DEPARTMENT OF CHEMISTRY
NAGALAND UNIVERSITY
HQRS: LUMAMI

Curriculum and Credit Framework
For P.G SYLLABUS
in
Chemistry

DEPARTMENT OF CHEMISTRY - YEAR 2025
COURSE STRUCTURE FOR M.Sc. PROGRAMME

Total Marks=2000			**Total Credits=80**	
Semester	**Course No**	**Course Name**	**Credit**	**Marks**
I	CHEM – 411	Basic Concepts of Inorganic Chemistry	4	100
	CHEM – 412	Stereochemistry and Basic Organic Reactions.	4	100
	CHEM – 413	Chemical Thermodynamics and Kinetics	4	100
	CHEM – 414	Analytical and Computational Chemistry	4	100
	CHEM – 415	Laboratory Course in Inorganic Chemistry	4	100
			20	**500**
II	CHEM – 421	Chemistry of Main Group, Transition, and Inner Transition Elements	4	100
	CHEM – 422	Advanced Heterocyclic Chemistry	4	100
	CHEM – 423	Quantum Chemistry and Statistical Thermodynamics	4	100
	CHEM – 424 A/B/C	CBCP (Choice Based Credit Paper)	4	100
	CHEM – 425	Laboratory Course in Organic Chemistry	4	100
			20	**500**
A student can exit after second semester with P.G. Diploma				
III	CHEM – 531	Organometallic and Bioinorganic Chemistry	4	100
	CHEM – 532	Organic Spectroscopy	4	100
	CHEM – 533	Advanced Physical Chemistry	4	100
	CHEM – 534	Massive Open Online Courses (MOOCS)	2	50
	CHEM – 535	Internship	2	50
	CHEM – 536	Laboratory Course in Physical Chemistry	4	100
			20	**500**
IV	CHEM – 541	Project Work	20	500
			20	**500**

* As per NEP guidelines, Credit up to a maximum of 40% can be earned from the SWAYAM platform and transferred to her/his Academic Bank of Credit.
* Educational exposure may be evaluated as an internal assessment.
The department will offer CBCP as follows:
1.544 A: Biological and Medicinal Chemistry
2.544 B: Green and Sustainable Chemistry
3.544 C: Polymer and Nano Chemistry
4. Course selected from the SWAYAM Platform

SEMESTER-I

CHEM-411: BASIC CONCEPTS OF INORGANIC CHEMISTRY

Total Marks: 100 **Credits: 4**

UNIT 1: Acid-Base Concepts

Acid-Base Concepts: Arrhenius concept - Water ion system; Bronsted-Lowry theory - proton-donor-acceptor system; general theory of solvent system; Lewis's concept - electron-donor-acceptor system; Hard-Soft Acid-Base concept and stability of the complex (A: B); Usanovich concept – positive-negative system.

UNIT 2: Non-aqueous Solvents

Classification of solvents; general properties of ionizing solvents; chemical reactions; Liquid ammonia as solvent; liquid sulfur dioxide as solvent; liquid dinitrogen tetra-oxide; liquid hydrogen fluoride; liquid hydrogen sulfide; liquid hydrogen cyanide; acetic acid; liquid bromine trifluoride; oxyhalides.

UNIT 3: Chemical Applications of Group Theory

Symmetry and Structure: Symmetry elements and operations; multiplication of symmetry operations; symmetry point groups with examples from inorganic compounds; groups of very high symmetry; molecular dissymmetry and optical activity; systematic procedure for symmetry classification of molecules and illustrative examples.

Symmetry group theory and its applications: Matrix representation of symmetry operations and groups; reducible and irreducible representations; Great Orthogonality Theorem; character tables. Application of group theory.

UNIT 4: Nuclear Chemistry

Basic concepts, models of nuclear structure and stability. Nuclear reactions: nuclear fission, nuclear fusion. Detection and measurement of radioactivity. Application of radioisotopes as tracers in chemical analysis. Isotope effect, isotopic exchange reactions, isotope dilution techniques and radiometric titrations. Radiopharmaceutical, radioimmunoassay and radiation sterilization. Hot atom chemistry.

Recommended Books:

1. B. R. Puri, L. R. Sharma, and K. C. Kalia, *Principles of Inorganic Chemistry*, Milestone.
2. W. U. Malik, G. D. Tuli, & R. D. Madan, *Selected Topics in Inorganic Chemistry*, S. Chand & Company Ltd.
3. P. Atkins, T. Overton, J. Rourke, M. Weller & F. Armstrong. *Shriver and Atkins Inorganic Chemistry*, Oxford University Press.
4. N. N. Greenwood & A. Earnshaw. *Chemistry of the Elements*, Pergamon Press.
5. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann. *Advanced Inorganic Chemistry*, John Wiley.
6. B. Douglas, D. McDaniel and J. Alexander. *Concepts and Models of Inorganic Chemistry*, John Wiley & Sons.
7. F. A. Cotton. *Chemical Applications of Group Theory*, John Wiley & Sons.

CHEM-412: STEREOCHEMISTRY AND BASIC ORGANIC REACTIONS

Total Marks: 100 **Credits: 4**

UNIT 1: Stereochemistry

Introduction to geometrical and optical isomerism, concept of chirality, recognition of symmetry elements and chiral structure, R-S nomenclature, optical activity in the absence of chiral carbon (biphenyls, allenes and spiranes), Diastereoisomerism in acyclic and cyclic systems, conformational analysis of simple cyclic(chair and boat cyclohexanes) and acyclic systems, interconversion of Fischer, Newman and sawhorse projections. Threo-erythro nomenclature enantiotopic and diastereotopic atoms, groups and phases, stereo specific and stereo selective synthesis; asymmetric synthesis.

UNIT 2: Oxidation Reactions

Oxidation with Chromium and Manganese Compound: Oxidation of alcohol, aldehydes, carbon–carbon double bonds, and carbon–hydrogen bonds in organic molecules by Potassium permanganate, manganese dioxide, chromic acid, sodium or potassium dichromate. Oxidation with Peracids and other Peroxides: Oxidation of carbon–carbon double bond, oxidation of carbonyl compound, Baeyer–Villiger oxidation.

Other methods of oxidation:
Prevost and Woodward hydroxylation, cis-and trans-hydroxylation and glycol cleavage reagents: $KMnO_4$, OsO_4, HIO_4, $Pb(OAc)_4$, Mercuric acetate, selenium dioxide.

UNIT 3: Reduction Reactions

Heterogeneous hydrogenation: Introduction to catalytic hydrogenation, reduction of different functional groups. Homogeneous hydrogenation: Wilkinson's catalyst. Dissolving Metal Reduction: Liquid ammonia reduction, Birch Reduction, Clemmensen Reduction, Metal Hydride reduction: Reduction with Lithium aluminium hydride, Sodium borohydride, Hydroboration including the reactions of alkyl borane, Meerwein-Pondorf-Verley reduction.

UNIT 4: Reactions of Carbonyl Compounds

Difference in Reactivity between aldehydes and ketones, stereochemical aspects for determining reactivity; familiar name reactions in carbonyl chemistry: Aldol condensation, Perkin condensation, Reformatsky reaction, Robinson Annulation, Stobbe condensation, Schmidt rearrangement, Beckmann rearrangement, Curtius rearrangement, Dieckmann condensation, Grignard reaction, Hoffmann rearrangement, Lossen rearrangement.

Recommended Books:

1. W. Carruthers, Modern Methods of Organic Synthesis, Third Ed., Cambridge University Press.
2. Organic Reaction Mechanisms, V. K. Ahluwalia, R. K. Parashar, Narosa Publishing House.
3. S.H. Pine, Organic Chemistry, McGraw-Hill.
4. T.W.G. Solomons – Organic Chemistry, John Wiley.
5. D. Nasipuri, Stereochemistry of Organic Compounds, New Age International.
6. P. S. Kalsi. Stereochemistry, Conformation and Mechanism, New Age.

CHEM-413: CHEMICAL THERMODYNAMICS AND KINETICS

Total Marks: 100 **Credits: 4**

UNIT 1: Chemical Thermodynamics

Brief resume: concepts of laws of thermodynamics, path and state function, thermodynamic processes, free energy, chemical potential and entropies; Maxwell Relations, Gibbs-Helmholtz, Gibbs-Duhem; solutions- partial molar quantities, partial molar volume and its determination, thermodynamics of mixing, chemical potentials of liquids, liquid mixtures; Activities- solvent activity, solute activity, determination of activity and activity coefficients.

UNIT 2: Non-equilibrium Thermodynamics

Entropy of irreversible processes- Clausius inequality, entropy production and entropy flow; entropy production due to- heat flow, chemical reactions, electrochemical reactions; entropy production in open system; rate of entropy production- generalized forces and fluxes, transformation of the generalized forces and fluxes; phenomenological equations, Onsager's reciprocity relations; electro kinetic phenomena; stationary non-equilibrium states- states of minimum entropy production.

UNIT 3: Chemical Kinetics

Methods of determining rate laws; Collision theory of reaction rates; steric factor; activated complex theory; Arrhenius equation and activated complex theory; ionic reactions – kinetic salt effects; steady state kinetic**s;** kinetic control of reactions, homogeneous catalysis.

UNIT 4: Chemical Dynamics

Dynamics of chain reactions (hydrogen-bromine reaction; photochemical reactions (hydrogen-bromine and hydrogen-chlorine reactions); general features of fast reactions; study of fast reactions by flow methods; relaxation method, flash photolysis and nuclear magnetic resonance method.

Oscillatory reactions (Belousov-Zhabotinsky reaction); kinetics of enzyme reactions

Books Suggested:

1. P.W. Atkins, Physical Chemistry, Oxford Uni. Press.
2. R. Haase, Thermodynamics of Irreversible Process, (Addition Wesley)
3. G.L. Agrawal, Basic Chemical Kinetics, Tata McGraw-Hill.
4. K.J. Laidler, Chemical Kinetics, McGraw-Hill.
5. K.L. Kapoor, A Textbook of Physical Chemistry Vol. 1, Mac-Millan.

CHEM-414: ANALYTICAL AND COMPUTATIONAL CHEMISTRY

Total Marks: 100 **Credits: 4**

UNIT 1: Analytical chemometrics and Separation techniques
Brief review of statistical treatment of experimental data (error, precision, accuracy, significant figures, mean, median, and standard deviation, methods of least squares).
Experimental techniques of purification and separation: ion exchange, partition and Adsorption chromatography, Gas chromatography (GC), High performance liquid chromatography (HPLC).

UNIT 2: Methods of Thermal Analysis
Thermogravimetric Analysis (TGA): Principles, instrumentation, methodology and applications, Differential Thermal Analysis (DTA): Principles, instrumentation, methodology and applications, and Differential Scanning Calorimetry (DSC): Principles, instrumentation, methodology and applications for analyses of chemical compounds.

UNIT 3: Computing and Hardware
Basic structure and functioning of computers PC as an illustrative example; memory – RAM, ROM, IROM, EPROM, EEPROM, I/O devices, Computer languages (generation of languages) differences between DOS, Windows, Macintosh, and Linux, Physical applications and usage of all constituents of a central processing unit.

UNIT 4: Computational Softwares
MS Word: Formatting, Spell and Grammer check, tables, MS Excel: Functions, charts, Autofill, Autosum, OLE, MS PowerPoint: Creating a master slide, Use of Hyperlink, inserting images, running a slide show, Microcal Origin: Learn to draw figures, complex figures, bar diagrams, 3-D diagrams, Math Type for equations: Write complex equations, Arrhenius equations, Adsorption equations, Chembiodraw: Draw molecules, polymers, proteins, complex mechanisms, Programming using C language: Introduction and basics, elements of the computer language, constants and variables, input and output format statement, termination statements.

Recommended Books:

1. Instrumental Methods of Analysis, H.H. Willard, L.L. Merritt, J.A. Dean, F.A. Settle, CBS Publications.
2. Principles of Instrumental Analysis, D.A. Skoog, W. B. Saunders.
3. Thermal Methods of Analysis, W.W. Wendlandt., Wiley Inter-Science.
4. Analytical Chemistry, D. Kealey, P.J. Haines, Viva Books Private Limited,
5. Essentials of Nuclear Chemistry, H. J. Arnikar, Wiley Eastern.
6. Basic Concepts of Analytical Chemistry, S.M. Khopkar
7. Vogel's Textbook of Quantitative Chemical Analysis, J. Mendham, R.C. Denney, J.D. Barnes and M.J. Thomas, Pearson Education.
8. Microcomputer Quantum Mechanics, Second Edition; J.P. Killingback and Adam Hilger Ltd., Bristol and Boston, 1985.
9. Meth Norton's; Introduction to Computers; Fourth Edition; McGraw Hill, New York.
10. Computers for Chemists; K.V. Rajoraman; Tata Megraw Hill Co. Ltd.; New Delhi; 1993.

CHEM-415: LABORATORY COURSE IN INORGANIC CHEMISTRY

Total Marks: 100 **Credits: 4**

1. Quantitative estimation involving volumetric (redox and complexometry), gravimetric and spectrophotometric methods of constituents in three-component mixtures and alloys.

2. Preparations and characterizations of the following compounds: (Green Chemistry Principle may be applied)
i) Reinecke salt
ii) Tris(oxalato) manganese(III)
iii) Tetrapyridine silver (II) peroxidisulphate
iv) Tris(acetylacetonato) iron(III)
v) Bis(N,N-diethyldithiocarbamato)nitrosyl iron(I)
vi) Optical isomers of tris(ethylenediamine) cobalt(III) chloride
vii) Linkage isomers of nitro and nitritopentamminecobalt(III) chloride
viii) Ferrocene or dibenzene chromium
ix) Hydridochlorocarbonyltris(triphenylphosphine) ruthenium(II)
x) Tris(2,2$^{/}$-bipyridine) ruthenium(II) perchlorate
xi) $[(p\text{-(cymene)}RuCl_2]_2$
xii) Tri(acetylacetonato) manganese(III)

3. Study of inorganic compounds using the following analytical techniques:
i) UV-VIS and IR spectroscopy
ii) TGA and DTA

Recommended Books:

1. J. Mendham, R. C. Danney, J. D. Barnes & M. Thomas. *Vogel's Textbook of Quantitative Chemical Analysis*, Peterson Education.
2. G. Marr & B. W. Rockett. *Practical Inorganic Chemistry*, Van Nostrand.
3. G. Pass & H. Sutcliffe. *Practical Inorganic Chemistry*, Chapman & Hill.
4. J. Basset, R. C. Denney, G.H. Jeffery & J. Mendham. *Vogel's Textbook of Quantitative Analysis*, English Language Book Society.
5. G. W. Parshall (Ed. in Chief). *Inorganic Synthesis*, Vol. 15, McGraw-Hill.
6. Aspects of Green Chemistry, Upasana Bora Sinha, M.R. Publishers.

SEMESTER-II

CHEM-421: CHEMISTRY OF MAIN GROUP, TRANSITION AND INNER TRANSITION ELEMENTS

Total Marks: 100 **Credits: 4**

UNIT 1: Chemistry of Main-Group Elements

Chemical periodicity; allotropy, Allotropy in carbon, phosphorous and sulphur; Structure and bonding in oxyacids of nitrogen, phosphorous, sulphur and halogens; Interhalogens and pseudohalides; Structure and bonding in homo- and heteronuclear molecules; VSEPR theory & Shapes of molecules.

UNIT 2: Inorganic Cages and Metal Clusters

Basics of cages and clusters. Wade's rule, Styx notation, electron count in polyhedral boranes. Synthesis, bonding, structures, and properties of boranes and related compounds, phosphazenes. Silicones and compounds with B-N, P-N, and S-N bonds. Introduction to molecular clusters. Main-group clusters. Closo-, nido-, arachno-borane structural paradigm, electron counting rules. Transition-metal clusters. Structure, synthesis and reactivity. Capping rules, isolobal relationships between main-group and transition metal fragments. Main group Transition Metal clusters. Clusters having interstitial main group elements, cubane clusters and Zintl clusters. Clusters in catalysis. Non-stoichiometric oxides: zeolites and clay.

UNIT 3: Chemistry of Transition and Inner Transition Elements

Transition elements: Periodic trends in general properties of transition and inner transition elements, Comparison of properties of first transition series elements with those of second and third transition series elements, Lanthanide contraction, Spectral and magnetic properties, Applications of lanthanide and actinide compounds in industries, Inner transition elements: Spectral and magnetic properties, redox chemistry, analytical applications, Coordination Chemistry: Introduction to coordination chemistry, bonding theories of transition metal complexes, MOT of complexes with and without π-bonding, MO diagrams for octahedral, square planar and tetrahedral complexes.

UNIT 4: Magnetic Properties of Transition Metal Complexes

Brief review of different types of magnetic behaviors; Measurement of magnetic susceptibility; Spin-orbit coupling, Quenching of orbital angular momenta, Temperature-independent paramagnetism.

Application of Crystal Field Theory to explain magnetic properties of coordination compounds. Spin crossover, Structural effects: ionic radii and Jahn-Teller effect; octahedral vs. tetrahedral coordination.

Recommended Books

1. B. R. Puri, L. R. Sharma, and K. C. Kalia, *Principles of Inorganic Chemistry*, Milestone.
2. J. E. Huheey, E. A. Keiter, R. L. Keiter & O. K. Medhi. *Principles of Structure and Reactivity*, Pearson Education.
3. F. A. Cotton and G. Wilkinson, *Advanced Inorganic Chemistry*, John Wiley.

4. W. U. Malik, G. D. Tuli, & R. D. Madan, *Selected Topics in Inorganic Chemistry*, S. Chand & Company Ltd.
5. P. Atkins, T. Overton, J. Rourke, M. Weller & F. Armstrong. *Shriver and Atkins Inorganic Chemistry*, Oxford University Press.
6. N. N. Greenwood & A. Earnshaw. *Chemistry of the Elements*, Pergamon Press.
7. F. Basolo& R. G. Pearson, *Mechanism of Inorganic Reactions*, Wiley Eastern.
8. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann. *Advanced Inorganic Chemistry*, John Wiley.
9. S. F. A. Kettle, *Physical Inorganic Chemistry*, Spectrum.
10. B. Douglas, D. McDaniel and J. Alexander. *Concepts and Models of Inorganic Chemistry*, John Wiley & Sons.

CHEM-422: ADVANCED HETEROCYCLIC CHEMISTRY

Total Marks: 100 **Credits: 4**

UNIT 1: (a) Introduction to heterocycles: Hantzsch-Widman Nomenclature; monocyclic, fused and bridged heterocycles; Aliphatic and aromatic heterocycles; Basicity and aromaticity of heterocycles.
(b) Small Ring Heterocycles: Syntheses of aziranes, oxiranes & thiiranes; Ring openings and heteroatom extrusion; Synthesis & reactions of azetidines, oxetanes & thietanes; Strain.

UNIT 2: Five-membered heterocycles with two heteroatoms: Structural and chemical properties; Synthesis of pyrazole, isothiazole and isoxazole; Synthesis of imidazoles, thiazoles & oxazoles; Nucleophilic and electrophilic substitutions; Ring cleavages; Benzofused analogues.

UNIT 3: (a) Six-membered heterocycles with two heteroatoms: Structural & chemical properties; Synthesis of pyridazines, pyrimidines, pyrazines; Nucleophilic and electrophilic substitutions.
(b) Bicyclic Heterocycles: Synthesis of quinolines, isoquinolines, benzofuseddiazines, acridines, phenothiazines, carbazoles and pteridines; Substitution reactions.

UNIT 4: (a) Condensed Five-membered Rings (1 Heteroatom): Synthesis of indole, benzofuran and benzothiophene; Nucleophilic, electrophilic and radical substitutions; Addition reactions; Indole rings in biology.
(b) Seven-membered Rings: Synthesis & reactions of azepines, oxepines, thiepines & diazepines.

Recommended Books:

1. L. A. Paquette. *Modern Heterocyclic Chemistry*, W. A. Benjamin.
2. I. L. Finar. *Organic Chemistry*, Vol. II, ELBS.
3. J. A. Joule, K. Mills, *Heterocyclic Chemistry*, John Wiley & Sons.
4. Thomas L. Gilchrist, *Heterocyclic Chemistry, Longman Ltd.*
5. Theophil Eicher, S. Hauptmann, *The chemistry of Heterocyclic Chemistry,* Wiley-VCH.
5. Katritzky, A. R., Ramsden, C. A., Joule, J. A., and V. V. Zhdankin, *Handbook of Heterocyclic Chemistry*, Pergamon Press.
6. A. R. Katritzky & C. W. Rees. *Comprehensive Heterocyclic Chemistry*, Vols. 1-7, Pergamon Press.
7. J. Alvarez-Builla, J. J. Vaquero (Editor), J. Barluenga, *Modern Heterocyclic Chemistry,* Wiley-VCH.
8. *Gupta*, Radha R., *Kumar*, Mahendra, *Gupta*, Vandana Heterocyclic Chemistry, Vol;1,2 and 3, *Springer*

CHEM-423: QUANTUM CHEMISTRY AND STATISTICAL THERMODYNAMICS

Total Marks: 100 **Credits: 4**

UNIT 1: General Principles of Thermodynamics, Mechanics, and Application to Model Systems

Introduction, operators and related theorems, uncertainty principle, postulates, properties of wave functions, Schrodinger equation, energy eigenvalue equation, equation of motion and constant of motion, Exactly solvable problems: Particle in a box, harmonic oscillator, rigid rotator, step potential and tunnelling, hydrogen atom.

UNIT 2: Theory of Angular Momentum

Angular momentum vectors, commutation relations, Chemical bonding in diatomics, elementary concepts of MO and VB theories, Huckel theory of conjugated systems, bond order and charge density calculations, Applications to ethylene, allyl system and butadiene.

UNIT 3: Statistical Thermodynamics: Theory and Applications

Different types of ensembles, ensemble averaging, thermodynamics of ensemble averaging, Distribution law (Boltzmann statistics), partition function and thermodynamic parameters, relation between molecular and molar partition functions, translational partition functions, rotational partition function for linear and non-linear molecules, vibrational partition function, electronic partition function, reference state of zero energy for evaluating partition function, equilibrium constant in terms of partition function.

UNIT 4: Applications of Statistical Thermodynamics

Equipartition theorem, heat capacity behaviour of crystals, Introduction to quantum statistics, Distribution law for fermions (Fermi-Dirac statistics) and for bosons (Bose-Einstein statistics), and its applications, Statistical mechanics of imperfect gases, derivation of the virial equation of state of one component gas, significance of virial coefficients, evaluation of second virial coefficient.

Books Suggested:

1. D.A. McQuarrie – Quantum Chemistry, Oxford University Press.
2. I. Levine – Quantum Chemistry, Tata McGraw-Hill.
4. R. Mc-Weeny – Coulson's Valence, ELBS.
5. J.N. Murrell, S.F.A. Kettle, J.M. Tedder, Valence Theory, ELBS.
6. D. A. McQuarrie and J.D. Simon –Physical Chemistry, VIVA Students Ed.
7. A.K. Chandra – Introductory Quantum Chemistry, Tata McGraw-Hill.
8. D. A. McQuarrie. *Statistical Mechanics*, Viva Books Pvt. Ltd., New Delhi.
9. T.L. Hill – An introduction to statistical thermodynamics, Dover Publications Inc., New York.
10. M.C. Gupta – Statistical Thermodynamics, Wiley Eastern.

(CHOICE BASED CREDIT PAPERS)

CHEM-424 (A): BIOLOGICAL AND MEDICINAL CHEMISTRY

Total Marks: 100 **Credits: 4**

UNIT 1:
Essential and trace elements in biological systems, structure and functions of biological membranes, mechanism of ion transport across membranes, ionophores, valinomycin and crown ether complexes of Na^+ and K^+, ATP and ADP, Photosynthesis: chlorophyll a, PS-I and PS-II and biological classification.

UNIT 2:
Iron-sulphur proteins: Rubredoxin and Ferredoxins: Metalloporphyrins, Heme proteins: Hemoglobin, Myoglobin and Cytochrome c; Non –Heme proteins: Hemerythrin, Ferritin and Hemocyanin, Nitrogen fixation and nitrogenases

UNIT 3:
Literature of Organic medicinal compounds, factors influencing the metabolism and metabolic changes in drugs, Relationship of chemical structure and biological activity and receptor theory.
Introduction and synthesis of Antibiotics, Antiviral, Anti-inflammatory, Anti-cancer, and Hypoglycemic agents.

UNIT 4:
Introduction and Synthesis of Central nervous system depressants, Anesthetics, stimulants and anti-anxiety drugs, sedative and hypnotics, tranquilizer anticonvulsants, psychomotor stimulants and hallucinogens.

Books:

1. A.L. Lehninger, Biochemistry, Kalyani Publishers, 1983.
1. I.L. Finar – Organic chemistry, Vol. II, Addison Wesley, 2001
2. Lubert Stryer, Biochemistry, Freeman, 1995.
3. G. Patrick, Medicinal Chemistry
4. Ashutosh Kar, Medicinal Chemistry, New Age publications

CHOICE BASED CREDIT PAPERS

CHEM-424 (B): GREEN AND SUSTAINABLE CHEMISTRY

Total Marks: 100 **Credits: 4**

UNIT 1: Spectroscopic and Radioanalytical Techniques

Neutron Activation Analysis (NAA) principles, instrumentation and applications, X-ray fluorescence spectroscopy (XRF) principles, instrumentation and applications, Atomic absorption spectroscopy (AAS) principles, instrumentation and applications, Radioactive dating techniques: Carbon 14 and fission tract dating methods.

UNIT 2: Surface and Electrochemical Techniques

Surface characterization techniques: Scanning electron microscopy (SEM), Tunneling electron microscopy (TEM), Atomic force microscopy (AFM), Principles, Instrumentation and its applications.
Electrochemical techniques: Electrochemical Impedance Spectroscopy (EIS) Principles, Instrumentation and its applications; Potentiodynamic Polarization (PDP) Principles, Instrumentation and its applications.

UNIT 3: Chemistry of Renewable Energy

Introduction to renewable energy systems. Fuel cells: Basic principle, types of fuel cells, and materials. Solar photovoltaic cells: Basic principle, materials. Batteries: Basic principle, types of batteries, and materials. Supercapacitors: Basic principle, types of supercapacitors, and materials.

UNIT 4: Green Chemistry

Green Chemistry Effects of chemistry on the environment; Emergence of green chemistry; Principles of Green Chemistry: Concept of atom economy, Waste prevention instead of waste clean-up, design of environmentally friendly synthetic methodologies, design of safer chemicals, Designing a Clean Synthesis; Green Chemistry Awareness Initiatives.

Recommended Books:

1. A.K. De, *Environmental Chemistry,* New Age International Ltd.
2. S. E. Manahan, *Environmental Chemistry,* Lewis Publishers, London
3. J. W. Moore & E. A. Moore, *Environmental Chemistry*, Academic Press, London.
4. I. Pulford & H. Flowers, *Environmental Chemistry at a Glance*, Blackwell Publishing.
5. Radon handbook published by BARC, 2013
6. Green Chemistry- Theory and Practice, Paul Anastas and J.C. Warner, OUP, 1998.
7. New Trends in Green Chemistry, V.K. Ahluwalia and M. Kidwai, Anamaya Publishers, New Delhi, 2004.
8 Aspects of Green Chemistry, Upasana Bora Sinha, M.R. Publications, 2014.

CHOICE BASED CREDIT PAPERS

CHEM-424 (C): POLYMER AND NANOCHEMISTRY

Total Marks: 100 **Credits: 4**

UNIT 1: Basics and Polymer Characterization: Importance of polymers. Basic concepts: Monomers, repeat units, degree of polymerization, Linear, branched and network polymers. Classification of polymers. Polymerization: condensation, addition, radical chain-ionic and co-ordination and co-polymerization. Polydispersion-average molecular weight concept. Number, weight and viscosity average molecular weights. Polydispersity and molecular weight distribution. The practical significance of molecular weight. Measurement of molecular weights. viscosity, light scattering, osmotic methods.

UNIT 2: a) Structure and Properties: Morphology and order in crystalline polymers-configurations of polymer chains. Crystal structures of polymers. Polymer structure and physical properties-crystalline melting point Tm. The glass transition temperature, Tg – Relationship between T_m and Tg, effects of molecular weight, chemical structure, chain topology, branching and cross linking. **b) Biomedical polymers:** Contact lens, dental polymers, artificial heart, kidney, skin and blood cells

UNIT 3:

a) Polymer Degradation: Types of Degradation, Thermal Degradation, Mechanical Degradation, Degradation by Ultrasonic Waves, Degradation by High-Energy Radiation.

b) Commercial Polymer: polyethylene, PVC, polyamides, polyester, phenolic resin, epoxy resin and silicone polymers, Functional polymers-fire retarding polymers and electrical conducting polymers.

UNIT 4: Nanomaterials

a) Introduction to nanomaterials and their characteristic differences over bulk materials: Novel method to harvest ultraviolet and infra-red photons, challenges in Nano chemistry and nano materials. Characterization of nanomaterials, Synthesis of mono disperse nanoparticles, synthesis of lanthanides (III) doped nanoparticles, Surface effects on the luminescence of lanthanide (III) doped nanoparticles, synthesis of Ln (III) doped semiconductor nanoparticles.

b) Applications of nanoparticles: Nanomaterials based solar cells, Tandem Solar cells, Nanomedicine: nanoparticle-based Diagnostics and Therapy, Drug deliveries, Photodynamic therapy, Photo chemical therapy, magneto cytolytic therapy, Nanotoxicity and Toxicokinetic studies.

***Recommended Books*:**

1. Textbook of Polymer Science, F.W. Billmeyer Jr, Wiley-Eastern.
2. Polymer Science, V.R. Gowariker, N.V. Viswanathan and J. Sreedhar, Wiley-Eastern.
3. Functional Monomers and Polymers, K. Takemoto, Y. Inaki and RM. Ottanbrite.
4. Contemporary Polymer Chemistry, H.R. Alcock and F.W. Lambe, Prentice Hall.
5. G. Cao, *Nanostructures and Nanomaterials: Synthesis, Properties Applications*, Imperial College Press.
6. C. N. R. Rao, A. Muller, A. K. Cheetham, *Nanomaterial Chemistry: Recent developments and new directions*, Wiley.
7. T. Pradeep, *Nano: The Essentials*, Tata McGraw-Hill, New Delhi.
8. C. N. R. Rao, *Nanomaterials*, Wiley-VCH.

CHEM-425: LABORATORY COURSE IN ORGANIC CHEMISTRY

Total Marks: 100 **Credits: 4**

1. Learning of laboratory equipment and techniques: Glass Apparatus, Assemblies for Reactions, Distillation, Recrystallization, Determination of melting point, Drying Agents, Cleaning of Apparatus.

2. Knowledge of Thin Layer Chromatography (TLC), preparation of TLC plates.

3. Extraction of natural products: any one (solasodine, caffeine, nicotine, piperazine, carotenoids, etc.).

4. Organic preparations: at least four preparations involving the following representative reactions; (a) esterification and saponification; (b) oxidation; (c) hydride reductions or hydrogenation; (d) nucleophilic substitutions; (e) cycloaddition reactions; (f) Grignard reactions; (g) condensation reactions; (h) preparation of dyes; (j) aromatic electrophilic substitution; (j) heterocyclic synthesis. Monitoring of reaction with TLC.

5. Separation and purification of organic compounds from a mixture, using chromatographic techniques, solubility methods, steam distillation, fractional crystallization and sublimation.

6. Introduction to Green Chemistry and learning of some greener reactions which involve solvent-free reactions, oxidation reactions, etc.

Recommended Books:

1. Laboratory manual of organic chemistry, Raj K. Bansal, Wiley-Eastern Ltd.
2. Vogel's Textbook of Practical Organic Chemistry, Longman Group UK Ltd.
3. Greener approaches to Undergraduate Chemistry Experiments, American Chemical Society.
4. Practical Organic Chemistry, F.G. Saunders and B.C. Mann, Orient Longman.
5. Aspects of Green Chemistry, Upasana Bora Sinha, M.R. Publishers.

SEMESTER-III

CHEM-531: ORGANOMETALLIC AND BIOINORGANIC CHEMISTRY

Total Marks: 100 **Credits: 4**

UNIT 1: Transition Metal π-Acid Complexes

Transition Metal π-Acid Complexes: Bonding, synthesis and reactivity of transition metal complexes with CO, NO, O_2, N_2 and tertiary phosphine/arsine ligands; metal carbonyl hydrides and metal carbonyl clusters: LNCC and HNCC.

UNIT 2: Structure and Reactivity of Organometallic Complexes

Synthesis and structure of transition metal complexes with σ-bonded alkyl groups, alkenes, carbenes, cyclic and acyclic polyenyl groups as ligands.
Reactions of σ-organyls: Cleavage, Oxidative addition, Reductive elimination, insertion reactions, Coordinative unsaturation.

UNIT 3: Homogeneous Catalysis

Reactions of coordinated ligand and activation of small molecules by complexation; catalytic reactions of alkenes: isomerization, hydrogenation, hydroformylation, hydrosilylation and polymerization.

UNIT 4: Bioinorganic Chemistry

Photosystems; Porphyrins; Metalloenzymes; Oxygen Transport; Electron-transfer reactions; Nitrogen fixation; Metal Complexes in medicine.

Recommended Books

1. B. R. Puri, L. R. Sharma, and K. C. Kalia, *Principles of Inorganic Chemistry*, Milestone.
2. F. A. Cotton, G. Wilkinson, C. A. Murillo & M. Bochmann, *Advanced Inorganic Chemistry*, John Wiley.
3. J. E. Huheey, E. A. Keiter, R. L. Keiter& O. K. Medhi, *Principles of Structure and Reactivity* (1st impression), Pearson Education.
4. W. U. Malik, G. D. Tuli, & R. D. Madan, *Selected Topics in Inorganic Chemistry*, S. Chand & Company Ltd.
4. F. A. Cotton & G. Wilkinson. *Advanced Inorganic Chemistry*, John Wiley.
5. D. M. P. Mingos & D. J. Wales. *Introduction to Cluster Chemistry*, Prentice Hall.
6. T. P. Fehlner, J. F. Halet& J-Y. Saillard, *Molecular Clusters: A Bridge to Solid-state Chemistry*, Cambridge University Press.
7. F. Mathey& A. Sevin. *Molecular Chemistry of the Transition Elements*, John Wiley.
8. P. Atkins, T. Overton, J. Rourke, M. Weller & F. Armstrong. *Shriver and Atkins Inorganic Chemistry*, Oxford University Press.
9. T. Moeller. *Inorganic Chemistry: A Modern Approach*, John Wiley.
10. R. S. Drago. *Physical Methods in Chemistry*, Saunders College Publishers.
11. C. Cutal & A.W. Adamson, *Comprehensive Coordination Chemistry*, Vol. 1, Editor-in-Chief G. Wilkinson.

CHEM-532: ORGANIC SPECTROSCOPY

Total Marks: 100 **Credits: 4**

UNIT 1: Infrared Spectroscopy
Characteristic vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols, amines; Detailed study of vibrational frequencies of carbonyl compounds (ketones, aldehydes, esters, amides, acid anydrides, lactones, lactams, conjugated carbonyl compounds); Effects of H-bonding and solvent effect on vibrational frequency, extension to various organic molecules for structural assignment.

UNIT 2: Mass Spectroscopy
Mass spectral fragmentation of organic compounds, common functional groups; molecular peak, McLafferty rearrangements, examples of mass spectral fragmentation of organic compounds with respect to their structure determination.

UNIT 3: ^{1}H-Nuclear Magnetic Resonance Spectroscopy
The measurement of spectra: chemical shift, the intensity of NMR signals (integration), spin-spin coupling. Approximate chemical shift values of various chemically non-equivalent protons bonded to carbon (aliphatic, olefinic, aldehydic and aromatic); Protons bonded to other nuclei (alcohols, phenols, enols, carboxylic acids, amines, amides); Chemical exchange (deuteration); Simplification of complex spectra using shift reagents, Nuclear Overhauser effect (NOE).

UNIT 4: ^{13}C- Nuclear Magnetic Resonance Spectroscopy
Introduction and important points of ^{13}C-NMR spectroscopy, 13C-NMR Chemical shifts values, and spectra for various organic compounds (aliphatic, olefinic, alkynes, aromatic, hetero-aromatic, carbonyl carbon, etc.).

Applications of IR, NMR and Mass spectroscopy for structure elucidation of organic compounds.

Recommended Books

1. R. M. Silverstein, G. C. Basseler & T. C. Morill. *Spectroscopic Identification of Organic Compounds*, John Wiley.
2. W. Kemp. *Organic Spectroscopy*, McMillan Press Ltd.
3. D. Williams & I. Fleming. *Spectroscopic Methods in Organic Chemistry*, McGraw Hill.
4. C. N. Banwell & E. M. McCash. *Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill, New Delhi.
5. Jag Mohan, *Organic Spectroscopy: Principles and Applications*, Narosa Publishing House, New Delhi.
6. Y. R. Sharma, *Elementary Organic Spectroscopy,* S. Chand Publishing, 2007.

CHEM-533: ADVANCED PHYSICAL CHEMISTRY

Total Marks: 100 **Credits: 4**

UNIT 1: Solid State Chemistry

Crystal Defects: Types of defects, thermodynamics for Schottky and Frenkel defect formation, Kroger-Vink notation for crystal defects. Solid Solutions: Substitutional, interstitial and subtractional solid solutions & distortions.Metals, insulators and semiconductors; Electronic structure of solids—band theory; intrinsic and extrinsic semiconductors, p-n junction. Superconductors, colour centre.

UNIT 2: Electrochemistry

Ion-Ion interactions-Debye Huckel theory of ion-ion interactions, ionic cloud and the chemical potential charge arising from ion-ion interactions, activity co-efficients, and ion-ion interactions, mean ionic activity coefficients, expression for mean ionic activity coefficients in terms of ionic strength, Ion-Solvent interactions: Free energy charge arising from ion-solvent interactions, Born model-Born expression for the free energy of ion-solvent system interactions, enthalpy and entropy of ion-solvent interaction.

UNIT 3: Microwave, Infrared and Raman Spectroscopy

Introduction: Interaction of light with matter, mechanism of absorption & emission of radiation, Microwave and Vibrational Spectroscopy: Classification of molecules, rigid rotor model, Rotational spectra of diatomics and polyatomics, effect of isotopic substitution and non-rigidity, selection rules and intensity distribution, Vibrational spectra of diatomics, effect of anharmonicity, Morse potential, Vibrational-rotational spectra of diatomics, P, Q, R branches, normal modes of vibration, overtones, hot bands, Raman Spectroscopy: Origin, rotational and vibrational Raman spectra of diatomic molecules.

UNIT 4: Electronic Spectroscopy

Electronic spectra of diatomic molecules, Franck-Condon principle, Vibronic transitions, Spectra of organic compounds, π-π^*, n-π^* transition, Photoelectron Spectroscopy, Basic principles, photoelectron spectra of simple molecules, X-ray photoelectron spectroscopy, Auger electron spectroscopy.

Recommended Books:

1. C. N. Banwell and E. M. McCash. *Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill, New Delhi.
2. D. A. McQuarrie and J.D. Simon –Physical Chemistry, VIVA Students Ed.
3. J. D. Graybeat. *Molecular Spectroscopy*, McGraw-Hill International Edition.
4. R. Chang Basic Principles of Spectroscopy, McGraw Hill, Kaga Kusha, New Delhi.
5. G.M. Barrow – Molecular Spectroscopy, McGraw Hill, Tokyo.
6. P.W. Atkins – Physical Chemistry, Oxford Uni. Press.
7. J.O.M. Bockris and A.K.N. Reddy-Modern Electrochemistry, Vol. 1 & 2, Plenum.
8. A.J. Bard, Electrochemical Methods, John Wiley.
9. E. Moore and L. Smart, *Solid state Chemistry: An Introduction*, Chapman & Hall.
10. A. R. West, *Solid State Chemistry and its Applications*, John Wiley.
11. N. B. Hannay, *Solid State Chemistry*, Prentice-Hall.
12. D. K. Chakraborty, *Solid State*, New Age International, New Delhi

CHEM-534: Massive Open Online Courses (MOOCS)

Total Marks: 50 **Credits: 2**

All the students are to register on the Swayam platform and then select an offered course from the NPTEL platform.

CHEM-535: INTERNSHIP

Total Marks: 50 **Credits: 2**

Students should complete an internship for at least 2 to 4 weeks from the 1st to 3rd semester (at any time), but the credit will be added in the 3rd semester only. It would be completed in any industry/ research institute/university/ NGOs/ civil societies to upgrade skills.

CHEM-536: LABORATORY COURSE IN PHYSICAL CHEMISTRY

Total Marks: 100 **Credits: 4**

Electrochemistry

1. To determine the strength of the given acid conductometrically using standard alkali solution.
2. To determine the solubility and solubility product of a sparingly soluble electrolyte conductometrically.
3. To study the saponification of ethyl acetate conductometrically.
4. To determine the ionization constant of a weak acid conductometrically.
5. To determine the rate of corrosion for steel in an acid solution.

Distribution Law

5. To study the distribution of iodine between water and CCl_4.
6. To study the distribution of benzoic acid between benzene and water.

Phase Equilibrium

7. To construct the phase diagram of two components (e.g. diphenylamine-benzophenone) system by cooling curve method.
8. To construct the phase diagram of three components (water, chloroform and benzene)

Chemical Kinetics

9. To determine the specific reaction of the hydrolysis of methyl acetate/ethyl acetate catalyzed by hydrogen ions at room temperature and determination of the energy of activation.
10. To study the effect of acid strength on the hydrolysis of an ester.
11. To compare the strengths of HCL and H_2SO_4 by studying the Kinetics of hydrolysis of ethyl acetate.
12. To study kinetically the reaction rate of decomposition of iodide by H_2O_2.
13. Determination of the order of reaction between potassium bromate and potassium iodide.
14. Study of the reaction between acetone and iodine in the presence of acid.

Refractometry, Polarimetry

15. To verify law of refraction of mixtures (e.g. of glycerol and water) using Abbe refractometer.
16. To determine the specific rotation of a given optically active compound.

Colorimetry

17. To verify Beer- Lambert law for $KMnO_4/K_2Cr_2O_7$ and determine the concentrations of the given solution of the substance.

Adsorption

18. Adsorption behaviour studies of dye and other adsorbate

Surface Chemistry

19. Determination of CMC for some ionic surfactant

Recommended Books:

1. J.N. Gurtu and R. Kapoor, Advanced Experimental Chemistry (Physical), S. Chand &Co.
2. J.C. Ghosh, Experiments in Physical Chemistry, Bharati Bhavan.
3. A. Findlay's Practical Physical Chemistry (Revised By B.P. Levitt), Longman.

SEMESTER-IV

CHEM-541: PROJECT WORK

Total Marks: 500 **Credits: 20**

For Course 541, students will be offered an advanced Laboratory Course (Project) which will be based on Research oriented Laboratory Course. Each Student will be attached to different teachers depending on the specialization.