(M.Sc. IV Semester)

Specialization Courses in Inorganic Chemistry

Course No. CHM – 401

Title: Acids-Bases, Chemistry in Non-aqueous solvents and Inorganic polymers

Max.Marks-100 **Total Duration-50 hrs.**

Unit-I **13hrs**

Acids and Bases:

Introduction, Concepts: Arrhenius; Bronsted—Lowry; Lux-Flood, Solvent system, Lewis and Usanovich. Strength of protonic acids, Leveling and Differentiating solvents. Super acids: Introduction,; H2SO4, HSO3F and HF—based systems and significance. HSAB principle and its applications in Geochemical differentiation of elements; Solubility prediction, Probability of occurrence of reactions, Qualitative analyses of metallic cations, Redox chemistry, Drug designing and Chelation therapy.

Unit-II **12 hrs**

Chemistry of Non-aqueous solvents:

Properties of a solvcnt The aqueous system, Non—aqueous solvents; classification and reactions in H_2SO_4, NH_3, SO_2, BrF_3 and N_2O_4

Unit-III **12hrs**

Inorganic Polymers -I:

Introduction, Comparison with Organic Polymers, Classification, and reasons for delayed introduction.

Inorganic Polymeric Reactions: Condensation, Addition, and Coordination. Types and significance of Coordination polymers.

Phosphonitrilic Halidcs ; Polymeric Sulphur and Sulphur Nitrides and Polyphosphates:- Introduction, Preparation, Properties, Structure—bonding and Uses.

Unit—IV **13hrs**

Inorganic Polymers -II:

Silicates: Introduction. Occurrence, Classification, Properties and Significance. Zeolites as ion-exchangers, adsorption agents, catalysts and gas separators.

Silicones: Introduction. Preparation, Properties and Uses.

Carborancs and Metaliocarboranes: introduction, Preparation, Properties and Uses.

Boron-Nitrides: Introduction, Preparation, Properties Structure—bonding and Uses.

Fluorocarbons: Introduction, Nomenclature, Preparation, Properties and Uses.

Books

- Inorganic Porymers F.G-A-Stone & W-A.Graham; Academic Press.
- Inorganic Porymers James. E.Mark, HarryAllock & Roberta West; Prentice Hall.
- Inorganic Polymers NJLRay; Academic Press; 1978.
- Inorganic Chemistry Gary Wulfsberg; Viva Books, 2002.
- Inorganic Chemistry; 4th edn; Huheey, Keiter and Keiter, Pearson Education ;1983.
- Development of Inorganic Polymer Chemistry; Lappert& Leigh; Elsevier; 1962. Fluoropolymers; Wall; Wiley; 1972.
- The Chemistry of Non aqueous solvents; Vols II & III Lagowski; Academic Press.
- Chemistry of Elements; 2nd edn; Greenwood , Earnshaw; ButterworthHeinemann;1998.
- Advanced Inorganic Chemistry, 5th edn ; F.A.Cotton & G.Wilikinson; Wiley;1988.

Course No.CHM-402
Title: Organo -Transition Metal Chemistry

Maximum. Marks 100 **Total Duration—50 hrs**

Unit—I **(10 hrs)**

Sigma bonded Organometallic Compounds:
Classification, Stability, Routes of synthesis, Reactions, Structure and bonding.
Decomposition Pathways: αand β hydrogen transfer. Intramolecular elimination of alkane.
Stability from bulky substituents, Agostic alkyls.
Metal Hydride Complexes: Synthesis, Characterization and Chemical reactions.

Unit—II **(12 hrs)**

π-bonded Organometallic Compounds:
Classification, Synthesis, Structure and bonding in Metal—alkynes, ally Is, 1,3-butadiene and Cyclobutadiene Complexes
Sandwich Compounds: General characteristics; Classification, Synthesis, Reactions, Structure and bonding of Cyclopentadienyl Complexes with special reference to Ferrocene.
Compounds with Transition Metal—Carbon multiple bonds: Alkylidene and Alkylidyne Synthesis ; Structural characteristics; Nature of bonding.

Unit—III **(13 hrs)**

Catalytic Processes involving Transition Metal Organometallic Compounds:-
Mechanistic aspects: -Oxidative addition, Insertion reactions and Reductive elimination.
Hydrogenation, Hydroformylation, Oxidation, Isomerization and Zeigler-Natta--polymerization of alkenes.
Fisher-Tropsch Synthesis and Water-gas shift reactions.

Unit—IV **(15 hrs)**

Fluxional Organometallic Compounds:-
General Characteristics ; Rates of rearrangement and Techniques of study. Classification of Fluxional Organometallic Compounds. Some simple examples of Non-rigid molecules in 4 and 5 Coordination geometries.
Fluxionality and Dynamic Equilibria in compounds such as η^2-olefin, η^3-allyl and dienyl Complexes.
Synthetic Reactions involving Organometallics:-
Nucleophllic and Electrophillic reactions of Coordinated Ligands like Carbon monoxide, Isocyanides, Alkenes & Alkyls.
Role of Organocopper and Organoiron in Organic Syntliesis.
Activation of Small molecules like CO, CO_2 and Alkanes.

Books Recommended:

- The Organometallic Chemistry of Transition Metals; 2nd edn; Robert. H . Crabtree; Wiley; 1994.
- Fundamental Transition Metal Organometallic Chemistry; Luke hart; Brooks / Cole; 1985.
- Organometallic Chemistry; 2nd edn ; Mehrotra & Singh ; New age international 2000
- Principles and Applications of Organo Transition Metal Chemistry; Collman &
- Finke; University Science Books; 1994.
- Principles of Organometallic Chemistry; 2nd edn.; P.Powel; Chapman & Hall; 1998.
- Metallo-Organic Chemistry ; A.J.Pearson; Wiley.
- Mechanisms of Inorganic and Organo metallic reactions; Twigg; Plenum press 1983.
- Reaction Mechanism of Inorganic and Organometallic systems; 2nd edn.; Robert .b. Jordan 1998.
- Inorganic Chemistry ; 4th edn.; Huheey ; E. Keiter & R. Keiter; Addison-Wesley ;1983
- Modern Inorganic Chemistry ; William . A. Jolly; McGraw Hill; 1985.

Course No. CHM-403
Title: Bio-inorganic Chemistry.

Maximum Marks: 100 **Total Duration: 50 hrs.**

Unit-I **(12hrs)**

Metal Storage, Transport and Biomineralization:

Structure and Coordinating sites in biologically important ligands: Proteins, Nucleotides, and Lipids.
The transport mechanism: uniport, symport and antiport mechanisms.
Ferritin, Transferrin and: Structure, Metal binding sites; incorporation and release of metal.
Biology of Calcium: Carriers, role in muscle contraction, effect on enzymes and membrane interactions.
Biological calcification: - Formation of calcium phosphate in bones; Calcium binding Proteins.

Unit-II **(12hrs)**

Metalloenzymes and Electron Carriers:
Enzyme, Apoenzyme, Coenzyme, Prosthetic group and Metalloenzymes. Mechanism of enzyme action.
Zinc enzymes: Carboxypeptadiase, Carbonic anhydrase and Alcohol dehydrogenase (Structure and biological role).
Xanthine oxidase and Aldehyde oxidase.
Vitamin Bn and biz Coenzymes; Vitamin B_6.
Electron Carriers: Rubredoxin & Ferridoxin.
Blue Copper proteins: Oxidases and Plastocyanin.

Unit-III **(14hrs)**

Metal-Ion Induced Toxicity and Chelation Therapy:
Toxic levels of different metals. Sources of metal ion poisoning (external sources and internal disorders).
Mechanism of metal ion induced toxicity: Toxicity ofHg,Cd,Pb, As, and CN" Metal ion promoted Carcinogenesis and probable mechanism of action. Chelation Therapy: Therapeutic aspects of chelating agents: - conditional stability constant, stereochemistry lipophilicity. HSAB theory and Plasma mobilizing index (PMI).
Types of Chelation therapy: Single. Double. Synergistic and mixed ligand Chelation therapy. Therapeutic index of different chelating drugs in metal ion detoxification. Radio protective chelating drugs. Metal—Metal Detoxification. Limitations and hazards of Chelation therapy in metal ion detoxification.

Unit-IV **(12hrs)**

Metallotherapy:
Biochemical basis of essential metal deficient diseases and their therapies.
Iron, Zinc, Copper and Manganese deficiencies and their therapies.
Metallic complexes as anticancer drugs: Platinum, Rhodium, Gold and Cobalt

complexes.
Anti bacterial, antiviral and antifungal activities of metal complexes: Labile and Robust metal complexes; probable mechanism of action.

Books Recommended:

- As listed for Course No. CHM—101 (Inorganic chemistry-M.Sc. 1st Semester! from serial No. 1 to 5.
- Bio inorganic Chemistry -An introduction; Ochai, Allyn and Bacon; 1977.
- Inorganic Bio-chemistry—Vol. 1&2; Eichhorn; Elsevier, 1973.
- Inorganic Aspects of Biological and Organic Chemistry; Hanzilik; Academic; 1976.
- The Inorganic Chemistry of Biological processes; 2nd edn.; Hughes ; Wiley; 1973.
- A Text book of Medicinal aspects of Bio inorganic Chemistry ; Das; CBS; 1990.
- The Biological Chemistry of Elements; Frausto de Silva; Williams; Clarenden; 1991.
- Principles of Bio inorganic Chemistry; Lippard, Berg; Univ. Science Books; 1994.
- Inorganic Chemistry in Biology; Wilkins C & Wilkins G; Oxford; 1997.
- Bio inorganic Chemistry ; K.Hussain Reddy; New Age International (P) Ltd;2005
- Metal -Ions in Biochemistry; P.K.Bhattacharya; Narosa Publishing House; 2005.

Course No: CHM-404
Title: Photo-Inorganic Chemistry

Maximum Marks: 100 **Total Duration: 50 hrs**

Unit-1 **(I5hrs)**

Basics of photo-chemistry:

Absorption; mechanism of absorption of light

Transition moment integral, Einstein's treatment, molar integrated absorption intensity, natural radiative lifetime & the calculation of life times.

Excitation; d-d transition, charge transfer & intraligand transitions and selection rules.

Excited states; term symbols, splitting of terms in ligand field, Orgel diagram ; electrostatic description of spin allowed d-d transitions & energy level diagrams depicting excited states.

Frank Condon principle, shapes of absorption & emission bands.

Fate of excited states; energy dissipation by radiative and non-radiative processes. Jablonoski diagram.

Tools and Technique: Light source, measurement of light intensity, chemical actinometry. Flash photolysis

UNIT-I **(I5hrs)**

The Chemistry of Excited state Molecules:

Photochemical laws & quantum yield. Kinetics & quantum yield of photo-physical (radiative) and photo-chemical processes. Photochemical processes: primary, secondary, adiabatic & non- adiabatic. Properties of thexi states; determination of dipole moments & acidity constants of excited state molecules.

Photosubstitution and photo reduction of Co (III) complexes. Photosabstitution reaction of Cr (III) and Rh (III) complexes. Organometallic-photochemistry: Reactions of metal carbonyls, cleavage of metal-metal bond.

UNIT-III **(10hrs)**

Redox Reactions by Excited Metal Complexes:

Energy transfer under conditions of weak and strong interaction. Excited state electron transfer. Marcus-Hush model. Conditions of the excited states to be useful as redox reactants. Photochemical electron transfer, $[Ru (bipy) 3]^{2+}$ and $[Os (bipy) 3]^{2+}$.

UNIT-IV **(10hrs)**

Solar Energy—Prospects and Challenges:

Solar energy storage, solar energy conversion, Metal complex sensitizers and electron relays

in photochemical splitting of water, Nitrogen fixation and CO_2 reduction.

Inorganic photolithography.

Books Recommended:

- Reaction Mechanisms of Inorganic and Organometallic Systems; 2nd edn.; Jordon; Oxford; 1998.
- Mechanism of Inorganic Reactions; Katakis, Gordon; Wiley; 1987.
- Inorganic Chemistry; 4* edn; Huheey; Harper & Row; 1990.

- Mechanism of Inorganic Reactions, 2nd edn, Basalo, Pearson; Wiley Eastern, 1997 x r
- Chemistry of Light; Suppan, Royal Society; 1994.
- Photochemistry, CarolJE.Wayane and Richard P.Wayne; Oxford University Press; 1996.
- Fundamentals of photochemistry; IfLiCRohatgi, Mukhergi; Wiley Eastern.; 1992
- Inorganic Photochemistry; J.ChemJEdu.; Vol .60, No.10,1983.

Applications of Inorganic Photochemistry; J.Chem.Edu.; Vol.74, No 69. 1997.

Course No. CHM-405
Title: Seminar lecture in Inorganic Chemistry

Max. Marks: 50

The Course shall comprise of following two components of 25 marks each and each component would be evaluated in the same manner as project works are evaluated. .

Part A : **Marks: 25**

Each student shall submit a seminar report (review) on the topic assigned to him/her by the supervisor concerned. The report would be evaluated on 25 point scale by another teacher of the same branch.

Part B: Lecture followed by viva-voce **Marks: 25**

The student shall deliver a lecture on the same topic before all M.Sc. students/Scholars and teachers of the departments followed by an open viva-voce session. This would be conducted by a team of three teachers, one from each branch, who would award marks out of 25 based on the presentation and performance in question answer session.

Course No: CHM-406L
Title: Inorganic Lab. Course.

Maximum Marks: 150 Total Duration: 45 working sessions

A: - Inorganic Preparations: (5 Experiments)

- Preparation of tetraamminecarbonatocobalt (III) nitrate and its conversion to pentaamminecholorocobalt (III) chloride.
- Preparation of trans dicholoro bis (ethylenediamine) cobalt (III) chloride and its conversion to cis-isomer.
- Preparation of tris (ethylenediamine) nickel (II) chloride dihydrate and its conversion to bis (ethylenediamine) nickel (II) chloride.
- Preparation of bis (acetylacetonato) copper (II) dihydrate.
- Preparation of pentaamminecholorocobalt (III) chloride and study of Linkage isomers by its conversion to pentaamminenitritocobalt (III) chloride and to nitro isomer followed by IR Characterization.

B: - Total analysis of a Coordination compound for determination of various components present. (1- Experiment)

C: - Separation by Column Chromatography and Estimations: (5 Experiments)

- Separation of Permanganate and Bichromate ions on Alumina column and their Estimation from Beer Law plots.
- Determination of lonisable chloride in a Complex by cation exchange column (separation followed by Mohr's titration of elute for estimation).
- Separation of Cobalt (II) and Nickel (II) on anion exchange column followed by estimation through EDTA titrations.
- Separation of two Cobalt (III) complexes viz $[Co(NH_3)_6]Cl_3$ and $[Co(NH_3)_5Cl]Cl_2$ on Silica column.
- Ion exchange separation of Hydration \ionization isomers of Chromium (III) Chloride ($CrCl_3$).

D: - Potentiometric Titrations: (6 Experiments)

- Standardization of an Iron (ii) solution with a standard dichromate solution over Pt & Calomel assembly.
- Determination of purity of Ce (IV) Sulphate with a standard Iron (II) solution over Pt & Calomel assembly.
- Estimation of Iodide with Standard $AgNO_3$ over Pt & Calomel assembly using I^-\ I2 redox couple.
- Simultaneous determinations of Chloride and Iodide ions with Standard $AgNO_3$ over Ag-Glass electrode assembly.
- Determination of the purity of $[Co(NH_3)_5Cl]Cl_2$ over Ag-Glass electrode assembly.
- Complexometric titration for determination of Ferro cyanide with standard Zinc (ii) solution and inorder to establish the composition of the complex $K_2Zn_3[Fe(CN)_6]_2$

E: - pH-metric Titrations: (2 Experiments)

- Quantitative analysis of Chromate Dichromate mixture by pH Titration.
- Purity of Acetyl Salicylic acid (Asprin) in a commercial tablet by pH Titration.

F: - Conductometric Titrations: (2 Experiments)

- To determine the solubility and solubility product of a sparingly soluble salt ($BaSO_4$) in water.
- To determine the basicity of sodium potassium tartarate by Conductometric method.

G:- Spectrophotometry: (5 Experiments)

- Determination of Iron (II) with 1,10-Phenanthroline.
- Determination of Phosphate by Molybdenum blue method.
- Determination of formula of Iron (III) thiocyanate complex by Job's Continuous variation method.
- Determination of composition of Iron (II)—2,2-bipyridyl complex by Mole ratio method.

- Determination of rate of Aquation of complex [Co $(NH_3)_5Cl]$ Cl_2 in acidic medium.

H: - Flame Photometry: (2 Experiments)

- Simultaneous determination of Sodium and Potassium in the given mixture.
- Determination of Cadmium and Magnesium in tap water.

Books Recommended:

- Vogel's quantitative analysis 6 Edn. Mendham, Denny; Pearson Education 2002
- Synthesis and Technique in Inorganic chemistry , G. S.Girlomi; R.J. Angleci 3rd edn.; University Science Books.
- Synthesis and characterization of Inorganic compounds W.AJolly
- Inorganic syntheses Vols II, VI Academic Press.
- Experimental Inorganic / Physical Chemistry ; Mounir A. Malati Horwood,1999.
- Quantitative Chemical Analysis ; 5th edn.; Harris ; Freeman ; 1999.
- Advanced Practical Inorganic Chemistry ; Adams ; Raynor, Wiley ; 1995.
- Advanced Experimental Inorganic Chemistry ; Ayodha Singh ; Campus Books 2002.

Specialization Courses in Organic Chemistry

Course No. CHM-407
Title: Designing Organic synthesis

Max. Marks: 100 **Total Duration: 50 hrs**

Unit-I **12 hrs**

Disconnection Approach

An introduction to synthoris, their types and synthetic equivalents. Reversal of Polarity (umpolung). Functional group interconversions. The disconnection approach. One group, two group and electrocyclic disconnections. Examples involving connections and rearrangements. Chemoselectivity and amine synthesis.

Protection of functional groups

Principle of protection of carbon-hydrogen bonds (in terminal alkynes and hydrogens of aldehydes), carbon-carbon double bonds, alcoholic hydroxyl groups, amine groups, carbonyl and carboxyl groups.

Unit-II **12 hrs**

One Group carbon-carbon Disconnections

Examples from simple alcohols, amines (aliphatic, aromatic), simple alkenes, carbonyl compounds, acids and acid derivatives. Regioslectivity in these reactions. Use of acetylenes and aliphatic nitro compounds in organic synthesis.

Two Group Disconnections

Diels-Alder reaction. Examples from 1,3-dioxygenated systems (p-hydroxy carbonyl and 1,3 dicarbonyl compounds), a,b- unsaturated carbonyl compounds. Control in carbonyl condensation. 1,5-difunctionalised compounds, Michael addition and Robinson annulation. Examples of some illogical two group disconnections. Synthesis ivolving some illogical alectrophiles.

Unit-III **13 hrs**

Ring Synthesis

Synthesis of saturated heterocyclic compounds of three, five and six-membered rings through disconnection or reterosynthetic approach. Aromatic heterocycles in organic synthesis.

Synthesis of some complex molecules

Application of reterosynthetic approach in the synthesis of camphor, longifoline, cortisone. Reserpine, Vitamin D, juvabione, Aphidicolin Fredericamycin A. or examples of other complex molecules.

Unit-IV **13 hrs**

Oxidation: Introduction, Different oxidative processes. Hydrocarbons: Alkenes, aromatic rings, saturated C-H group.(activated and unactivated). Alcohols, aldehydes, ketones, carboxylic acids, amines. Oxidation with lead tetracetate, Chromic acid, Selenium dioxide, ruthenium tetraoxide, iodobenzene diacetate and thaluim (III) nitrate.

Reduction:lntroduction- Different reductive processes. Hydrocarbons: alkanes, alkynes and aromatic rings. Carbonyl compounds: Aldehydes, ketones. acids and their derivatives. Epoxides. nitro, nitroso, azo and oxime groups. Reduction with LiAlH4, NaBH4. Birch reduction, Bouveault-Blanc reduction.

Reagents in Organic Synthesis:

Synthetic applications of following reagents: Aluminium isopropoxide, A,luminium-t-butoxide, Borontrifluoride, N-bromosuccinimide, Diazomethane, Dicyclohexylcarbodiimide, Dimethyl formamide, Polyphosphoric acid, Sodamide, Selenium dioxide, Trifluoroacetic acid, Raney nickel, Oilman's Reagent (Lithium

dimethyjl copper), Lithium diisopropoxide, 1,3-dithiane, trimethylsilyl iodide, tributyltinhydride, Woodward and provost hydroxylation, Osmiumtetraoxide, Crown ethers, Peterson Synthesis, Wilkinson catalyst.

Books Recommended:

1. Designing Organic Synthesis, S. Warren (Wiley-1978)
2. Organic Synthesis- concept, methods and Starting Materials, J. Furhop and G. Penzlin (Verlage VCH-1986).
3. Some Modern Methods of Organic Synthesis, 3rd Ed., W. Carruthers (Cambridge University Press-1986).
4. Modern Synthesis Reactions, 2nd Ed. H.O. House (W.A.Benjamin, NY-1972).
5. Advanced Organic Chemistry: Reactions, Mechanism and Structure, 4lh Ed., J. March, (Wiley-1992).
6. Principles of Organic Synthesis 2nd, R.O.C.Norman (Chapman and Hall-1978).
7. Advanced Organic Chemistry Part B, 4lh Ed., F. A. Carey and R.J Sundberg -... (Plenum-2000).

Course No. CHM-408
Title: Heterocyclic Chemistry

Max. Marks: 100 **Total Duration: 50 hrs**

Unit-I **12hrs**

Structure of six membered, five membered and bicyclic heteroatomic systems. Tautomerism in heterocyclic systems, Mesoionic systems. Criterion of Aromaticity, bond length, empirical resonance energy, delocalization.

UV/Visible (Electronic Spectroscopy), NMR spectroscopy . Nomenclature of monocyclic, bicyclic and polycyclic heterocycles. Hantzsch-Widman nomenclature, Replacement nomenclature, Fusion nomenclature.

Unit-II **13 hrs**

Synthesis of Aromatic Heterocycles. Reaction types most frequently used in heterocyclic ring synthesis . Typical reactant combinations. Reactants of type A and type B synthesis. Cyclisation reactions, Cycloaddition reactions, Electrocyclic processes in heterocyclic ring synthesis.

Reactivity of aromatic heterocycles. Electrophilic addition at Nitrogen, Electrophilic and Nucleophilic substitution at Carbon. De-protonation of N-Hydrogen.

Unit-Ill **13 hrs**

Small ring heterocycles. Synthesis and reactions of oxiranes, thiranes, azetidine, pyroles, furans and thiophene. Synthesis and reactions of six membered heterocycles with one heteroatom like pyrillium salts pyrones and their comparison with pyridinium and thiopyrillium salts and puyridines. Synthesis and reactions of benzopyryllium salts, coumarins and chromones. ;

Unit-lV **12hrs**

Synthesis and reactions of benzo fused five membered heterocycles like benzofuran. benzopyrolles and benzothiophenes. Six membered heterocycles with two or more than two heteroatoms like diazine, triazine, tetrazines. Large ring heterocycles like a/.cpine, thiepines, diazepines, azocines. diazocines, dithiocines.

Books Recommended:

1. Heterocyclic Chemistry, 4th Ed., J.A.Joule and K. Mills (Black Well Science. 2000). '
2. The Chemistry of Heterocycles: T. Eicher and S. Hauptman (Thieme-1995).
3. An Introduction to Heterocyclic compounds. R.M. Acheson (Wiley-1967).
4. Aromatic Heterocyclic Chemistry, D.T. Davies, (Oxford,-1992).

Course No. CHM-409
Title: Chemistry of Natural Products

Max. Marks: 100 **Total Duration: 50 hrs**

Unit-I **12hrs**

Terpenoids and Carotenoids

Classification based on Isoprene rule, nomenclature, occurrence, isolation and general methods of structure determination.

Structure determination, stereochemistry and synthesis of following representative molecules: α-terpineol, abietic acid and β-carotene.

Biosynthesis of mono and sesquiterpenoids.

Unit-II **13hrs**

Alkaloids

Definition, classification based on Nitrogen heterocyclic ring, nomenclature and physiological action, occurrence, isolation and general methods of structure elucidation, degradation. Structure, stereochemistry, synthesis and biosyjthesis of ephiderine, quinine, ???????? and reserpine.

Unit-Ill **15hrs**

Steroids

Definition, basic carbon skelton, nomenclature, Diel's hydrocarbon and stereochemistry, Structure determination and synthesis of cholesterol and its relationship with bile acids. Structure determination and synthesis of Androsterone, Testosterone and Progesterone. Biosynthesis of Cholesterol.

Steroidal hormones (Glucocorticoids, mineral corticoids). Mechanism of action and synthesis of Cholecalciferols.

Unit-IV **10 hrs**

Plant pigments and Porphyrins

Occurrence, nomenclature, general methods of structure determination, isolation and synthesis of Chrysin. Quercitin, Genistein and Cyanidin. Biosynthesis of flavonoids- Acetate and Shikimic acid pathways. Structure and synthesis of Haemoglobin and structure of chlorophyll.

Books Recommended:

1. Mono and sesqueterpenoids, P. De-Mayo (Interscience-1959).
2. Terpene Chemistry, J. Verghese (Tata- Me Graw Hill-1982).
3. Organic Chemistry, 5th Ed. Vol.2,1.L. Finar (Addison Wisley Longman-2000).
4. The Natural Pigment, Bentlay (Interscience).
5. New Trends in Natural Product Chemistry, Atta-ur-Rahman (Harwood Academic)
6. Chemistry of Natural Products, N.R. Krishnaswamy (University press-1999).
7. Chemistry of the Alkaloids, S.W. Pelletier (Reinhold-1970).
8. The Flavovoids. Harbone and Mabry (Chapman and Hall-1975).

Course No. CHM-410
Title: Medicinal Chemistry

Max. Marks: 100 **Total Duration: 50 hrs**

Unit-I **12 hrs**

Drug Dgsign: Classification and sources of Drugs, Development of new drugs; concept of lead compounds and lead modification. Analogues, prodrugs, factors governing drug design. Structure activity relationship (SAR), Isosterism, bioisosterism, changing the size and shape, changing the number of methylene groups in chain, changing the degree of unsaturation. Introduction/ removal of ring systems. Introduction of methyl groups, halogen groups, hydroxyl group, basic group, carbonylic and sulphonic group, thiols, sulphides and other groups, changing the existing substituent of lead. Latent and patent protection.

Unit-II **10 hrs**

Quantitative structure activity relationships (QSAC): Theories of Drug activity, dark occupancy theory, the rate theory, the two state theory. Concept of drug receptors, classification of receptors. Physico-chemical parameters, partition coefficient, hypophilic constituent constant, electronic parameters, Hamett constant, steric parameters, Free Wilson analysis, Hansch analysis. Surface activity parameters.

Unit-III **15 hrs**

Antibiotics: Classification, cell wall biosynthesis inhibitors, protein synthesis inhibitors, structure and synthesis of Pencillins, V & G chloroamphenical and tetra cyclins. Psychoactive Drugs: Introduction, CNS depressants, CNS stimulants, sedatives and hypnotics, barbutirates. Synthesis of diazepam, phenytonis and glutehismide. Antineoplastic drug: Introduction; cancer chemotherapy, carcemolytic antibiotic, role of alkylative agents and antimetabolites in treatment of cancer, mitotic inhibitors (elementary idea)

Unit-IV **13 hrs**

Cardiovascular Drugs: Introduction, cardiovascular diseases, synthesis of Amylnitrate. sorbitrate, quinidine, verapanil methyl dopa, athenolol

Local anti infective drugs: Introduction and general mode of action, synthesis of sulphanamides, furazolidine, cipafloxacin dapsone, amminosalicylic acid fluconazole. eronozole, chloroquin and prmaquin.

Books Recommended:

1. Introduction to Medicinal Chemistry, Alex Gringauz (Wiley- VCH-1997).
2. Medicinal Chemistry- An Introduction, Gareth Thomas (Wiley-2000). 3v^edicinal Chemistry-Principles and Practice, Edited by F.D. King (RSC-1998).
4. Medicinal Chemistry, Ashutosh Kar. (Wiley Eastern-1993).
5. Topics in Medicinal Chemistry, Robinonitz & Myerson (Interscience-1967).
6. Burger's Medicinal Chemistry and Drug Discovery (Wiley Interscience-1970).
7. Text book of Organic Medicinal and Pharmaceutical Chemistry, 8th Ed, Wilson & Gisvold, (Lippincott).
8. The Organic Chemistry & Drug Design and Drug action, R.B. Silverman (Academic Press).
9. Strategies for Organic Drug Design and Drug, D. Lednicer (Wiley).
10. Organic Chemistry of Drug Synthesis by Daniel Lednicer, Lester A. Mitscher and G.I. George Vol. I to IV (Wiley interscience Publications-1990).
11. Medicinal Chemistry, Vol III & IV, F.F. Blidse & R. H. Cox (Wiley- 1956).

Course No. CHM-411
Title: Seminar lecture in Organic Chemistry

The Course shall comprise of following two components of 25 marks each and each component would be evaluated in the same manner as project works are evaluated.

Part A: **Marks: 25**

Each student shall submit a seminar report (review) on the topic assigned to him/her by the supervisor concerned. The report would be evaluated on 25 point scale by another teacher of the same branch.

Part B: **Lecture followed by viva-voce** **Marks: 25**

The student shall deliver a lecture on the same topic before all M.Sc. students/Scholars and teachers of the departments followed by an open viva-voce session. This would be conducted by a team of three teachers, one from each branch, who would award marks out of 25 based on the presentation and performance in question answer session.

Course No: CHM- 412 L

Title: Laboratory Course in Organic Chemistry

Max. Marks 150 **Total Duration: 150 hrs.**

1. **Multistep synthesis of drugs/ organic coinpouiuls involving name reactions**
   (1) Synthesis oflocal anesthetics
   (2) Synthesis of analgesics .
   (3) Synthesis of sulpha drugs
   (4) Synthesis using microwaves: Alkylation of diethyl malonate with benzoyl chloride
   (5) Skraup synthesis : Preparation of quinoline from aniline.
   (6) Beckmann rearrangement.
2. **Extraction/Estimation of Organic compounds from natural sources**
   (1) Isolation of lycopene and b-carotene from tomato. Characterisation of lycopene/P-carotene by uv -absorption process.
   (2) Isolation of limonene from its natural source and physicochemical analysis.
   (3) Assay of Belladona for Hyoscyamine.
   (4) Assay of lemon for citric acid and vitamin-C
   (5) Isolation of cholesterol from gallstone
   (6) Assay of coke (soft drink)
3. **Column Chromatography**
   Separation of two component solid mixture. Identification using physical, chemical and spectral techniques.
4. **Spcctrophotomctric estimation** (UV/visible)
   (1) Vitamin-C (Ascorbic acid)
   (2) Caffeine from tea.
   (3) Cholesterol
   (4) Aspirin
5. **Elcctrophoresis/ Paper chromato^raphy**
   Separation and identification of aminoacids by elcctrophoresis / Paper chromatography.
6. **Spcctroscopy**
   Identification of Organic compounds through interpretation of their spectra (UV, IR, PMR, CMR and Mass spectra to be provided).

Books Recommended :

1. Comprehensive Practical Organic Chemistry, V.K. Ahluwalia, Renu Aggarwal (Univ. Press India Limited -2000).
2. Vogel's Text Book of Practical Organic Chemistry, B.S.Furniss, A. J. Hannaford (AWL 5th Ed.-1998).
3 Organic Laboratory Techniques , Donald .C. Pavia, Gary . M. Lampman (SCP 3rdEd.-1999)
4 Experiment Organic Chemistry, John.C. Gilbert., Stephen.F.Martin (SCP -1998)
5 Advanced Practical Organic Chemistry Vol. II, Jag Mohan (Himalaya Pub. House First Ed.-1992 V

Specialization Courses in Physical Chemistry

Course NO: CHM- 413
Title: Computational Chemistry

Max.Marks-100 **Total Duration-50 hrs.**

Unit-I: Programming with Fortran . (13 hrs)

Program units and procedures: Review of function and subroutine subprograms, Procedures with multidimensional arrays, Functions as dummy arguments, recursive functions. Derived data types. Modules and Interface Blocks. Dynamic storage allocation, allocatable and allocate statements. Kind specification, Namelist Input/output, Forall statement. Pointers

Unit-II: Numerical Methods-I (13 hrs)

Basic theory, discussion of algorithms and errors for following numerical methods:

Solution of Equations: ….4 hrs

Bisection, false-position, Newton-Raphson and related methods for solving polynomial and transcendental equations. Convergence. Errors and ill-conditioning.

Linear Simultaneous equations: ….5 hrs

Gaussian elimination, Gauss-Siedel method, gauss-Jordan method. Pivoting strategy. Errors and ill-conditioning.

Eigenvalues and Matrix Diagonalization: … 4hrs

Eigenvalue problem, diagonalization of a matrix, Jacobi and Householder methods, analysis of errors.

Unit- III: Numerical Methods-II (13 hrs)

Basic theory, discussion of algorithms and errors for following numerical methods:

Numerical differentiation …4 hrs

Solutions of simple differential equations by Taylor series and Runga-Kutta methods.

Numerical integration … 4 hrs

Newton-Cotes formulae, Romberg integration, errors in integration formulae.

Interpolation and Data Fitting … 5 hrs

Lagrange's interpolation method, Newton's divided differences, Cubic spline, piecewise interpolation.
Least squares approximation, linear and quadratic.

Unit-IV : Advanced Scientific Packages (12 hrs)

Brief introduction to basic theory, methodology and applications of following Chemical packages:

a. Ab *initio* quantum mechanical package GAMESS. …6 hrs

b. Semi-empirical/Dynamics package MOPAC …6 hrs

Books Recommended:

1. Computer Programming in Fortran 90 and 95, Rajaraman , (PHI, 2002)
2. Fortran 90/95 Explained, Metcalf and Reid, (OUP, 1997)
3. Data Reduction & Error Analysis, Bevington & Robinson, (McGraw-Hill, 2003)
4. Computational Chemistry, A. C. Norris, (Wiley.)
5. Computer Software Applications in Chemistry - P. C. Jurs, (John Wiley, 1996.)
6. Numerical Methods for Scientists and Engineers, H. M. Antie, (TMH,).
7. Numerical Recipes in Fortran/C, W.H. Press et al., (CUP,1992)
8. Applied Numerical Analysis, Gerald & Wheatly, (Pearson Education, 2002)
10. GAMESS and MOPAC Manuals

Course NO: CHM- 414

Title: Advanced Quantum Chemistry

Max.Marks-100 **Total Duration-50 hrs**

Unit-I: Electronic Structure Theory, Hartree-Fock Method (12 hrs)

Self consistent field methods: Hartree-Fock approximation, HF Equation, Fock, Coulomb and exchange operators and integrals , restricted and unrestricted Hartree-Fock formalism, Roothaan equation. The Fock matrix elements, Matrix form of Roothaan equation, the SCF procedure.
Electron correlation, Slater-Condon rules, Koopmans theorem, Slatter-type orbitals, STOs and Gaussian basis sets.Model SCF calculations on H_2/He.

Unit- II: Configuration Interaction and Molecular properties (13 hrs)

Configuration Interaction: Introduction to configuration interaction (CI), Configuration state functions, Brillouin theorm. Full and truncated CI theories- CID, CISD, CISDTQ. Size consistency problem. Introductory treatment of MC-SCF and MRCI methods. MP_2 and Coupled Cluster methods. …8 hrs

Molecular Properties: Basic ideas about molecular geometry, Optimization of molecular geometry-quasi-Newton, steepest descent and conjugate gradient methods. Molecular vibrational frequencies, thermodynamic properties. …5 hrs

Unit-III: Semi-Empirical and Density Functional Theories (13 hrs)

Semiempirical methods: A review of Huckel theory, extended Huckel (EHT) and Parisar-Parr-Pople (PPP) treatments, ZDO approximation. Detailed treatment of CNDO and INDO theories. Introduction to MNDO, AM1 and PM3 methods. Molecular mechanics methods, force fields. …8 hrs

Density Functional Theory: Electron probability density. Hohenberg-Kohn theorms, Kohn-Sham formulation, n- and v- representabilities; the local density approximation, E_x & E_c functionals, X_α methods. …5hrs

Unit- IV: Quantum Chemistry Software Packages (12 hrs)

A quick tour of GAUSSIAN Interface.. Input to Gaussian. Exercises on model calculations illustrating various features of the package**..**

1. A single point energy calculation: HCHO / $CH_3CH=CH_2$, $CH_3.CO.CH_3$/HCHO MOs
2. NMR properties of alkanes, alkenes and alkynes.
3. Geometry Optimization: Input and Output for GO, ethene, fluoroethene, chromium hexacarbonyl, propene conformers.
4. Optimization of $C_{60}O$ isomers / NMR chemical shift for benezene
5. Frequency Calculations: Input, Formaldehede frequencies, Normal modes, zero point energy, polarizability, heperpolaraziability.

6. Stationary points characterization –C_3H_5F

7. Model Chemistries: Basis set effect on HF bond length / NMR calculation (C_6H_6)/ Geometry of DMF. Basis set definitions.

8. Selecting an appropriate theoretical method:

   a) Semi-empirical methods: TPP (tetraphnylporphin) molecular orbitals, Limitations of semi-empirical methods: HF dimmer
   b) Electron correlation and post SCF methods, limitations of hartree- Fock theory: HF bond energy, Optimization of O_3.
   c) Density Functional Theory: CO_2 structure and atomization energy.
   d) Butane/Isobutane, acetaldehyde/ethylene oxide ismerization energy, rotational barrier in n-butane.

9. Chemical reactions and reactivity:
   a) Electron densities of substituted benzenes.
   b) Hydration enthalpy of the reaction $H^+ + H_2O \rightarrow H_3O^+$
   c) Potential energy surfaces. Reaction path following (IRC calculation)
   $CH_2O \rightarrow HCHO$

Recommended:

1. Quantum Chemistry , Ira. N. Levine, (Prentice Hall, 2000).
2. Molecular Quantum Mechanics, P. W. Atkins and R. S. Friedmann, (Oxford, 2005).
3. Methods of Molecular Quantum Mechanics, R. McWeeny, (Academic Press, 2001).
4. A Computational Approach to Chemistry, D. M. Hirst, (Blackwell Scientific, 1990).
5. Modern Electronic Structure Theory, D. R. Yarkouy (ed). (World Scientific, 1995)
6. Molecular Quantum Chemistry - Introduction to Advanced electronic structure theory - A. Szabo & N. S. Ostlund, (Macmillan, 1982).
7. Ab Initio Molecular Orbital Theory**,** by Hehre, Radom, Schleyer and Pople, (Wiley)
8. Density Functional Theory of Atoms and Molecules, R.G. Parr and W. Yang, Oxford(1989).

Course NO: CHM- 415

Title: Non-Equilibrium and Statistical Thermodynamics

Max.Marks-100 **Total Duration-50 hrs**

Unit-I: Non-equilibrium Thermodynamics (12 hrs)

Fluctuation theory, principle of microscopic reversibility, Derivation of reciprocity relation. …3 hrs

Stationary non-equilibrium states, thermodynamic significance. States of minimum entropy production, stability of stationary states, entropy flow in stationary systems. Stationary state coupling in irreversible processes. Variation of entropy production in stationery states, Glansdroff- Prigogine inequality …6 hrs

Self-Organization in physico-chemical systems - thermal convection, oscillatory reactions, living systems …3 hrs

Unit-II: Statistical Thermodynamics (12 hrs)

Thermodynamic functions of polyatomic gases, internal rotation, heat capacity and residual entropy. Statistical thermodynamics of solids- Einstein and Debye models (Partition function, Average energy and heat capacity). Limitations of the models.

…5 hrs

Chemical Equilibrium: Equilibrium constant in terms of partition functions. Examples of application to different types of equilibria: Isomerization equilibrium, Ionization equilibria, dissociation of molecules, isotopic exchange. ... 4 hrs

Nuclear spin statistics, symmetry and nuclear spin, Ortho and Para nuclear spin states, Ortho and Para Hydrogen and Deuterium, CO. …3 hrs

Unit- III: Ensemble Theory, Classical and Quantum Statistics (14 hrs)

Concept of ensembles, ensemble average and postulate of equal a priori probablilty. Canonical, grand-canonical and Micro-canonical ensembles. Ensemble partition functions and related thermodynamic functions. Ideal gas in canonical and Grand canonical ensemble. …4 hrs

Lagranges and Hamiltons equations of motion, concept of phase space, Lioville's equation. Kinetic theory of gases, equipartition of energy, Maxwell's velocity distribution. ….5 hrs

Quantum Statistics : Fermi-Dirac and Boson-Einstein statistics. Application of grand partition function to Boson-Einstein and Fermi-Dirac statistics. Ideal Fermi-Dirac

gas: Electrons in metals, Ideal Photon gas: Black body radiation, Ideal Bose-Einstein gas: Helium ….5 hr

Unit- IV: Statistical Thermodynamics of Interacting Systems

(12 hrs)

Statistical Mechanical treatment of imperfect gases. Virial equation of state from grand partition function, virial coefficient in the classical limit, second and third virial coefficients. …3 hrs

Lattice statistics: One-dimensional lattice gas (adsorption), two-dimensional square lattice, Bragg-Williams approximation, quasi-chemical approximation, first-oreder phase transitions. …3 hrs

Statistical mechanics of liquids. Distribution function, radial distribution function, Monte-Carlo simulations …3 hrs

Theory of solutions: Lattice model, regular solution theory. Statistical Mechanics of polymer solution. …3 hrs

Books Recommended:

1. Thermodynamics of Irreversible Processes, De Groot, Mazur, (Dover, 1986).
2. Introduction to Thermodynamics of Irreversible Processes, I. Prigogine, (Wil-Interscience, 1967.)
3. Thermodynamics for students of Chemsitry, Kuriacose, Rajaram, (S. Chand and Co., 1996).
4. Exploring Complexity, I. Prigogine, G. Nicolis, (Freeman, 1998).
5. Molecular Thermodynamics, D. A. McQuarrie, J. D. Simon, USB, 1998.
6. Statistical Thermodynamics, M.C.Gupta, (New Age International, 1993).
7. Statistical Mechanics, D. A. McQuarrie, (Viva, 2003).
8. Introduction to Statistical Thermodynamics, Chandler, (OUP, 1987).
9. Statistical Thermodynamics and Kinetic Theory, C. E. Hecht, (Dover, 1990).
10. Statistical Mechanics - Principles and Applications, Hill, Dover, 1987.
11. Statistical Thermodynamics for Chemists, A. Ben-Naim, (Plenum, 1992).
12. An introduction to Statistical Thermodynamics, Hill, (Addison-wesley, 1987).

Course NO: CHM- 416

Title: Chemistry of Materials

Max.Marks-100 **Total Duration-50 hrs**

Unit-I: Ceramics, Polymers and Langmuir Blodgett Films (13 hrs)

Ceramics: Introduction, Pauling rules and mechanical properties. Glasses – Types , thermodynamics of glass formation and applications; Refractory materials, Clay and Clay products – Properties and applications. …3 hrs

Polymers: Structure of polymers – Chemical and geometric, crystallinity and defects in polymers, Properties – Thermal and Mechanical, Applications – structural plastics, conducting polymers, photo-resists, piezoelectric and ferroelectric polymers. …4 hrs

Langmuir- Blodgett Films: Introduction and general preparative techniques. LB Films of various compounds (hydrocarbon, liquid crystals compounds and polymers), Applications – nonlinear optical effects, conduction, photoconductivity and sensors. …4 hrs

Multiphase materials: Iron-carbon system. …2 hrs

Unit- II: Organic Solids, Molecular Devices and High T_c Superconductors

(12 hrs)

Organic solids and fullerenes: Organics conductors, organic superconductors, magnetism in organic materials. Fullerenes- History, bonding, properties, doped fullerenes, fullerenes as superconductors and fullerene related compounds (carbon nanotubes) …4 hrs

Molecular devices: Molecular rectifiers and transistors, artificial photosynthetic devices, switches and sensors. 3 hrs

High T_c superconductors: Superconductors: Properties and types. high Tc superconductivity in cuprates: Structure, preparation and characterization of 1-2-3 materials, mechanism of high Tc superconductivity, Defect perovskites, Applications of High Tc materials. …5 hrs.

Unit-III: Optical materials and liquid crystals (13 hrs)

Optical materials: Luminesence and phosphors. Lasers – general principle of lasing action, Ruby laser, Neodymium-YAG lasers, semiconducing lasers, quantum cascade and quantum dot lasers.

Nonlinear optical effects, second and third order harmonic generation, nonlinear optical materials. …6 hrs

Liquid Crystals: Mesomorphism, types of liquid crystals, molecular structural requirement of mesomorphism, properties of liquid crystals, Applications – Liquid crystal displays, thermography, optical imaging and ferroelectric liquid crystals.

Unit- IV: Solid electrolytes and semiconductor electrodes (12 hrs)

Ionic Conductors: Introduction to ionic conduction and mechanism. Types of ionic conductors, mechanism of ionic conduction, interstitial jumps (Frenkel); vacancy mechanism. Super-ionic conductors: Diffusion and transition superionic conductors and mechanism of conduction in superionic conductors; examples and applications of ionic conductors. …6 hrs

Semiconducting electrodes: Structure of seminconducting/electrolyte interface. Kinetic of electron transfer reactions and fundamentals of photoelectrochemical phenomena across semiconductor/electrolyte interface. Semiconducting electrodes for solar energy conversion, photoelectrochemical celles (photoelectrosynthesis and photogalvanic cells).

…6 hrs.

Books Recommended:

1. Introduction to Solids, Azaroff, Tata McGraw,1993.
2. Solid State Chemistry and its Applications, West, Wiley,1989.
3. The Physical Chemistry of Solids, Borg, Biens, Academic press, 1992.
4. Solid State Physics, N. W. Ashcroft and N. D. Mermin, Saunders college, 2001
5. Principles of Solid State, H. V. Keer, Wiley Eastern.
6. Thermotropic Liquid Crystals, Ed., G.W. Gray, John Wiley.
7. The Physics and Chemistry of materials, J.I. Gersten, F.W. Smith, John Wiley and sons, Inc. 2001.

Course NO: CHM- 417

Title: Seminar Lecture in Physical Chemistry

Max.Marks-50

Each student shall be attached with a particular teacher of Physical Chemistry section who in consultation with the student concerned will assign a topic of current/ general interest.

Part A : **25 Marks**

The student shall consult literature/internet and collect the relevant material. He/she will prepare a review on the topic and shall submit in a prescribed format (both hard and soft copies).

Part B : **25 Marks**

The candidate will deliver the seminar lecture on the date and time fixed for the purpose.

Both the components shall be evaluated internally by a group of teachers of the concerned branch, headed by the senior most teacher. The total marks of the course out of 50 shall be communicated to the controller of examination.

COURSE NO: CHM-418L

Title: Laboratory Course in Physical Chemistry

Max.Marks-100

A. Tensiometry

1. Determination of CMC value of a detergent.
2. Investigation of variation of surface tension of n-butanol and sodium chloride solutions with concentration and hence determination of their surface excess concentrations using Gibb's Adsorption Isotherm.

B. Polarography

1. Determination of half-wave potential of Pb^{++},Zn^{++} and Cd^{++}
2. Establishing the linear dependence of diffusion current on the concentration of depolariser.
3. Determination of composition of a mixture of two components by diffusion current measurements.

C. Cryoscopy

1. Investigation of variation of freezing point depression with concentration & determination of molecular mass.
2. Determination of the degree of dissociation of a salt/weak acid in solution.
3. Determination of activity co-efficient.

D. pH-metry

1. Determination of pK-value of an amino acid.
2. Titration of a tribasic acid with alkali to find the pK values.

E. Spectrophotometry

1. To study the complexation reaction between Fe(III) & salicylic acid.
2. Determination of pK value of an indicator.
3. Titration of Fe(II) vs $KMnO_4$

F. Potentiometry

1. Determination of pKa values of a dibasic acid.
2. Precipitation titration of KCl, KBr, KI and their mixture with $AgNO_3$
3. Thermodynamics of a chemical reaction by EMF-method.
4. Determination of formation constant of Ag-NH_3 complex.
5. Determination of (a) Standard electrode potential & (b) Activity Coefficient.

G. Conductometry

1. Verification of Debye-Huckel-Onsagar law.
2. Precipitation titration between:
   i) $BaCl_2$ and $K_2SO_4/(NH_4)_2SO_4$
   ii) Mixture of H_2SO_4 and K_2SO_4 with $Ba(OH)_2$.
3. Estimation of the concentrations of H_2SO_4, CH_3COOH and $CuSO_4$ in a mixture.

H. Kinetics

1. Kinetic Study of the iodine - acetone reaction.
2. Study of effect of temperature and ionic strength on rate constant of persulphate-iodide reaction.
3. Kinetic study of enzyme catalyzed inversion of cane sugar.

I. Data Analysis

1. Preparation of data set of density of a given liquid and calculation of the mean, deviation from mean, variance and standard deviation.
2. Linear Least squares fitting procedure. Analysis of temperature dependence of rate of Iodide – persulphate reaction.

J. Bomb Calorimetery

1. Determination of Enthalpy of Combustion of a hydrocarbon. (Napthalene/Anthracene/Phenanthraline)

K. Viscometry and densiometery

1. Determination of Mol. Mass of a Polymer (Polyvinyl alchol) using viscosity method.
2. Determination of partial molar volume of sodium chloride solutions as a function of concentration from density measurements.

Books Recommended

1. Practical Physical Chemistry ----Findley revised by Kitchner.(Longman, 1971)

2. Advanced Practical Chemistry ----- Yadav. (Goel Pub. House. 1994)

3. Experiments in Physical Chemistry, 5th ed. ---- Schoemaker et al. (MGH, 1989)