true statement(s) regarding the carbonic anhydrase enzyme is/are

(A) It is involved in peptide bond cleavage.
(B) Redox inactive Zn^{2+} ion is involved in the catalytic activity of this enzyme.
(C) Activated $M-OH_2$ (M = metal ion) acts as the nucleophile in the enzyme.
(D) The metal ion is coordinated to the side chain of histidine residues.

Q.36   The correct statement(s) about NO_2, NO_2^+ and CO_2 is /are

(A) Both NO_2 and CO_2 are paramagnetic.
(B) NO_2 is paramagnetic and NO_2^+ is diamagnetic
(C) Both CO_2 and NO_2^+ have linear geometry.
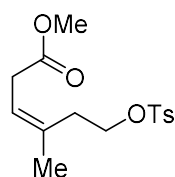(D) CO_2 and NO_2^+ are isoelectronic.

Q.37 The compound(s) formed as intermediate(s) in the following reaction sequence is/are

1) Li, NH$_3$, THF
2) O$_3$, MeOH, H$_2$S
3) NaBH$_4$, EtOH
4) tosyl chloride (TsCl), pyridine
5) LiAlH$_4$, Et$_2$O

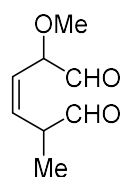(A)   (B)   (C)   (D)
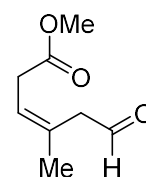
Q.38 The correct statement(s) among the following is/are

(A) Secondary structure of a polypeptide describes the number and type of amino acid residues.
(B) Uracil is a pyrimidine nucleobase.
(C) Natural fatty acids have odd number of carbon atoms.
(D) Reaction of (D)-glucose with Ca(OH)$_2$ gives a product mixture containing (D)-fructose, (D)-mannose, and (D)-glucose.

Q.39 The diastereomeric pair(s) among the following option(s) is/are

(A)

(B)

(C)

(D)

Q.40   The reaction(s) that result(s) in the formation of aromatic species is/are
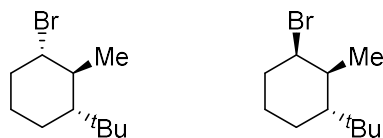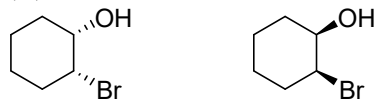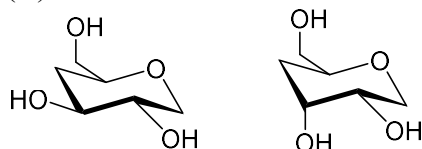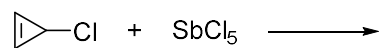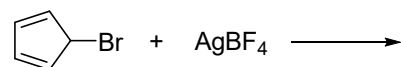
(A)

[cyclopropenyl ring]—Cl   +   SbCl$_5$ ⟶

(B)

[cyclopentadienyl ring]—Br   +   AgBF$_4$ ⟶

(C)

Ph
   |
[cyclopropene ring]—COPh   +   NaH   ⟶
   |
Ph

(D)

[cyclopentadiene ring]   +   Na   ⟶
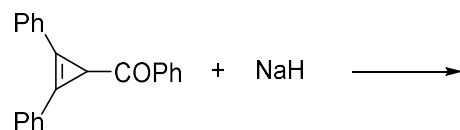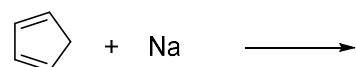
SECTION – C

NUMERICAL ANSWER TYPE (NAT)

Q. 41 – Q. 50 carry one mark each.

Q.41   The bond order of N_2^+ ion is _____. (Round off to one decimal place)

Q.42   One liter of a buffer solution contains 0.004 mole of acetic acid ($pK_a = 4.76$) and 0.4 mole of sodium acetate. The pH of the solution is _____. (Round off to two decimal places)

Q.43   The limiting molar conductivity of La^{3+} and Cl^- ions in aqueous medium at 298 K are 209.10×10^{-4} and 76.35×10^{-4} S m^2 mol^{-1}, respectively. The transport number of Cl^- in an infinitely dilute aqueous solution of LaCl$_3$ at 298 K is _____. (Round off to two decimal places)

Q.44   The magnetic field strength required to excite an isolated proton to its higher spin state with an electromagnetic radiation of 300 MHz is _____ Tesla (T). (Round off to two decimal places)
[Magnetogyric ratio of proton is 26.75×10^7 rad T^{-1} s^{-1}]

Q.45   The value of n for the complex $[Fe(CO)_4(SiMe_3)]^n$ satisfying the 18-electron rule is _____.

Q.46   In the structure of P_4O_{10}, the number of P-O-P bond(s) is _____.

Q.47   Number of vertices in an icosahedral *closo*-borane is _____.

Q.48   Based on the information given below, the isoelectric point (pI) of lysine is _____. (Round off to one decimal place)
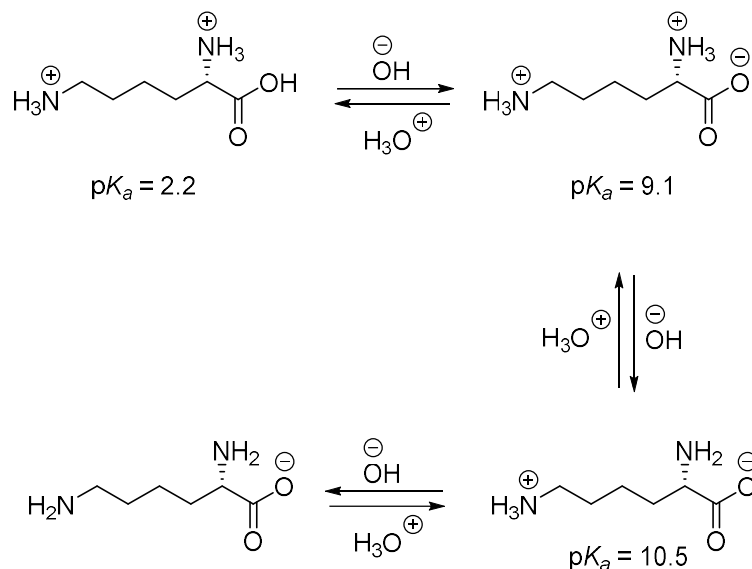
Q.49   (*R*)-2-methyl-1-butanol has a specific rotation of +13.5°. The specific rotation of 2-methyl-1-butanol containing 40% of the (*S*)-enantiomer is _____ °. (Round off to one decimal place)

Q.50   The number of gauche-butane interaction(s) in the following compound is_____.
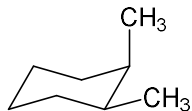
Q. 51 – Q. 60 carry two marks each.

Q.51   The ionization energy of hydrogen atom is 13.6 eV and the first ionization energy of
       sodium atom is 5.1 eV. The effective nuclear charge experienced by the valance electron of
       sodium atom is _____. (Round off to one decimal place)

Q.52   One mole of an ideal gas is subjected to an isothermal increase in pressure from 100 kPa to
       1000 kPa at 300 K. The change in Gibbs free energy of the system is _____ kJ mol^{-1}.
       (Round off to one decimal place)
       [Given: Gas constant (R) = 8.3 J K^{-1} mol^{-1}]

Q.53   One liter of an aqueous urea solution contains 6 g of urea. The osmotic pressure of the
       solution at 300 K (assuming an ideal behavior) is _____ kPa. (Round off to one
       decimal place)
       [Given: Molecular weight of urea is 60, gas constant (R) is 8.3 J K^{-1} mol^{-1}]

Q.54   A first order reflection of X-ray from {220} plane of copper crystal is observed at a
       glancing angle of 22º. The wavelength of the X-ray used is _____ pm. (Round off to
       one decimal place)
       [Given: Copper forms fcc crystal with unit cell edge length of 361 pm.]

Q.55   The collision flux of a monoatomic gas on copper surface is 3.0×10^{18} m^{-2} s^{-1}. Note that
       copper surface forms a square lattice with lattice constant of 210 pm. If the sticking
       coefficient of the atom with copper is 1.0, the time taken by the gas to form a complete
       monolayer on the surface is _____ s. (Round off to one decimal place)

Q.56   The turnover frequency (TOF) for the catalytic reaction,

$$\textbf{A} \ (1 \ \text{mol}) \xrightarrow[\text{5 hours}]{\text{Catalyst (0.01 mol)}} \textbf{B}$$
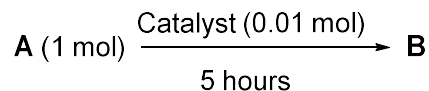
with 90% yield of the product is _____ hour^{-1}. (Round off to the nearest integer)

Q.57   A radioactive sample decays to 10% of its initial amount in 4600 minutes. The rate
constant of this process is _____ hour^{-1}. (Round off to two decimal places)

Q.58   Given that the radius of the first Bohr orbit of hydrogen atom is 53 pm, the radius of its
third Bohr orbit is _____ pm. (Round off to the nearest integer)

Q.59   5.3 g of benzaldehyde was reacted with an excess of acetophenone to produce 5.2 g of the
enone product as per the reaction shown below. The yield of the reaction is _____ %.
(Round off to the nearest integer)
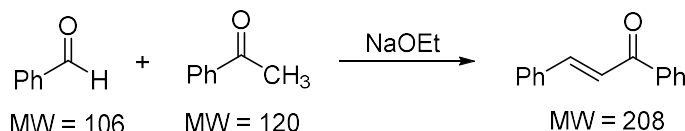
Q.60   Assume that the reaction of MeMgBr with ethylacetate proceeds with 100% conversion to
give *tert*-butanol. The volume of 0.2 M solution of MeMgBr required to convert 10 mL of a
0.025 M solution of ethylacetate to *tert*-butanol is _____ mL. (Round off to one
decimal place)

END OF THE QUESTION PAPER