

Total number of printed pages-7

1 (Sem-4) CHE 1

2025

CHEMISTRY

Paper : CHE0400104

(Inorganic Chemistry-I)

Full Marks : 45

Time : Two hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions as directed :

1×5=5

(i) The point group symmetry for benzene is :

(a) C_{6h}

(b) D_{6h}

(c) C_{6v}

(d) D_{2d}

(Choose the correct option)

(ii) In the complex $[E(en)_2(C_2O_4)]NO_2^-$ (where (en) ethylenediamine); the coordination number and the oxidation state of the element 'E' are respectively.

(a) 6 and 2

(b) 2 and 2

(c) 4 and 3

(d) 6 and 3

(Choose the correct option)

(iii) La^{3+} , Lu^{3+} , Yb^{2+} , Ce^{4+} is diamagnetic, while Sm^{3+} exhibits low paramagnetic behaviour. Why? *unpaired e-*

(iv) Which of the following oxides of a first-row transition metal is most acidic in nature?

(a) TiO_2

(b) Mn_2O_7

(c) Fe_2O_3

(d) CuO

(Choose the correct option)

(v) The mass defect of a nucleus is 0.035 amu. If 1 amu corresponds to 931.5 MeV of energy, what is the binding energy of the nucleus?

(a) 32.6 MeV

(b) 326.0 MeV

(c) 26.6 MeV

(d) 931.5 MeV

(Choose the correct option)

2. Answer **any five** from the following questions : 2×5=10

(i) What do you mean by identity (E) and n-fold proper axis of symmetry (C_n) element ?

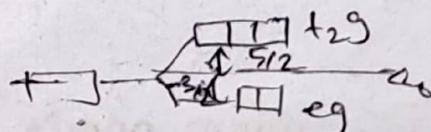
(ii) What is Nugget ? How electrode potential values determine the occurrence of metal in ore.

Ti
(iii) Why do second and third transition series elements (e.g., Mo, W) exhibit higher oxidation states more readily than their first-row counterparts (e.g., Cr) ?

(iv) Aqueous solution of Cu^{2+} ions is blue in colour whereas that of Zn^{2+} is colorless. Explain.

(v) Determine the configuration in term of $t_{2g}^x e_g^y$ and the number of unpaired electrons of the $[Fe(CN)_6]^{3-}$. octa

(vi) Tetrahedral complexes are only high spin complexes. Explain.



(vii) ^{24}Na decays to one-fourth of its initial amount in 29.8 hours. Find out its decay constant.

(viii) Explain why actinides form oxocation while lanthanides do not ?

(ix) Which is more basic - $\text{La}(\text{OH})_3$ or $\text{Lu}(\text{OH})_3$? Why ?

(x) What are interfering radicals ? When and Why is it necessary to remove ?

3. Answer **any four** from the following questions : $5 \times 4 = 20$

(i) Discuss the conditions under which symmetry elements form a group.

(ii) Find and show with diagram all the symmetry elements of either NH_3 or BF_3 molecule and write its point group.

(iii) How the energy level of d -orbital changes during distortion of an octahedral Cu(II) complex ? Discuss.

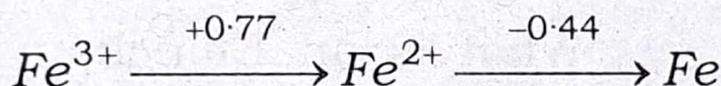
(iv) Explain the trend in the acid-base character of oxides across the first-row transition elements. Why does TiO_2 exhibit amphoteric behaviour, while CuO is basic ?

(v) Show and explain the d-orbital splitting from octahedral to square planar complexes via square pyramidal structure.

(vi) What is lanthanide contraction and what is its cause? How the lanthanide contraction affects the basicity of ions?

$$2+1+2=5$$

(vii) The Latimer diagram of Fe in acidic solution is given below:



(a) Calculate the E^0 for the reduction of Fe^{3+} to Fe. 1.21 2

(b) What is the most stable oxidation state of Iron? 1

(c) Does Fe^{2+} undergoes disproportionation? Justify your answer. 2

(viii) Describe Fermi's theory of beta decay. Explain how the theory accounts for the emission of electrons and neutrinos in beta-minus decay.

4. Answer any one from the following questions :

(i) (a) A given molecule is assigned with the point group D_3h . What information will it provide in terms of symmetry ? 3

(b) What is the origin of paramagnetism in inorganic compound ? $[\text{Fe}(\text{H}_2\text{O})_6]^{3+}$ more paramagnetic than $[\text{Fe}(\text{CN})_6]^{3-}$. Why ? 2+2=4

(c) What is an Ellingham diagram? What thermodynamic information does it provide about the formation of metal oxides ? 1+2=3

(ii) (a) Give an account for oxidation states, stability and magnetic properties of actinide elements and compare with those of the transition metals. 2×3=6

(b) What factors determine the stability of a nucleus, and how does the neutron-to-proton ratio influence whether a nucleus is likely to undergo radioactive decay ? 2+2=4

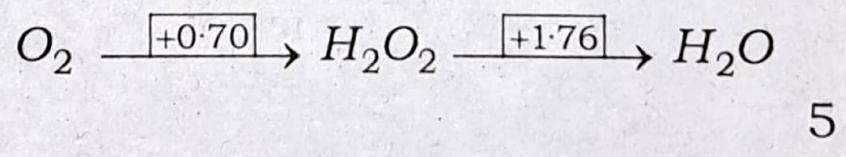
CFSE

(iii) (a) What is meant by crystal field splitting energy? On the basis of crystal field theory, write the electronic configuration of d^4 in terms of t_{2g} and e_g in an octahedral field when (i) $\Delta_0 > P$ and (ii) $\Delta_0 < P$. 1+2=3

(b) What is Jahn-Teller distortion? Describe the conditions which lead to Z-out distortion in octahedral complexes? 1+3=4

(c) Calculate the CFSE of a d^6 complex having $\Delta = 25000 \text{ cm}^{-1}$ and $P = 15000 \text{ cm}^{-1}$. 3

(iv) (a) Construct a Frost diagram from the following Latimer diagram.



(b) Discuss the applications of radioisotopes in age determinations. 5

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1 (Sem-4) CHE 2

2025

CHEMISTRY

Paper : CHE0400204

(Organic Chemistry-I)

Full Marks : 45

Time : 2 hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions : 1×5=5

(A) Find out the correct answers :

(a) Complete hydrolysis of proteins produces—

(i) NH_3 and CO_2

(ii) Glycogen and fatty acid

(iii) Urea and Uric acid

(iv) a mixture of amino acids

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Contd.

(b) Substances which reduce the rate of enzyme catalyzed reactions are known as :

(i) substrates

(ii) enzymes

(iii) products

(iv) inhibitors

(c) The heterocyclic diene employed in cyclo-addition reaction is—

(i) Furan

(ii) Pyrrole

(iii) Thiophene

(iv) 2, 5-dimethyl pyrrole

(B) Fill in the blank :

Hydroxy acids undergo intramolecular esterification in the presence of acid catalyst to yield _____.

(C) Write the structure of nicotine.



2. Answer the following : (*any five*) $2 \times 5 = 10$

(a) 'Thiophene is less reactive than furan'.
Explain.

(b) Why the boiling point of ethylamine ($\text{CH}_3\text{CH}_2\text{-NH}_2$) is less than that of ethyl alcohol ($\text{CH}_3\text{CH}_2\text{OH}$).

(c) Arrange the following sets of compounds in increasing order of basicity. $1 \times 2 = 2$

Set I : (i) $\text{CH}_3\text{CH}_2\text{-NH}_2$

(ii) CH_3CONH_2

(iii) $\text{C}_6\text{H}_5\text{CONH}_2$

(iv) $\text{C}_6\text{H}_5\text{NH}_2$

Set II : (i) *p*-toluidine

(ii) *p*-nitroaniline

(iii) *N,N*-dimethyl-*p*-toluidine

(iv) aniline

(d) Give the different types of bonds responsible for the tertiary structure of proteins.

(e) How will you synthesize alanine from ethyl chloride ?

(f) How can you prepare mono-carboxylic acids from— 1×2=2

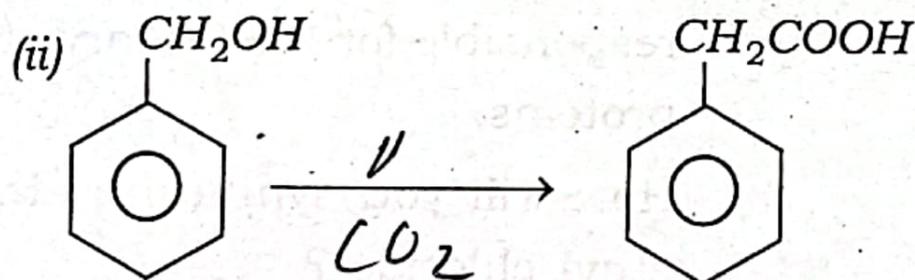
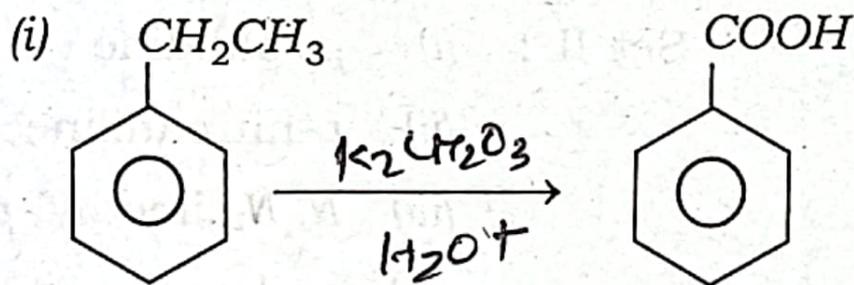
(i) a primary alcohol

(ii) an aldehyde

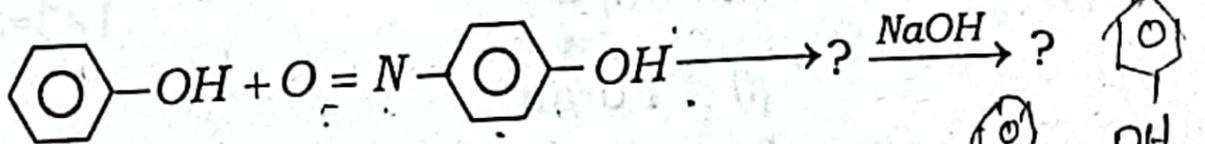
(g) Explain briefly why ethyl benzoate ($Ph-COOEt$) can not undergo claisen condensation reaction.

(h) How will you prepare lactic acid from acetylene ?

(i) Write chemical reactions for the following transformations— 1×2=2



(j) Complete the following reaction—



3. Answer **any four** from the following : 4H
5×4=20

(a) (i) How substituted pyridines can be prepared by Hantzsch synthesis? 2

(ii) Explain the Fisher Indole synthesis with mechanism. 3

(b) (i) How will you establish the presence of pyridine nucleus in nicotine? 2

(ii) What class of alkaloid does nicotine belongs to? 1

(iii) What happen when aliphatic primary amine is diazotized? 1

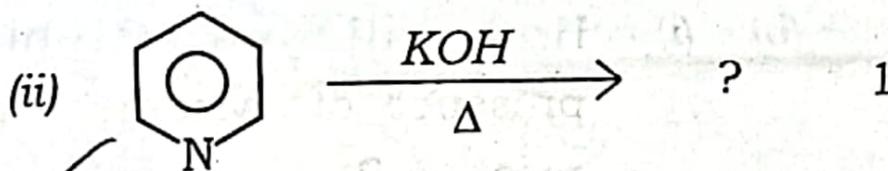
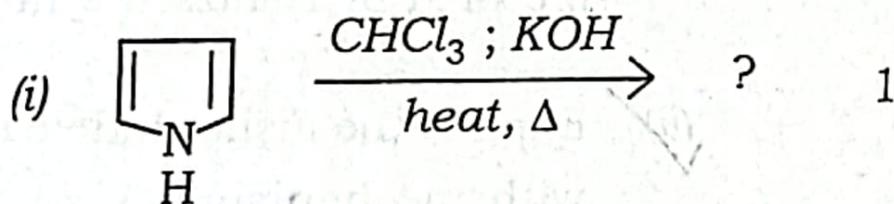
(iv) Mention one application of diazotization reaction. 1

✓ (c)

(a) Give one method of preparation of each of— 1×3=3

- (i) Furan
- (ii) Pyrrole
- (i) Thiophene

(b) complete the following reactions— 1×2=2



✓ (d) (i) Compare the basicities of furan, pyrrole and thiophene. 3

(ii) Explain briefly why furan is less reactive than pyrrole. 2

✓ (e) Describe the following (*any two*) : 2½×2=5

(i) ISO-electric point of amino acid

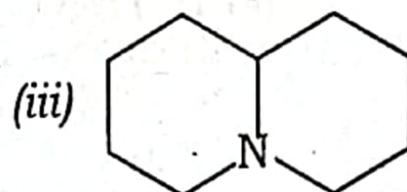
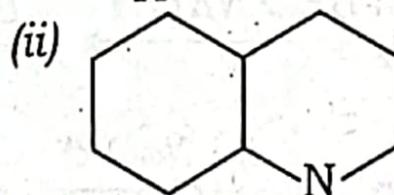
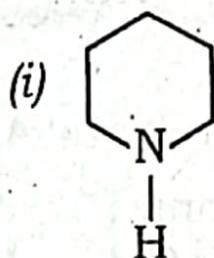
(ii) Denaturation of protein

(iii) Enzyme inhibitors.

(f) Write a short note on the effect of ring substituents on the basicities of aromatic amines.

(g) (i) What is Hoffmann Exhaustive Methylation reaction ? 2

(ii) Identify the products of the following compounds by using Hoffmann Exhaustive Methylation reaction. $1 \times 3 = 3$



- (h) (i) Explain various types of electronic transmissions possible for organic compounds in *uv*-visible spectroscopy.

OR

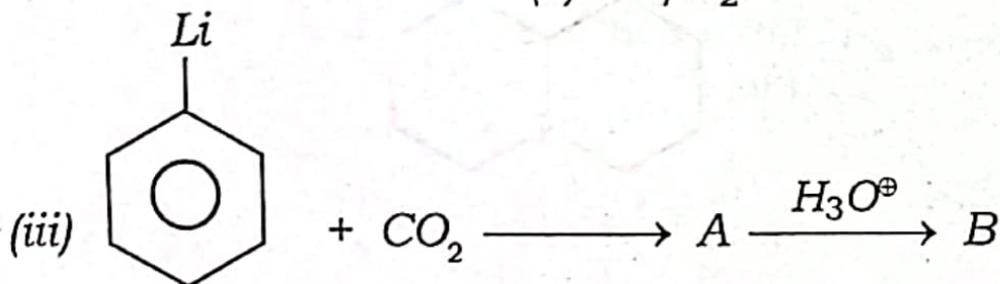
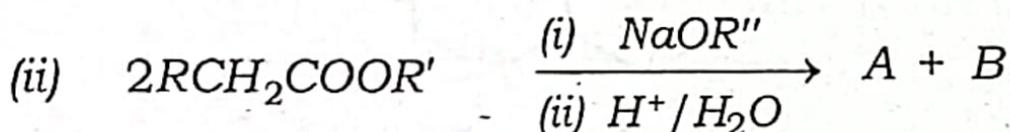
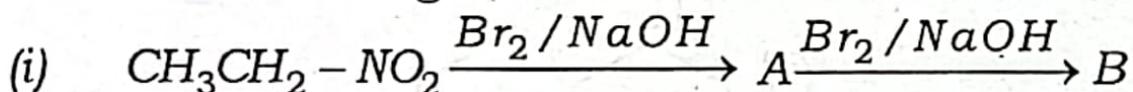
- (ii) In IR spectroscopy, absorption signals for molecular vibrations are recorded. What are these molecules vibrations?

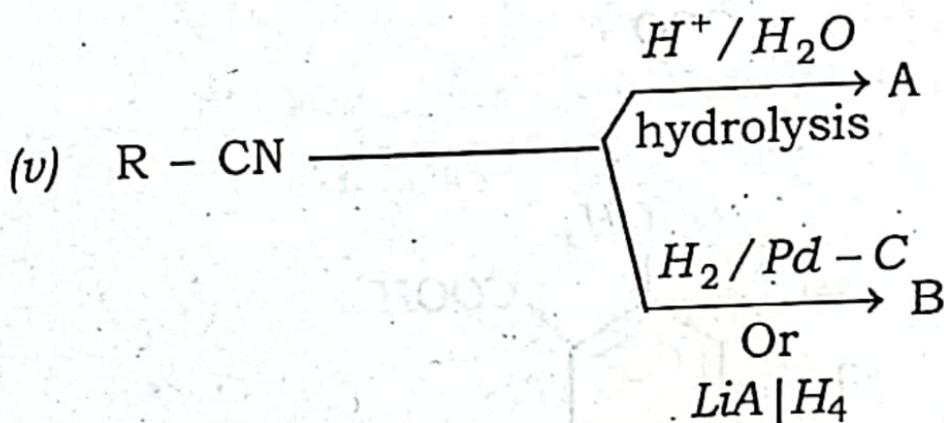
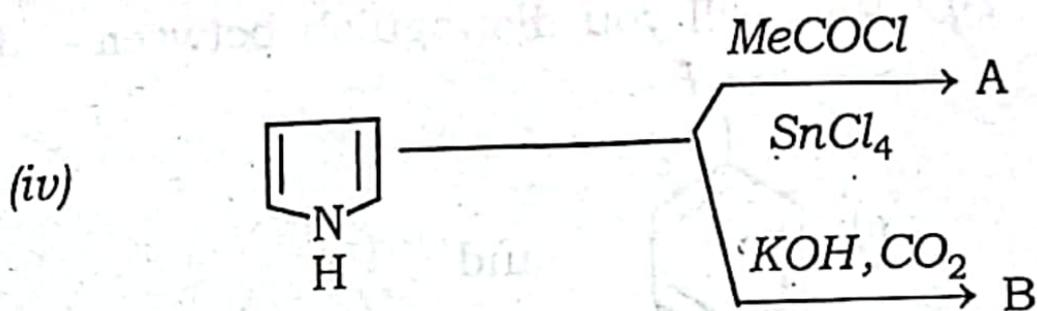
Show the types of molecular vibrations possible in a molecular of the type A_2x where 'x' is called anchor atom.

4. Answer **any four** from the following :

1×10=10

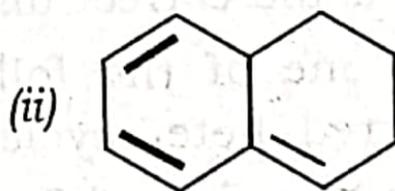
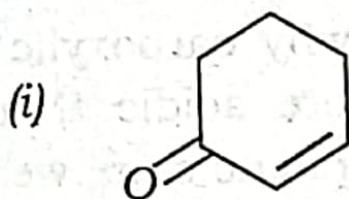
- (A) Find out the products A and B in the following reactions : 2×5=10



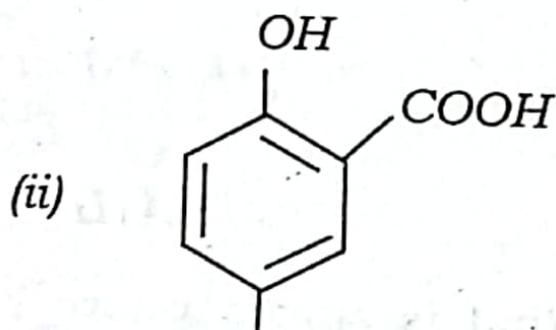
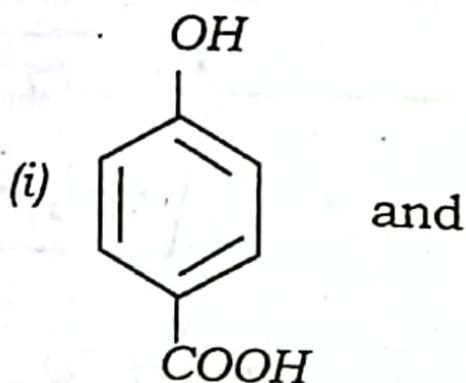


(B) (a) What is chromophore ? Give one example. 1

(b) Calculate the λ_{max} of the following compounds— 2×2=4



(c) How will you distinguish between— 3



by using IR-spectroscopy

(d) What is overtone and combination bond ? 2

~~(c)~~ (a) Explain why carboxylic acids are much more acidic than alcohol, whereas phenols are weaker acids than carboxylic acids. 3

(b) Find out the correct answer—

(I) Which one of the following 5-membered heterocycle is most resonance stabilized ? 1

- (i) Furan
- (ii) Thiophene
- (iii) Pyrrole
- (iv) Pyridine
- (II) In aqueous solution, an amino acid exists as— 1
- (i) cation
- (ii) anion
- (iii) dianion
- (iv) Zwitter-ion
- (c) Write the name of the optically inactive amino acid. 1
- (d) Why the electrophilic substitution of furan usually takes place at C-2 position ? 2
- (g) Write Paal-Knorr synthesis of furan. 2

- ~~(D)~~ (a) What is Hinsberg reagent ? How will you distinguish between 1°, 2° and 3° amines by using Hinsberg reagent. 1+3=4
- (b) Why aniline can not undergo Friedel Craft reaction and nitration reaction ? 4
- (c) How will you prepare ethylamine by Gabriel synthesis ? 2
-

Total number of printed pages-7

1 (Sem-4) CHE 3

2025

CHEMISTRY

Paper : CHE0400304

(Theoretical Chemistry)

Full Marks : 45

Time : Two hours

The figures in the margin indicate full marks for the questions.

1. Answer the following questions as directed :

1×5=5

(i) State function Ψ of a system must be an eigenfunction of the operator H .
(State whether the statement is True or False)

(ii) Show whether the operator \hat{A} in the equation $\hat{A}\Psi = \Psi^2$ is linear or not.

(iii) At what distance is the radical probability maximum for 1s orbital? What is the distance called?

(iv) The first derivative of each particle in a box stationary state wave function is discontinuous at

(a) midpoint ($a/2$)

(b) ($a/3, 0$)

(c) $a/4$

(d) end point ($0, a$)

(Choose the correct option)

(v) Closed shell configuration is always represented by the term symbol _____.
(Fill in the blank)

2. Answer **any five** from the following questions : $2 \times 5 = 10$

(i) If $\hat{A} = 3x^2$ and $\hat{B} = d/dx$, show that \hat{A} and \hat{B} do not commute.

(ii) Normalize the function in the given range $\cos \pi x / a$; $-a \leq x \leq a$.

(iii) Define complementary observable with one example.

(iv) State why the eigenfunction of an operator should be single-valued and continuous.

(v) Write how the molecular orbitals of a homonuclear diatomic molecule can be classified a σ and π .

(vi) Show that the wave function for a particle in one-dimensional box of length a , where the potential energy is zero, is not an eigenfunction of the linear momentum operator.

(vii) Considering the sun as black-body radiator calculate the temperature of its surface for the maximum wavelength of emitted radiation 480nm . (Given Wein's displacement constant is 2.88 mmK)

(viii) Give the values of L and S in 1D .

(ix) What do you mean by orbital? State the differences between an orbit and an orbital.

(x) Write the expression of Debye equation. Why the alkali metal atoms have high polarizability volume ?

3. Answer **any four** from the following questions : 5×4=20

(i) Determine which of the following functions are eigenfunctions of the operator d/dx :

(a) e^{-ikx}

(b) $\cos kx$

(c) $\sin x$?

Determine the Eigenvalue wherever appropriate.

(ii) What is a Hermitian operator ? Show that the eigenvalue of a Hermitian operator is real ? 2+3=5

(iii) The wavefunction for the electron in the ground state of hydrogen atom is

$$\psi = (\pi a_0^3)^{-1/2} e^{-r/a_0}, \text{ where } a_0 \text{ is the}$$

radius of Bohr orbit. Calculate the probability of finding the electron somewhere between 0 and $2a_0$. What is the probability beyond $2a_0$? 4+1=5

(iv) Write down the Schrödinger equation for a particle of mass m moving in three-dimensions and state the properties of wave function to have physical significance. What do you mean by orthonormal wave function ? $1+2+2=5$

(v) Derive the term symbols inner for the excited state configuration of Helium ($2s^1 2p^1$) and arrange the terms in increasing order of energy. $3+2=5$

(vi) Write, what you mean by radial distribution function ? Find an expression for the radial distribution function. Give the plot of radial distribution function against the radial distance from the nucleus for $1s$ orbital. State how this plot differs from the plot of square of the radial function against the radial distance. $1+2+1+1=5$

(vii) Calculate the zero-point vibrational energy of HCl if its force constant is 516 Nm^{-1} .

(viii) What is meant by polarizability of a molecule? Derive the Clausius-Mossotti equation. 1+4=5

4. Answer **any four** from the following questions : 10×1=10

(i) (a) Show that the following sets of functions are orthogonal

$$\psi_1 = x \text{ and } \psi_2 = x^2$$

within the interval $-k \leq x \leq k$. 3

(b) A particle of mass m is moving in a one-dimensional box of length a , where potential energy is zero. Calculate the average kinetic energy of the particle. 4

(c) An electron is confined to a molecule of length $10^{-9}m$. Considering the electron to be a particle in one-dimensional box, where $V=0$, calculate its minimum energy. 3

(ii) Discuss the valence bond treatment of hydrogen molecule.

- (iii) (a) What do you mean by degeneracy? Determine the degree of degeneracy of the energy level $17h^2/8ma^2$ of a particle in a cubical box. 1+3=4
- (b) Consider a particle in a three-dimensional box of dimensions $a \neq b = c$. Find the condition under which the levels (2, 2, 1) and (4, 1, 1) are doubly degenerated. 4
- (c) What do you mean by space quantization? 2
- (iv) (a) How van-der forces affect in boiling point in isomers? Explain briefly by taking pentane as example. 2
- (b) Discuss the temperature method for measurement of dipole moment. 4
- (c) Discuss how dipole moment of a molecule helps in distinguishing (i) linear and non-linear molecules, (ii) *cis*-, *trans*-isomer. 4

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1 (Sem-4) CHE 4

2025

CHEMISTRY

Paper : CHE0400404

**(Magnetic Resonance Spectroscopy and
Analytical Techniques)**

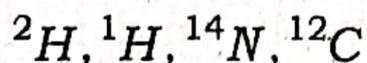
Full Marks : 45

Time : Two hours

**The figures in the margin indicate
full marks for the questions.**

1. Answer the following questions as directed :
1×5=5

(a) Which of the nuclei show magnetic properties for NMR spectrometry ?



(b) State which of the following radiations is associated with NMR spectroscopy :
X-ray, infrared, γ - ray, radiowave

(c) Name the crystal system with characteristics $a = b \neq c$; $\alpha = \beta = 90^\circ$, $\gamma = 120^\circ$.

(d) Which is the commonly used adsorbent in column chromatography?

NH_4OH , H_2SO_4 , $CuSO_4$, Silica gel

(e) In mass spectrometry, the sample that has to be analyzed is bombarded with which of the following?

protons, electrons, neutrons,
 α -particles

2. Answer **any five** questions : $2 \times 5 = 10$

(a) What are α -cleavage and induce cleavage in mass spectroscopy ?

(b) What is the basic difference between the principles of conventional chromatography and HPLC ?

(c) Write *two* reasons for using TMS as reference in non-aqueous solvents in 1H NMR spectroscopy.

(d) Explain spin-spin coupling in case of 1, 1-dibromoethane.

(e) What is R_f value? During a chromatography experiment, a pigment moved 3.4 cm and the solvent had moved 4.8 cm. Calculate the R_f value.

(f) What is McLafferty rearrangement?

(g) The edge length in NaCl crystal is 5.63×10^{-10} m. Find the distance between (111) planes.

(h) How the molar conductance of strong electrolyte changes with dilution?

(i) Write briefly about redox electrode.

(j) How the metal-amalgam electrode is set up? How is it represented?

3. Answer **any four** questions : $5 \times 4 = 20$

(a) What do you understand by adsorbent? Give *two* classes of an adsorbent. Give examples of each class. $1+2+2=5$

(b) Name the different ionization techniques in mass spectrometry. Explain any two techniques. 2+3=5

(c) What do you mean by ionic doublets? Write briefly about asymmetry effect. 1+4=5

(d) What is metal-metal insoluble salt electrode? How this electrode is represented? Write the overall electrode reaction and electrode potential of metal-metal insoluble electrode. 1+1+3=5

(e) Write the principle of NMR spectroscopy and draw the block diagram of NMR spectrometer. 2+3=5

(f) The mass spectrum of 2-methylpentane shows two prominent peaks and m/z values of 71 and 43. Identify each species showing adequate fragmentation. Also identify the base peak. Distinguish between molecular ion peak and base peak in mass spectrometry. 2+1+2=5

(g) Draw a rough sketch of ^1H NMR spectrum of 1-bromoethane and predict the chemical shift positions of the protons. Name *two* factors that affect chemical shift. 3+2=5

(h) Why are liquid N_2 and He used in NMR spectrometers? Name *one* solvent used in NMR spectroscopy. Calculate the chemical shift in ppm unit for a proton that shifted to 270 Hz downfield from the TMS in a 100MHz NMR spectrometer. 2+1+2=5

4. Answer **any one** question : 10×1=10

(a) (i) What are shielding and deshielding involved in NMR spectroscopy? 3

(ii) How many signals will be shown by $\text{Br}_2\text{CHCH}_2\text{Br}$ in NMR spectroscopy? 3

(iii) How will you distinguish 1-propanol and 2-propanol using NMR spectroscopy? 2

(iv) Write the structure of the compound with molecular formula $C_3H_6Cl_2$ which exhibits only one signal in the 1H NMR spectrum.

2

(b) (i) Discuss the theory of electron spin resonance spectroscopy.

5

(ii) Taking example of hydrogen atoms, explain what is meant by hyperfine splitting in electron spin resonance spectroscopy ?

3

✓ (iii) How many signals will be observed in the ESR spectrum of methyl radical ?

2

(c) ✓ (i) State Bragg's law and deduce the equation $n\lambda = 2d \sin \theta$

3

(ii) The parameters of an orthorhombic unit cell are $a = 50pm$, $b = 100pm$, $c = 150pm$. Determine the spacing between the (123) planes.

3

(iii) Calculate the Miller indices of crystal plane which cut through the crystal axes at $(2a, 3b, c)$ and (a, b, c) . 4

(d) (i) What is a concentration cell ?
Write a short note on concentration cells without transference. 1+4=5

(ii) What is liquid junction potential ?
Show that liquid junction potential depends upon the transference number of anions and cations. 1+4=5