New Course Structure- **To be effective from academic session 2018-2019**
Based on **CBCS** System & **OBE** Model

For

M. Sc. Programme in Chemistry

DEPARTMENT OF CHEMISTRY
BIRLA INSTITUTE OF TECHNOLOGY
MESRA, RANCHI - 835215

98A, Academic Council, 2nd May, 2018

CBCS Based Course structure and Syllabus for M.Sc. Programme in Chemistry

Important notes:

- The basic criteria of UGC have been followed in preparing the course structure of this programme.

Department Vision

To become a recognized centre of excellence for teaching and research in Chemical Sciences through producing excellent academicians, professionals, entrepreneur and innovators

Department Mission

Inoculate fundamental concepts of Chemical Sciences to students & scholars through our state of art laboratory, teaching and research facilities, Building a scientific environment and motivation towards innovation with quality research in chemical sciences and allied areas.

Program Educational Objectives of M.Sc. Programme in Chemistry

1. To impart high quality education and research to develop future academicians, scientists and technocrats.
2. To develop a vibrant and motivational work environment by availability of high end research exposure at PG and research levels.
3. To instill values like work commitment, honesty, integrity, empathy as fundamental basis for serving humanity through chemical education and research.

Program Outcomes of M.Sc. Programme in Chemistry

1. The students will be trained personnel resource in Chemical Sciences who will get through national and international level tests and be an asset to the nation.
2. They will have knowledge of basic fundamentals of chemical sciences and allied areas and will be able to compete national level tests such as UGC-CSIR NET, GATE, etc., successfully.
3. They will have an exposure to high end modern facilities used in research at par with global standards.
4. They will implement their educational and research skills with basic human values, integrity, empathy and ultimate objective of serving humanity.

The contents of laboratory papers are designed to meet the course objectives and outcomes of their respective theory papers.

COURSE INFORMATION SHEET

Course code: CH 401
Course title: Inorganic Chemistry-V: Basic Inorganic Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. I/ I. M. Sc. VII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To know about the chemical bonding quantum mechanically
B.	To understand the reaction mechanism of coordination complexes
C.	To understand the principle of electronic spectroscopy
D.	To study the experimental spectrum

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain the chemical bonding by quantum mechanics
2.	Able to explain the kinetics in coordination complexes
3.	Able to explain the principle of electronic absorption
4.	Able to interpret the experimental spectrum

Syllabus

Module I:Chemical Bonding: Valency Theories- Quantum Chemical Approach (9 Lectures)
Huckel approximation applied to H_2^+ and H_2 type systems, comparative study of the application of VB and MO methods to diatomic (homo and hetero) species; MO of polyatomic molecules; Walsh diagram, configuration interaction, orbital construction for Hn type systems, localized and delocalized M.O., σ, π, δ bonds, polyatomic molecules, electron deficient and hypervalent molecules.

Module II:Quantitative basis of Crystal Fields (9 Lectures)
Crystal Field Theory, The octahedral Crystal Field potential, The effect of V_{oct} on the *d* wave-functions, the evaluation of Δ, The tetrahedral and cubic potentials. Energy level of transition metal ions, Effect of ligands fields on the energy levels of trasition metal ions.

Module III:Reaction Mechanism of Transition Metal Complexes (9 Lectures)
Energy profile of a reaction, reactivity of metal complexes, inert and labile complexes, kinetic application of valency bond and crystal field theory, kinetics of octahedral substitution, acid hydrolysis, factors affecting acid hydrolysis, base hydrolysis, substitution reaction in square complexes, trans effect, redox reactions, electron transfer reactions, mechanism of one electron transfer reaction, outer sphere type reactions, inner sphere type reactions.

Module IV:Introduction to electronic Spectra of transition metal complexes (9 Lectures)
Important features of transition metal electronic spectra- band intensities, band energies, band width and sets; characteristic spectra of complexes of fast row transition metal ions, Octahedral, tetrahedral and square planar complexes of first row transition metal ions; Effect of temperature on electronic bands, Spectrochemical & Nephelauxetic series.

Module V:Theoretical basis of Electronic Spectra of transition metal complexes (9 Lectures)
Spectroscopic ground state, Orgel and Tanabe–Sugano diagrams for transition metal complexes, calculations of D_q, B and beta parameters, Charge transfer spectra: Intraligand charge transfer spectra, Metal to ligand charge transfer spectra, Ligand to metal charge transfer spectra Absorption spectra of *f*-block elements.

Text books:

1. G. Wulfsberg, Inorganic Chemistry, University Science Books, 2000.
2. C. J. Ballhausen & H. B. Gray, Molecular Orbital Theory, W.A. Benjamin, 1978.
3. F. Basolo & R. G. Pearson, Inorganic Reaction Mechanism, 2nd ed., John Wiley & Sons Inc., 1967.
4. A. B. P. Lever, Inorganic Electronic Spectroscopy, Elsvier, 1984.

Reference books:

1. B. N. Figgis and M. A. Hitchman, Ligand Field Theory and its Applications, Wiley–VCH, New York, 2000.
2. I. B. Bersuker, Electronic Structure and Properties of transition metal compounds, 2nd ed., Wiley, 2010.
3. C. J. Ballhausen, Introduction to Ligand Field Theory, McGraw-Hill Inc., 1962.
4. R. B. Jordon, Reaction Mechanisms of Inorganic and Organometallic Systems, 3rd ed., Oxford Unversity Press, 2007.
5. D. N. Sathyanarayana, Electronic Absorption Spectroscopy, Universities Press, 2001.
6. E. A. B. Ebsworth, D. W. H. Rankin, S. Cardock, Structural Methods in Inorganic Chemistry; 2nd ed., Wiley-Blackwell, 1991.
7. A. K. Das, M. Das, Fundamental Concepts of Inorganic Chemistry; Volume-1-5; CBS Publishers, 2012.
8. R Sarkar, General and Inorganic Chemistry- Volume-I and Volume-II, 3rd revised ed., New Central Book Agency, 2011.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√		
Quiz –I	√			
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	M	H	L	L
CO2	H	M	M	L
CO3	H	H	H	M
CO4	M	H	H	M

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L09	**1**	Chemical Bonding: Valency Theories-Quantum Chemical Approach	**T1, T2, R1**	**1**	**PPT Digi Class/Chock -Board**
4-6	L10-L18	**2**	Quantitative basis of Crystal Field Theory	**T2, R2**	**2**	**-do-**
7-9	L19-L27	**3**	Reaction mechanism of Transition metal complexes	**T1, R1**	**3**	**-do-**
10-12	L28-L36	**4**	Introduction to Electronic spectra	**T1, R4**	**3**	**-do-**
13-15	L37-L45	**5**	Theory-electronic spectra	**T1, R3**	**4**	**-do-**

Course code: CH 402
Course title: Physical Chemistry-VI: Chemical Kinetics & Surface Chemistry
Pre-requisite(s): B.Sc. (H) Chemistry
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. I/ I. M. Sc. VII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To apply the knowledge of chemical kinetics for very fast reactions, photophysical, photochemical and surface processes.
B.	To apply theories and concept of electrochemistry to study electrode kinetics.
C.	To develop concepts on photophysical and photochemical processes.

Course Outcomes

After the completion of this course, students will be:

1.	Able to solveproblems on rate/rate constants/efficiency for complex reactions and electronically excited state dynamics.
2.	Able to understand the mechanism of chemical reactions for optimizing the experimental conditions and apply homogeneous and heterogeneous catalysis in chemical synthesis.
3.	Able to calculateelectrochemical cell parameters, current and overpotential under given condition, amount of corrosion and its rate and plotpotential vs current, surface coverage vs. potential, potential vs. pH, concentration profile vs. distance from the electrode.
4.	Able to explain the mechanism of fluorescence and phosphorescence.
5.	Able to understand the importance of adsorption process and its application.
6.	Able to develop the concept of colloidal material and their stability for many practical uses.

Syllabus

Module I: Chemical Reaction Dynamics (10 lectures)

Introduction to reaction kinetics; Temperature dependence of reaction rate: Linear and non-linear Arrhenius equation, Interpretation of Arrhenius parameters; Theories of reaction rates: Collision theory and Activated complex theory (ACT) thermodynamic treatment of bimolecular gaseous reactions (Eyring equation). Theories of unimolecular gaseous reactions: Lindemann-Hinshelwood, RRK and RRKM theories. Kinetics of reactions in solution. Kinetics of fast reactions: Relaxation method, Flow methods, Pulse methods, flash photolysis. Molecular reaction dynamics, potential energy surfaces. Electron transfer reactions. Heterogeneous catalysis: Kinetics of surface reactions unimolecular and bimolecular. Autocatalysis and oscillatory reactions.

Module II: Electrochemistry (10 lectures)

Debye-Hückel theory of ion-ion interaction and activity coefficient, Applicability and limitations of Debye-Hückel limiting law, its modification, Effect of ion-solvent interaction on activity coefficient. Debye-Hückel-Onsagar theory of conductance of electrolyte solution: Its applicability and limitations. Thermodynamic treatment of electrified interfaces, Introduction to electrical double layer, Introduction to electrode kinetics: Butler-Volmer equation, polarography, cyclic voltammetry, corrosion, fuel cells.

Module III: Photochemistry (10 lectures)

Consequences of light absorption; Kinetics of photochemical reactions: H_2-Br_2, H_2-Cl_2& decomposition of HI. The Jablonski diagram. Potential energy diagram, Franck-Condon principle. Photophysical processes: fluorescence emission, triplet states and phosphorescence emission, delayed fluorescence.

Measurement of emission characteristics–fluorescence, phosphorescence, and chemiluminescence. Photophysical kinetics of unimolecular processes. Bimolecular collisions in gases and vapours and the mechanism of fluorescence quenching. Kinetics of collisional quenching: Stern-Volmer equation. Techniques for the study of transient species in photochemical reactions. Actinometry, Lasers in photochemical kinetics.

Module IV: Surface Chemistry: (9 lectures)

Adsorption by solids-Types and applications. Adsorption of gases by solids. Adsorption isotherms: Freundlich and Langmuir adsorption isotherms, BET theory of multilayer adsorption, Types of adsorption isotherms. Adsorption from solution: Gibbs adsorption isotherm. Modern techniques for investigating surfaces.

Module V: Colloidal States: (6 lectures)

Basics of colloidal states,electrical and electrokinetic properties, Micelles: Surface active agents, Classifications, micellization, hydrophobic interaction, CMC, factors affecting the CMC surfaces, counter ion binding, Thermodynamics of micellization-phase separation, solubilization, Micro-emulsion, Reverse micelles

Text books:

1. P. Atkins and J. Paula, Physical Chemistry, 10th ed., Oxford University Press, Oxford, 2014.
2. K. J. Laidler, Chemical Kinetics, 3rd ed., Harper & Row, New York, 1998.
3. J. O'M. Bockris and A. K. N. Reddy, Modern Electrochemistry, Vol. 2, 2nd ed., Plenum Press, New York, 1998.
4. K. K. Rohatgi-Mukherjee, Fundamentals of Photochemistry, New Age International Pvt. Ltd.; 3rd ed., New Delhi, 2014.
5. A. W. Adamson and A. P. Gast, Physical Chemistry of Surfaces, 5th ed., Wiley, 1997.

Reference books:

1. M. R. Wright, An introduction to chemical kinetics, 1st ed., Wiley, 2005.
2. I. N. Levine, Physical Chemistry, 5th ed., 2002.
3. M. J. Pilling and A. P.W, Seakins, Reaction Kinetics, Oxford Science Publication, New York, 1998.
4. J. G. Calvert and J. N. Pitts, Jr., Photochemistry, John Wiley & Sons, New York, 1966.
5. R. P. Wayne, Principles and Applications of Photochemistry, Oxford University Press, Oxford, 1988.
6. J. I. Steinfeld, J. S. Francisco, W. L. Hase, Chemical Kinetics and Dynamics, 2nd ed., Pearson, 1998.
7. M. Satake, S. A. Iqbal, Colloidal & Surface Chemistry, Discovery Publishing Pvt. Ltd, 2003.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Industrial/guest lectures
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	10+10+10
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4	CO5	CO6
Assignment	√	√	√	√		
Quiz –I	√	√				
Quiz II			√	√	√	
End Sem Examination Marks	√	√	√	√	√	√

Indirect Assessment –

1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L
CO5	M	H	M	L
CO6	M	H	M	L

Mapping of Course Outcomes onto Program Outcomes:

Mapping Between COs and Course Delivery (CD) methods			
CD	**Course Delivery methods**	**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4, 5, 6	CD1
CD2	Tutorials/Assignments	CO2, 3, 4, 5, 6	CD1, 2
CD3	Seminars	CO3, 4	CD3
CD4	Mini projects/Projects	CO1, 2, 3, 4, 5	CD4
CD5	Laboratory experiments/teaching aids	CO2, 3	CD5
CD6	Industrial/guest lectures	CO4	CD6, 7
CD7	Self- learning such as use of NPTEL materials and internet	CO1, 2, 3, 4, 5, 6	CD7
CD8	Simulation	CO1 ,2	CD8

Lecture wise Lesson planning Details.

Week No.	**Lect. No.**	**Ch. No.**	**Topics to be covered**	**Text Book / References**	**COs mapped**	**Methodology used**
1-4	**L1-L12**	**1**	Dynamics of Chemical Reactions	**T1, T2, R1**	**1,2**	**PPT Digi Class/Chock -Board**
4-7	**L13-L20**	**2**	Theory of Ion Transport	**T3, R2**	**3**	**-do-**
7-10	**L21-L32**	**3**	Photophysical and Photochemical Processes	**T4, R4**	**4**	**-do-**
11-13	**L33-L41**	**4**	Surface Science and its Applications	**T1, T5, R7**	**5**	**-do-**
14-15	**L42-L45**	**5**	Colloidal States of the matter	**T5, R7**	**6**	**-do-**

Course code: CH 403
Course title: Reaction Mechanisms in Organic Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. I/ I. M. Sc. VII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the physico-chemical factors affecting the course and outcome of an organic reaction
B.	To understand the different types of organic reactions operating on the aliphatic and aromatic systems

Course Outcomes

After the completion of this course, students will be:

1.	To learn the various concepts of acids and bases, stereoelectronic effects, reactive intermediates and types of organic chemical reactions
2.	To understand the mechanisms of different types of substitution reactions operating on the aliphatic and aromatic systems
3.	To understand the mechanisms of elimination and addition reactions operating on the organic substrates
4.	To apply the influence of stereo-electronic effects on the course of a reaction from unimolecular to bimolecular or intra-molecular suitable for some particular types of substrate
5.	To differentiate the paths followed by aromatic and aliphatic substrates in a nucleophilic substitution reaction
6.	To analyse the conditions favoring the substitution and elimination pathway followed by a particular substrate

Syllabus

Module I: Fundamentals of Reaction Mechanism [9 Lectures]

Acids and bases; nucleophile and electrophile, basicity vs nucleophilicity; Resonance and aromaticity-Huckel's rule for aromaticity in benzenoid and non-benzenoid compounds, antiaromaticity and homo-aromaticity, breaking and formation of bond, electronic effect: inductive, hyperconjugation, mesomerism and steric effect; reactive intermediates: generation, stability and fate of carbocation, carbanion, free radical, carbene and nitrene.

Module II: Aliphatic substitution reactions [12 Lectures]

Nucleophilic substitution: The S_N2, S_N1, mixed S_N1 and S_N2 and SET mechanisms, neighbouring group participation by pi and sigma bonds, anchimeric assistance, The S_Ni mechanism, Nucleophilic substitution at an allylic, aliphatic trigonal and vinylic carbon, Reactivity effects of substrate structure, attacking nucleophile, leaving group and reaction medium; Electrophilic bimolecular mechanism-S_E2 and S_Ei: The S_E1 mechanism, electrophilic substitution accompanied by double bond shift, effect of substrates, leaving group and the solvent polarity on the reactivity.

Module III: Aromatic substitution reactions [6 Lectures]

The arenium ion mechanism, orientation and reactivity, energy profile diagrams, The*ortho*/*para* ratio, ipso attack, Diazonium coupling, Vilsmeir reaction, Gattermann-Koch reaction, The S_NAr, S_N1, benzyne and $S_{RN}1$ mechanisms, Reactivity–effect of substrate structure, leaving group and attacking nucleophile, The Von Richter, Sommelet-Hauser, Smiles Rearrangement.

Module IV: Addition and Elimination Reactions [9 Lectures]

Mechanism and stereochemical aspects of addition reaction in carbon-carbon and carbon-hetero multiple bonds, regio-and chemoselectivity, orientation and reactivity, Mechanism of condensation reactions involving enolates- Aldol, Knoevenagel, Claisen, Perkin and Stobbe reactions.

The E2, E1 and E1cB mechanism and their spectrum, orientation of the double bond, Reactivity- effect of substrates structure, attacking base, the leaving group and the medium, Mechanism and orientation in pyrolytic elimination.

Module V: Rearrangement Reaction [9 Lectures]

General Mechanistic considerations – nature of migration, migratory aptitude, A detailed study of the following rearrangements involving carbonation (Wagner-Meerwein, Pinacol-Pinacolone rearrangement), reaction involving acyl cation, PPA cyclization and Fries rearrangement, rearrangement of carbenes (Wolff & Arndst-Eistert synthesis), rearrangement of nitrenes (Hoffman, Curtius, Schmidt, Lossen, Beckman rearrangement).

Text books:

1. I. L. Finar, Organic Chemistry, Vol. I and II, 5th ed., Longman Ltd., New Delhi, 2011.
2. P. Sykes, A Guide Book to Mechanism in Organic Chemistry, 6th ed., John Wiley & Sons, New York, 1985.
3. T. W. G. Solomons, Fundamentals of Organic Chemistry, 4th ed., John Wiley, 1994.
4. R. N. Morrison & R. N. Boyd, Organic Chemistry, 7th ed., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education), 2010.

Reference books:

1. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, 2nd ed., Oxford Press, 2012,
2. J. March, Organic reaction and mechanism-structure and reactivity, 7th ed., John Wiley, 2015.
3. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, New York, 2006.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4	CO5	CO6
Assignment	√	√	√	√	√	
Quiz –I	√	√	√			
Quiz II				√	√	
End Sem Examination Marks	√	√	√	√	√	√

Indirect Assessment –
1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L
CO5	M	H	M	L
CO6	M	H	M	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4,5,6	CD1
CD2	Tutorials/Assignments	CO1, 2, 3,	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3,5	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4, 5	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	**L1-L9**	**1**	Fundamentals of reaction mechanism	**T1, T2, R1**	**1,2**	**PPT Digi Class/Chock -Board**
4-7	**L10-L21**	**2**	Aliphatic substitution reaction	**T3, R2**	**3**	**-do-**
8-9	**L22-L27**	**3**	Aromatic substitution reaction	**T4, R3**	**4**	**-do-**
10-12	**L28-L36**	**4**	Addition-elimination reactions	**T1, T4, R2**	**5**	**-do-**
13-15	**L37-L45**	**5**	Rearrangement reactions	**T1, R4**	**6**	**-do-**

Course code: CH 404
Course title: Inorganic Chemistry-VI: Organometallic Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. I/ I. M. Sc. VII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To learn the basics of organometallic chemistry
B.	To grow concept of bonding in organometallic compounds
C.	To study the reactivity of organometallic compounds
D.	To know the application of organometallic compounds

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain the basic features of organometallic compounds
2.	Able to explain the bonding in organometallic compounds
3.	Able to predict the reactivity of organometallic compounds
4.	Able to discuss the application of organometallic compounds

Syllabus

Module I: Organometallic Complexes: General properties and types (9 Lectures)

Introduction, Classical and non-classically bonded organometallic compounds, 18 electron rule in Organometallic complexes-Ionic and Covalent Model; Metal Alkyls, Aryls, and Hydrides and Related σ-Bonded Ligands: Transition Metal Alkyls and Aryls, Related σ-Bonded Ligands, Metal Hydride Complexes, σ Complexes, Bond Strengths for Classical σ-Bonding Ligand; Complexes of π-Bound Ligands: Alkene and Alkyne Complexes, Allyl Complexes, Diene Complexes, Cyclopentadienyl Complexes, Arenes and Other Alicyclic Ligands, Metalacycles and Isoelectronic and Isolobal Replacement, Stability of Polyene and Polyenyl Complexes.

Module II: Metal–Ligand Multiple Bonds (9 Lectures)

Carbenes: Fischer Versus Schrock Carbenes - conditions, synthesis examples reactivity and structure, Cases Intermediate Between Fischer and Schrock Carbenes, Boryl Complexes, Vinylidene Carbynes-synthesis, examples and reactivity, structure, Bridging Carbenes and Carbynes, N-Heterocyclic Carbenes-synthesis examples reactivity and structure, Multiple Bonds to Heteroatoms.

Module III: Reactivity of Organometallic Complexes: I (9 Lectures)

Oxidative Addition and Reductive Elimination: Concerted Additions, S_N2 Reactions, Radical Mechanisms, Ionic Mechanisms, Reductive Elimination, σ-Bond Metathesis, Oxidative Coupling and Reductive Cleavage.

Insertion and Elimination: Reactions Involving CO, Insertions Involving Alkenes, Other Insertions, α, β, γ, and δ Elimination.

Module IV: Reactivity of Organometallic Complexes: II (9 Lectures)

Nucleophilic and Electrophilic Addition and Abstraction: Nucleophilic Addition to CO, Nucleophilic Addition to Polyene and Polyenyl Ligands, Nucleophilic Abstraction in Hydrides, Alkyls and Acyls, Electrophilic Addition, Electrophilic Abstraction of Alkyl Groups, Single-Electron Transfer Pathways, Reactions of Organic Free Radicals with Metal Complexes.

Homogeneous Catalysis: Alkene Isomerization, Alkene Hydrogenation, Alkene Hydroformylation, Hydrocyanation of Butadiene, Alkene Hydrosilation and Hydroboration, Coupling Reactions, Surface and Supported Organometallic Catalysis.

Module V: Applications of Organometallic Chemistry (9 Lectures)

Alkene Metathesis- mechanism, Type and commercial application, Dimerization, Oligomerization, and Polymerization of Alkenes- mechanism, Type and commercial application, Activation of CO and CO_2 - mechanism, Type and commercial application, CH Activation- mechanism, Type and commercial application, Organometallic Materials and Polymers.

Text books:

1. R. H. Crabtree, The Organometallic Chemistry of the Transition Metals, Wiley-Interscience; 4th ed., 2005.

Reference books:

1. B- M. Bochmann, Organometallic Chemistry: (Oxford series), 1994.
2. R. C. Mehrotra & A. Singh, Organometallic Chemistry, New Age Int. Publishers, 2nd ed., 1991.
3. M. Gielen, R. Willem, B. Wrackmeyer, Fluxanol Organometallic and Coordination compounds, Wiley, 1st ed., 2008.
4. F. A. Cotton, G. Willkinson, Advanced Inorganic Chemistry,Wiley, 6th ed., 2007.
5. J. E. Huheey, Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education India, 4th ed. 2006.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Quiz –I	√	√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-2	**L1-L10**	**1**	Organometallic Complexes: General properties and types	**T1, R1**	**1**	**PPT Digi Class/Chock -Board**
2-3	**L11-20**	**2**	Metal–Ligand Multiple Bonds	**T1, R2**	**2**	**-do-**
3-4	**L21-28**	**3**	Reactivity of Organometallic Complexes: I	**T1, R3**	**3**	**-do-**
5-6	**L29-35**	**4**	Reactivity of Organometallic Complexes: II	**T1, R4**	**4**	**-do-**
6-9	**L36-45**	**5**	Applications of Organometallic Chemistry	**T1, R5**	**5**	**-do-**

Course code: CH 405
Course title: Principles of Organic Synthesis
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. I/ I. M. Sc. VII
Branch: Chemistry
Name of Teacher:

Course Objectives
This course enables the students:

A.	To understand effect of conformation on chemical reactivity of organic molecule
B.	To correlate stereochemistry with the chemical reaction mechanism
C.	To understand the requirement and principles for organic reaction
D.	To identify the mechanistic approach for chemical (including concerted) reaction

Course Outcomes
After the completion of this course, students will be:

1.	Able to explain effect of conformation on chemical reactivity of organic molecule
2.	Able to define stereochemistry with the chemical reaction mechanism
3.	Able to explain the principles for various types of organic reaction
4.	Able to analyse the mechanism of chemical (including concerted) reaction

Syllabus

Module I: Conformation and Reactivity [9 Lectures]
Conformation of acyclic systems (substituted ethane/n-propane/n-butane), conformation around sp^3-sp^2 and sp^2-sp^2 bond, conformation around carbon hetero atom bond, conformations of cyclic system (cyclopentane, cyclohexane with mono and di substituted cyclohexanes, cycloheptane, cyclooctane and decalins), conformation of cyclohexane with 1/2 sp^2 bond, conformation analysis of heterocycles, the conformations of sugars, anomeric effect and reverse anomeric effect, conformationaly rigid and mobile diastereomer, conformation and reactivity in cyclic system (substitution, addition, elimination, rearrangement etc.).

Module II: Stereochemistry [9 Lectures]
Optical rotatory dispersion (ORD) and circular dichroism (CD), classification of ORD and CD Curves, Cotton effect curves and their application to stereochemical problems; the Octant rule and its application to alicyclic ketones, stereoisomerism, molecular dissymmetry and chirality- elements of symmetry, enantiomerism, diastereomerism, pseudoasymmetric carbon, diastereo isomerism in acyclic and cyclic-systems, interconversion of Fischer, Newman and Sawhorse projections, methods of resolution, optical purity, prochirality, enantiotopic and diastereotopic atoms, groups and faces, optical activity in absence of chiral carbon (biphenyls, allenes and spiranes), chirality due to helical shape, geometrical isomerism in alkenes and oximes, methods of determining the configuration.

Module III: Principles of organic reaction [9 Lectures]
Reagent type and reaction type, Investigation of reaction mechanism (nature of products, kinetic data, use of isotope, study of intermediate, stereochemical criteria.Types of mechanisms, types of reactions, thermodynamic and kinetic requirements, free energy relationships, kinetic and thermodynamic control, Nature of reaction energy, Potential energy diagrams, transition states and intermediates, methods of determing mechanisms, nonkinetic methods of determining reaction mechanism, isotope effects, solvent effect.

Module IV: Principles of reaction mechanism [9 Lectures]

Hammond's postulate, Curtin-Hammett principle, Hammett energy diagrams and reaction rate laws, Hammett's σ_x and ρ values and their physical significance through-conjugation, deviations from straight line plots; steric effects: Taft equation, Softness (Hardness) Scales, HSAB principle, HSAB application for organic reactions: Reaction Selectivity, Alkylation vs. Acylation, C- vs. O-Alkylation, Reactions of Organosulfur Compounds, Reactions of Organophosphorus Compounds, Elimination and Substitution, Addition to Double Bonds, Addition to Carbonyl Compounds.

Module V: Concerted reaction [9 Lectures]

Definition, ionic, radical and concerted reaction, classification, Molecular orbital symmetry, Woodward-Hoffman correlation diagram method and perturbation of molecular (PMO) approach for the explanation of pericyclic reactions under thermal and photochemical conditions, frontier orbitals of ethylene, 1,3 Butadiene, 1,3,5- Hexatriene, allyl system, FMO approach, types of cyclo-additions and cyclo-reversion reactions, electrocyclic reaction and the electroreversion reactions, sigmatropic reactions, group transfer reaction.

Text books:

1. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, 2nd ed., Oxford Press, 2012.
2. I. L. Finar, Organic Chemistry, Vol. I & II, 5th ed., Longman Ltd., New Delhi, 2011.

Reference books:

1. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th ed., John Wiley & Sons, New York, 1985.
2. D. Nasipuri, Stereochemistry of Organic Compounds, 2nd ed., New Age Int., New Delhi, 1994.
3. I. Fleming, Pericyclic Reactions, Oxford Scientific Publication, Cambridge, 1998.
4. E. V. Anslyn and D.A. Dougherty, Modern Physical Organic Chemistry, University Science Books, USA, 2006.
5. L. P. Hammett, Physical Organic Chemistry, 1st ed., McGraw-Hill Book Co. Inc., New York, 1940.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Quiz –I	√	√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L09	**1**	Conformation and reactivity	**T1, T2, R1**	**1**	**PPT Digi Class/Chock -Board**
4-6	L10-L18	**2**	Stereochemistry	**T2, R2**	**2**	**-do-**
7-8	L19-L27	**3**	Principles of organic reactions	**T1, R1**	**3**	**-do-**
9-12	L28-L36	**4**	Principles of reaction mechanism	**T1, R4**	**3**	**-do-**
13-15	L37-L45	**5**	Concerted reaction	**T1, R3**	**4**	**-do-**

Course code: CH 406
Course title: Physical Chemistry-VI Lab
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week: 04
Class: M. Sc. and I. M.Sc.
Semester / Level: M. Sc. I/ I. M. Sc. VII
Branch: Chemistry
Name of Teacher:

Syllabus

Adsorption: (any two)
(i) To study surface tension-concentration relationship for solutions.
(ii) To study the adsorption of iodine from alcoholic solution of charcoal.
(iii) To study the adsorption of acetic acid on charcoal.

Chemical equilibrium: (any one)
(i) To determine congruent composition & temperature of a binary system- Phenol-water.
(ii) To determine glass transition temperature of a given salt conductometrically.
(iii) To construct the phase diagram for a three component systems.
(iv) To determine the equilibrium constant for the reaction $KI + I_2 = KI_3$.

Chemical Kinetics: (any two)
(i) To determine rate constant of saponification ethyl acetate by NaOH.
(ii) To determine the velocity constant of hydrolysis of an ester in micellar media.
(iii) To determine the rate constant for the oxidation of iodide ion by hydrogen peroxide, studying the kinetics as an iodine clock reaction.

Conductometry: (any two)
(i) To determine velocity constant, order of reaction and energy of activation for saponification of ethyl acetate by NaOH conductometrically.
(ii) To determine solubility and solubility product of sparingly soluble salt conductometrically.
(iii) To determine the strength of strong and weak acids in a given mixture conductometrically.
(iv) To determine activity co-efficient of zinc ions in the solution of 0.002 M $ZnSO_4$ using Debye-Huckel's limiting law.

Potentiometry-pH metry: (any one)
(i) To determine the strengths of halides in a mixture potentiometrically.
(ii) To determine the valancy of mercurous ions potentiometrically.
(iii) To determine the strength of strong and weak acids in a given mixture using a potentiometer-pH meter.
(iv) To determine the temperature dependence of E.M.F. of a cell.
(v) Acid-base titration in a non-aqueous media using a pH meter.
(vi) To determine the transport number by Hittrof's method.

Cyclic voltametry:
(i) To find the redox potential of the given sample using cyclic voltametry.

Polarography: (one one)
(i) To determine DO in aqueous solution of organic solvent
(ii) To determine half way potential of Cd & Zn EMF:
(iii) To determine single electrode potential of Cu/Cu^{2+}
(iv) Potentiometric titration of a redox system.
(v) To determine E.M.F. of concentration cell.

Polarimetry: (any one)
(i) To determine rate constant for hydrolysis/inversion of sugar using a Polarimeter.
(ii) Enzyme kinetics-inversion of sucrose.

Spectroscopy:(any one)

(i) To determine pK_a of an indicator in aqueous and micellar medium.

(ii) To determine stoichiometry and stability constant of inorganic (ferric-salicylic acid) and organic (amine-iodine) complexes.

Thermochemistry: (any one)

(i) To determine the enthalpy of neutralization of hydrochloric acid with NaOH

(ii) Enthalpy of combustion of benzoic acid using DSC.

Text books:

1. J. B. Yadav, Advanced Practical Physical Chemistry, 22nd ed., Goel Publishing House, Krishna Prakashan Media, 2014.
2. B. Viswanathan and P. S. Raghavan, Practical Physical Chemistry, Viva Books, 2012.

Reference books:

1. B. P. Levitt, Findlay's Practical Physical Chemistry, 9th ed., Longman, London, 1985.
2. A. M. Halpern and G. C. McBane, Experimental Physical Chemistry: A Laboratory Text Book, 3rd ed., W. H. Freeman, 2006.
3. A. M. James and F. E. Prichard, Practical Physical Chemistry, Prentice Hall Press, 1974.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Course code: CH 407
Course title: Organic Chemistry-VI Lab
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week: 04
Class: I. M. Sc. and M.Sc.
Semester / Level: M. Sc. I/ I. M. Sc. VII
Branch: Chemistry
Name of Teacher:

Syllabus

1. Identification of functional groups through qualitative analysis in a given binary mixture of organic compounds.
2. Isolation of the organic compounds from above mentioned binary mixture through solvent extraction and verifying their complete separation through thin layer chromatography.
3. Identification of the isolated organic compounds through derivative preparation and characterization by FTIR, UV-VIS & NMR.
4. Electrophilic aromatic substitution: acylation of bromobenzene and checking thin layer chromatography to check the reaction outcome (product distribution and extent of reaction).

Reference Books:

1. A. I. Vogel, Quantitative Organic Analysis, Part 3, Pearson, 2012.
2. F. G. Mann, & B. C. Saunders, Practical Organic Chemistry, Pearson Education, 2009.
3. B.S. Furniss, A. J. Hannaford, P.W.G. Smith, A. R. Tatchell, Practical Organic Chemistry, 5th Ed., Pearson, 2012.
4. V.K. Ahluwalia, & R. Aggarwal, Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press, 2000.
5. V. K. Ahluwalia, & S. Dhingra, Comprehensive Practical Organic Chemistry: Qualitative Analysis, University Press, 2000.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Course code: CH 408
Course title: Inorganic Chemistry-VII: Advanced Inorganic Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. II/ I. M. Sc. VIII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the general properties of magnetic bodies
B.	To study the effect of thermal energy on magnetism
C.	To understand the anomalous magnetic moments
D.	To study about the inorganic rings, chains and clusters

Course Outcomes

After the completion of this course, students will be:

1.	Able to classify the magnetic bodies
2.	Able to explain the effect of temperature on magnetic properties
3.	Able to interpret the anomalous magnetic properties
4.	Able to explain several types of inorganic rings, chains and clusters

Syllabus

Module I: Magnetic properties of coordination Complexes (9 Lectures)
Definition of magnetic properties, Types of magnetic bodies, Experimental arrangements for the determination of magnetic susceptibility: Guoy method, Faraday method, Vibrating sample magnetometer, SQUID, NMR method; Diamagnetism in atoms and polynuclear systems, Pascals constant, Two sources of paramagnetism.

Module II:Thermal energy and magnetic properties (10 Lectures)
Spin & Orbital effects, Spin orbit coupling, Lande interval rule, Energies of J levels, Multiplet width and temperature; Curie equation, Curie & Curie–Weiss law, 2nd order Zeeman Effect, Temperature independent paramagnetism, Van Vleck susceptibility equation, Thermal Equillibrium between High Spin and Low spin state in Spin Cross over region, Magnetic behavior of lanthanides & actinides, Anomalous magnetic moments, magnetic properties of binuclear and polynuclear complexes—ferromagnetism and anti-ferromagnetism.

Module III: Anamolous Magnetic Moments in Coordination Complexes (9 Lectures)
Superexchange interaction in terms of Goodenough-Kanamori-Anderson Rules (GKA Rules), Interpretation of magnetic exchange by GKA Rule in terms of Molecular Orbital Theory, Antiferromagnetism in magnetically concentrated system, Cooperative magnetic interactions in binuclear Cu(II) complexes, Antiferromagnetic coupling in other metal complexes: Dimers of oxidovanadium(IV) and oxidomolybdenum(V) complexes, Dinuclear complexes of Ti(III), Dimeric Cr(II) acetate-monohydrate, $Mn_2(CO)_{10}$

Module IV: Inorganic Rings and Cages (8 Lectures)
Rings: Homocyclic rings of S, Se and Te. Heterocyclic rings of S, N, P and O; Cages: Higher boron hydrides: structures and reactions, equation of balance, Lipscomb topological diagrams, polyhedral skeletal electron pair theory (PSEPT), carboranes, metalloboranes and heteroboranes, metallocarboranes.

Module V: Inorganic Cluster (9 Lectures)

Clusters in elemental states, cluster classification, Low nuclearity ($M_3 – M_4$) and high nuclearity cluster ($M_5 – M_{10}$), Metal metal bonding (MOT), Carbonyl clusters, skeletal electron counting, Wade-Mingos-Luber rule, application of isolobal and isoelectronic analogy, capping rules, carbide, nitride, chalcogenide and halide containing cluster of Re, Nb, Ta, Mo, W.Zintl ions, chevrel compounds, infinite metal chains, application of cluster compounds in catalysis.

Text books:

1. F. A. Cotton, G. Willkinson, Advanced Inorganic Chemistry,Wiley, 6th ed., 2007.
2. J. E. Huheey, Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education India, 4th ed. 2006.
3. R. L. Dutta, A. Syamal, Elements of Magnetochemistry, East-West Press, 1993.
4. A. K. Das, M. Das, Fundamental Concepts of Inorganic Chemistry; Volume-6; CBS Publishers, 2012.

Reference books:

1. G. Wilkinson, R. D. Gillars & J. A. Mccleverty, Comprehensive Co-ordination Chemistry, 2nd ed., Elsvier, 2003.
2. J. D. Lee, Concise Inorganic Chemistry, 5th ed., Oxford, 2008.
3. F. E. Mabbs and D. J. Machin, Magnetism and Transition Metal complexes, Dover Publications; 2008.
4. N. N. Greenwood and E. A. Earnshaw; Chemistry of elements, 2nd ed., Butterworth- Heinemann, 1997.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√		
Quiz -1		√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	**H**	**H**	**L**	**L**
CO2	**H**	**H**	**H**	**L**
CO3	**H**	**H**	**H**	**L**
CO4	**M**	**H**	**H**	**L**

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD 1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD 2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD 3	Seminars	CO 2, 3	CD3
CD 4	Mini projects/Projects	CO3, 4	CD4
CD 5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD 6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD 7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-2	**L1-L8**	**1**	Definition of magnetic properties, Types of magnetic bodies, Experimental arrangements for the determination of magnetic susceptibility: Guoy method, Faraday method, Vibrating sample magnetometer, SQUID, NMR method	**T1, T2, R1**	**1**	**PPT Digi Class/Chock -Board**
3-6	**L9-L20**	**2**	Spin & Orbital effects, Spin orbit coupling, Lande interval rule, Multiplet width and temperature; Curie equation, Curie & Curie–Weiss law, 2nd order Zeeman Effect, Van Vleck susceptibility equation	**T1, T3, R2**	**2**	**-do-**
5-6	**L21-L30**	**3**	Superexchange interaction in terms of Goodenough-Kanamori-Anderson Rules (GKA Rules), Interpretation of magnetic exchange by GKA Rule in terms of Molecular Orbital Theory, Antiferromagnetism	**T1, T2, T3, R1**	**3**	**-do-**
7-10	**L31-L38**	**4**	Rings: Homocyclic rings of S, Se and Te. Heterocyclic rings of S, N, P and O; Cages: Higher boron hydrides: structures and reactions, equation of balance, Lipscomb topological diagrams, polyhedral skeletal electron pair theory (PSEPT)	**T1, T2, T3, R2**	**4**	**-do-**
11-15	**L39-L45**	**5**	Clusters in elemental states, cluster classification, Low nuclearity ($M_3 – M_4$) and high nuclearity cluster ($M_5 – M_{10}$), Metal metal bonding (MOT), Carbonyl clusters, skeletal electron counting, Wade-Mingos-Luber rule,	**T1, T2, T3, R2**	**5**	**-do-**

Course code: CH 409
Course title: Physical Chemistry-VII: Quantum Chemistry & Group Theory
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. II/ I. M. Sc. VIII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To use operators in quantum mechanics to derive and solve Schrodinger equation.
B.	To solve elementary model problems in quantum mechanics, particle in a potential-free box, particle on a ring, harmonic oscillator and particle in a Coulomb potential exactly and demonstrate the solutions for hydrogen atom.
C.	To use techniques of approximations to solve the quantum mechanical problems.
D.	To apply the concept of linear combination of atomic orbitals to hybridization and directed bonding in polyatomic molecules.
E.	To show that molecular symmetry operations form a group and can be characterized by fundamental representations of groups known as irreducible representations and apply the great orthogonality theorem to derive simple point groups.

Course Outcomes

After the completion of this course, students will be:

1.	Able to solvethe model problems in quantum mechanics for which exact analytical methods and solutions are available which forms the foundations for advanced study of the subject.
2.	Able to applythis knowledge to complex problems of atomic and molecular energy levels and structure.
3.	Able to determinethe symmetry elements of any small and medium-sized molecules.

Syllabus

Module I: Classical Mechanics and Postulates of Quantum Mechanics (9 lectures)
Postulates of quantum mechanics. Operators in quantum mechanics: Linear and Hermitian operators, operator algebra, eigenvalues and eigenfunctions, commutation relations. Solution of Schrödinger's equation for (i) particle in 3D-boxes and applications, (ii) particle in a ring and sphere, spherical harmonics, angular momentum rigid rotator, (iii) Simple harmonic oscillator, and (iv) Hydrogen atom. Stark and Zeeman effect.

Module II: Approximation Methods (8 lectures)
Perturbation (Time-independent & Time-dependent) and Variation methods: Examples of Variation methods: (i) Hydrogen atom, Hydrogen atom in an electric field, (ii) Helium atom. Examples of Perturbation method: (i) perturbed particle in a box, (ii) perturbed harmonic oscillator (iii) Hydrogen atom in electric field.

Module III: Atomic Spectra and Atomic Structure (9 lectures)
The spectrum of atomic hydrogen: Electronic configuration of atoms, addition of angular momenta, spectroscopic term symbols, spin-orbit coupling, selection rules for atomic spectra; The structure of helium; Many-electron atoms: Antisymmetric wave functions of many electron atoms, Slater determinants, Hartree and Hartree-Fock self-consistent field model for atoms.

Module IV: Theory of Angular Momentum & Chemical Bonding (9 lectures)

Angular momentum: Classical & quantum mechanical concept, application in many-electron atom, splitting of term level into atomic levels. *Molecular structure & Chemical bonding*: Born–Oppenheimer approximation, Hydrogen molecule ion. LCAO–MO and VB treatments of the hydrogen molecule. Hybridization and MOT of H_2O, NH_3 and CH_4. Huckel pi-electron theory and its applications to ethylene, butadiene and benzene.

Module V: Basic Concept of Symmetry & Group Theory (10 lectures)

Definition and theorem of group theory. Molecular symmetry & the symmetry group: Symmetry operations & symmetry elements, classification of molecules, multiplication tables. Representation of molecular point groups, character, reducible and irreducible representations. The Great Orthogonality Theorem (GOT, without proof), use of GOT to construct character table, character table for point groups & their uses.

Text books:

1. P.W. Atkins and R.S. Friedman, Molecular Quantum Mechanics, 4th edition, Oxford University Press. Oxford, 2005.
2. D. A. McQuarrie, Quantum Chemistry, University Science Books, 1983.
3. R. K. Prasad, Quantum Chemistry, 3rd ed., New Age International, 2006.
4. A. K. Chandra, Introductory Quantum Chemistry, Tata Mcgraw-Hill, New Delhi, 1988.
5. F. A. Cotton, Chemical Applications of Group Theory, Wiley, 1996.

Reference books:

1. H. Eyring, J.Walter and G. E. Kimball, Quantum Chemistry, John Wiley, New York, 1944.
2. I. N. Levine, Quantum Chemistry, 5th ed., Pearson Educ., Inc., New Delhi, 2000.
3. D. J. Griffiths, Introduction to Quantum Mechanics, Pearson Education, 2005.
4. J. P. Lowe and K. A. Peterson, Quantum Chemistry, 3rd ed., Academic Press, 2005.
5. D. M. Bishop, Group theory and Chemistry, Dover, 1993.
6. S. N. Datta, Lectures on Chemical bonding and quantum chemistry, Prism Books, Bangalore, 1997.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3
Assignment	√	√	
Quiz –I	√		
Quiz II		√	
End Sem Examination Marks	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes:

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	H	L
CO2	H	H	H	L
CO3	H	H	M	M

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3	CD1
CD2	Tutorials/Assignments	CO2, 3	CD1, 2
CD3	Seminars	CO3	CD3
CD4	Mini projects/Projects	CO1, 2, 3	CD4
CD5	Laboratory experiments/teaching aids	CO2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internet	CO1 ,2, 3	CD6
CD7	Simulation	CO1, 2, 3	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book /References	COs mapped	Methodology used
1-3	**L1-L9**	**1**	Introduction to Quantum Mechanics	**T1, T2,T3,R2, R3**	**1**	**PPT Digi Class/Chock -Board**
4-6	**L10-L17**	**2**	Perturbation and Variation Methods	**T1,T2,R2,R3**	**1**	**-do-**
6-9	**L18-L26**	**3**	Atomic Spectrum	**T1, T2,R2**	**2**	**-do-**
9-12	**L27-L35**	**4**	Molecular Structure and Chemical Bonding	**T2,R6**	**2**	**-do-**
12-15	**L36-L45**	**5**	Symmetry and Group Theory	**T5,R5**	**3**	**-do-**

Course code: CH 410
Course title: Modern Organic Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. II/ I. M. Sc. VIII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the photochemical, free radical and pericyclic reactions and their mechanisms
B.	To understand the heterocyclic systems, their synthetic principles and their chemical reactivity
C.	To understand the various principles and rules of reaction mechanism and their stereochemical outcomes

Course Outcomes

After the completion of this course, students will be:

1.	To learn different photophysical and photochemical fates of an organic compound upon photo-irradiation
2.	To learn the mechanisms of photochemical and free radical reactions
3.	To learn the different heterocycles, their synthesis and understand their reactivity
4.	To understand the mechanism of different pericyclic reactions and differentiateendo and exo additions, suprafacial and antrafacial shifts and conrotatory and disrotatory motions
5.	To apply the rules of organic reactions to determine the stereochemical outcome

Syllabus

Module I: Organic Photochemistry (9 Lectures)

Singlet and triplet excited state, radiative and non-radiative transitions, potential energy surfaces, photoreduction, photoaddition, photorearrangement, photooxidation, aromatic substitution, Norrish Type I, Norrish Type II, excimers and exciplexes, photochemistry of alkenes, carbonyl, aromatic compounds.

Module II: Free Radical Reaction (10 Lectures)

Types of free radical reactions, free radical substitution mechanism, mechanism at an aromatic substrate, neighboring group assistance, Reactivity for aliphatic and aromatic substrates, Reactivity in the attacking radicals, the effect of solvents on reactivity, Allylic halogenation, Oxidation of aldehydes to carboxylic acids, auto-oxidation, Sandmeyer reaction, free radical rearrangement, Hunsdiecker reaction.

Module III: Pericyclic Reaction (8 Lectures)

FMO & PMO approach, Electrocyclic reactions – conrotatory and disrotatory motions, 4n, 4n+2 and allyl systems, Cyloaddition Reaction: Antarafacial and suprafacial additions, 4n and 4n+2 systems, 2+2 addition of ketenes, 1,3 dipolar cycloadditions and Cheleotropic Reactions, Effect of Diene and dienophile stereochemistry, Endo rule in Diels-Alder Reaction, Reverse electron Demand Diels-Alder Reaction, Intramolecular Diels-Alder Reaction, Regioselective Diels-Alder Reactions, Sigmatropic rearrangements: Suprafacial and antarafacial shifts of H, sigmatropic shifts involving carbon moieties, 3,3- and 5,5-sigmatropic rearrangements, Claisen, Cope and aza-Cope rearrangements, Ene and Retro Ene Reactions.

Module IV: Heterocyclic Chemistry (9 Lectures)

Heterocyclic synthesis: Principles of heterocyclic synthesis involving cyclization and cycloaddition (1,3-dipolar, hetero-diels alder and 2+2 cycloaddition reactions).

Heterocyclic chemistry of 3 and 4, 5 and 6 membered rings. Synthesis, medicinal applications and reactions of oxirane, aziridine, azetidinone (β-lactam), oxetane, pyridine, pyrylium salts and pyrones. Heterocyclic chemistry of benzo-fused derivatives: Synthesis, medicinal applications and reactions of benzofurans, benzothiophenes, quinolines, isoquinolines, quinolizines, Indolizines, benzopyrylium salts, coumarin, chromene, chromones.

Module V: Asymmetric synthesis (9 Lectures)

Cram's rule, Felkin's rule, Prelog's rule, Karabatso's rule and their application in organic synthesis (stereoselectivity in hydride reduction), Homogenous and heterogenous asymmetric catalysis.

Text books:

1. J. March, M. B. Smith, Advanced Organic Chemistry – Reactions, Mechanism and Structure, 7th ed., John Wiley, 2015.
2. S. M. Mukherjee, Pericyclic Reactions: A Mechanistic Study, 3rd ed., Macmillan, India, 2010.
3. I. L. Finar, Organic Chemistry, Vol. I & II, 5th ed., Longman Ltd., New Delhi, 2011.
4. D. Nasipuri, Stereochemistry of Organic Compounds, 2nd ed., New Age Int., New Delhi, 1994.

Reference books:

1. T. H. Lowry and K. S. Richardson, Mechanisms and Theory in Organic Chemistry, 2nd ed., Harper and Row, New York, 1981.
2. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, New York 2006.
3. I. Fleming, Frontier orbitals and organic chemical reactions, John Wiley and sons, Student edition, 2009.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3
Assignment	√	√	
Quiz –I	√		
Quiz II		√	
End Sem Examination Marks	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	M	H	L
CO4	M	H	H	L
CO5	M	H	M	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4, 5	CD1
CD2	Tutorials/Assignments	CO1, 2, 3	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3	CD6
CD7	Simulation	CO2	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	**L1-L9**	**1**	Organic photochemistry	**T1, T2, R1**	**1**	**PPT Digi Class/Chock -Board**
4-7	**L10-L21**	**2**	Free radical reactions	**T3, R2**	**1**	**-do-**
8-9	**L22-L27**	**3**	Pericyclic reactions	**T2, R3**	**1**	**-do-**
10-12	**L28-L36**	**4**	Heterocyclic chemistry	**T1, T3, R2**	**2**	**-do-**
13-15	**L37-L45**	**5**	Asymmetric synthesis	**T1, R4**	**3**	**-do-**

Course code: CH 411
Course title: Physical Chemistry-VIII: Equilibrium, Non-Equilibrium & Statistical Thermodynamics
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc. and I. Msc.
Semester / Level: M. Sc. II/ I. M. Sc. VIII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the basic principles of equilibrium and non-equilibrium thermodynamics.
B.	To familiarize with the fundamental concepts of statistical thermodynamics.

Course Outcomes

After the completion of this course, students will be:

1.	Able to calculate change in thermodynamic properties, equilibrium constants, partial molar quantities, chemical potential.
2.	Able to solve numerical problems based on non-ideal solutions, chemical potentials, thermodynamic properties.
3.	Able to measure the partition function of ideal and real gases.

Syllabus

Module I: Equilibrium Thermodynamics Basics (8 lectures)
Introduction to thermodynamics: Concept of work and heat, first law of thermodynamics, enthalpy and heat capacities, concept of entropy, second law of thermodynamics, third law of thermodynamics-residual entropy. Maxwell's Relations and its applications and thermodynamic equations of state.

Module II: Equilibrium Thermodynamics Applications (9 lectures)
Free energy, free energy of mixing of gases and variation of free energy with temperature, pressure and volume (Gibbs-Helmholtz equations with its applications). Chemical potential, Gibbs-Duhem equation, determination of partial molar quantities, equilibrium constant, temperature dependence of equilibrium constant. Clapeyron & Clapeyron-Clausius equation, fugacity & activity of gas and liquid. Third law of thermodynamics: Determination of absolute entropy of solids, liquids & gases, Boltzmann entropy equation.

Module III: Statistical Thermodynamics Basics (8 lectures)
Concept of distribution, Thermodynamic probability and most probable distribution, Maxwell-Boltzmann statistics, Bose-Einstein statistics, Fermi-Dirac statistics. Ensemble averaging, Canonical, Grand canonical and micro canonical ensembles.

Module IV: Statistical Thermodynamics Applications (10 lectures)
Ideal Gases: Partition functions: Translational, rotational, Vibrational and electronic partition functions and calculation of thermodynamic properties in terms of partition functions for ideal monatomic and diatomic gas. Equilibrium constant of an ideal gas reaction in terms of partition function. *Real gases:* intermolecular potential and virial coefficients. Debye and Einstein theory of heat capacity of solids. Structure and thermal properties of liquids, Pair correlation functions. *Solids:* Thermodynamics of solids - Einstein and Debye models. T^3 dependence of heat capacity of solids at low temperatures (universal feature). *Metals:* Fermi function, Fermi energy, free electron model and density of states, chemical potential of conduction electrons.

Module V: Non-equilibrium thermodynamics (10 lectures)

Thermodynamic criteria for non-equilibrium state, Phenomenological laws and Onsager reciprocal relations, Conservation of mass and energy in closed and open system. Entropy production: Due to heat flow, involving chemical reactions. Entropy production and entropy flow in open system. Transformation properties of fluxes and forces. Electrokinetic phenomena. Stationary non-equilibrium state: Prigogine's principle. Irreversible thermodynamics for biological systems.

Text books:

1. D. A. McQuarrie and J. D. Simon, Molecular Thermodynamics, Viva Books Private Limited, 1st Indian edition, 2004.
2. D. A. McQuarrie and J. D. Simon, Physical Chemistry: A molecular Approach, Viva, 1998.
3. C. Kalidas and M. V. Sangaranarayan, Non-Equilibrium Thermodynamics: Principles and Applications, McMillan India Ltd., 2002.
4. R. P. Rastogi and R. R. Misra, An Introduction to Chemical Thermodynamics, Vikas Publishing House Pvt. Ltd., 6th ed., 2000.
5. S. Glasstone, Thermodynamics for Chemists, East-West Press Pvt. Ltd. 2008.

Reference books:

1. P. W. Atkins, Physical Chemistry, 7thed., Oxford University Press, New York, 2002.
2. I. N. Levine, Physical Chemistry, 5th ed., Tata McGraw Hill Pub. Co. Ltd., New Delhi. 2002.
3. F. W. Sears & G. L. Salinger, Thermodynamics, Kinetic Theory & Statistical Thermodynamics, Narosa, 1986.
4. I. Prigogine, Introduction to Thermodynamics of Irreversible Processes. 3rded., Interscience, New York, 1978.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3
Assignments	√	√	
Quiz I	√		
Quiz II		√	
End Sem Examination Marks	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping of Course Outcomes onto Program Outcomes:

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	M	L
CO2	H	H	M	L
CO3	H	H	M	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3	CD1
CD2	Tutorials/Assignments	CO1, 2, 3	CD1, 2
CD3	Seminars	CO3, 4	CD3
CD4	Mini projects/Projects	CO1, 2, 3, 4, 5	CD4
CD5	Laboratory experiments/teaching aids	CO2, 3	CD5
CD6	Industrial/guest lectures	CO4	CD6, 7
CD7	Simulation	CO5	CD8

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	**L1-L8**	**1**	Basics of Equilibrium Thermodynamics	**T1, T2,T3,R2**	**1**	**PPT Digi Class/Chock -Board**
3-6	**L9-L17**	**2**	Applications of Equilibrium Thermodynamics	**T1,T2,T3 R2,R3**	**1**	**-do-**
6-9	**L18-L25**	**3**	Basics of Statistical Thermodynamics	**T2, T3,R2**	**1, 2**	**-do-**
9-12	**L26-L35**	**4**	Application of Statistical Thermodynamics	**T1,R4**	**3**	**-do-**
12-15	**L36-L45**	**5**	Basics of Non-equilibrium Thermodynamics	**T1,T2**	**2**	**-do-**

Course code: CH 412
Course title: Analytical Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. II/ I. M. Sc. VIII
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the basics of analytical Chemistry
B.	To understand several separation techniques
C.	To know about the classical analytical methods
D.	To learn the thermal and electrochemical techniques of analysis

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain the basics of analytical Chemistry
2.	Separate the mixtures by different separation methods
3.	Able to determine the sample by volumetric and gravimetric analysis
4.	Determine the samples through different thermal and electrochemical techniques of analysis

Syllabus

Module I: Introduction to Analytical Chemistry (10 lectures)

Types of analysis-qualitative and quantitative. Classification of analytical methods- classical and instrumental, basis of their classification with examples. Statistical analysis and validation: Errors in chemical analysis. Classification of errors- systematic and random, additive and proportional, absolute and relative. Accuracy and precision. Mean, median, average deviation and standard deviation. Significant figures and rules to determine significant figures. Calculations involving significant figures. Confidence limit, correlation coefficient and regression analysis. Comparison of methods: F-test and T-test. Rejection of data based on Q test. Least squares method for deriving calibration graph. Validation of newly developed analytical method. Certified reference materials (CRMs). Numerical problems.

Module II: Separation Techniques (10 lectures)

Chromatography: Definition and Classification. Techniques used in Paper, Thin Layer and Column chromatography. Applications in qualitative and quantitative analysis.

Ion exchange: Principle and technique. Types of ion exchangers. Ion exchange equilibria. Ion exchange capacity. Effect of complexing ions. Zeolites as ion-exchangers. Applications.

*Solvent extraction:*Principle and techniques. Distribution ratio and distribution coefficient. Factors affecting extraction efficiency: Ion association complexes, chelation, synergistic extraction, pH. Numericals based on multiple extractions. Role of chelating ligands, crown ethers, calixarenes and cryptands in solvent extraction. Introduction to Solid phase extraction (SPE) and Microwave assisted extraction (MAE), Applications.

Module III: Classical Methods of Analysis (9 lectures)

Volumetric analysis: General principle. Theory of indicators. Types of titrations with examples- Acid-base, precipitation, redox and complexometric. Titration curves for monoprotic and polyprotic acids and bases. Indicators used in various types of titrations. Masking and demasking agents.

Gravimetric analysis:General principles and conditions of precipitation. Concepts of solubility, solubility product and precipitation equilibria. Steps involved in gravimetric analysis. Purity of precipitate: Co-precipitation and post-precipitation. Fractional precipitation. Precipitation from homogeneous solution. Particle size, crystal growth, colloidal state, aging and peptization phenomena. Ignition of precipitates.

Module IV: Thermal Methods of Analysis (7 lectures)

Principle, methodology and applications: thermogravimetric and differential thermal analysis, differential scanning calorimetry; Thermo-mechanical and dynamic mechanical analysis; thermometric titrations

Module V: Electrochemical Methods of Analysis (9 lectures)

Conductometry: Concepts of electrical resistance, conductance, resistivity and conductivity. Specific, molar and equivalent conductance and effect of dilution on them. Measurement of conductance. Kohlrausch's law, Applications of conductometry in determination of dissociation constant, solubility product. Conductometric titrations. High frequency titrations. Numerical problems.

Potentiometry: Circuit diagram of simple potentiometer. Indicator electrodes: hydrogen electrode, quinhydrone electrode, antimony electrode and glass electrode. Reference electrodes: Calomel electrode and Ag/AgCl electrode. Theory of potentiometric titrations. Acid-base, redox, precipitation and complexometric titrations. Nernst equation, standard electrode potential, Determination of cell potential, n, K_f and K_{sp}. pH titrations. Buffers and buffer capacity. pH of buffer mixtures based on Henderson-Hasselbalch equation.

Text books:

1. G. D Christian, Analytical Chemistry. 5th ed., John – Wiley and Sons Inc., 1994.
2. D. A. Skoog, D. M. West and F. J. Holler, Fundamentals of Analytical Chemistry. 7th ed., Saunders College Publishing, 1996.
3. H. H. Willard, L. L. Merrit, J. A. Dean and F. A. Set, Instrumental methods of Analysis, CBS Publishers, 1996.

Reference books:

1. G. W. Ewing, Instrumental Methods of Chemical Analysis, 5th ed., McGraw-Hill, New York, 1988.
2. A. J. Bard & L. R. Faulkner, Electrochemical methods, 2nd ed., Wiley, New York, 2000.
3. Vogel's text book of Quantitative Chemical analysis 5th edition, Ed., Jeffery et al. ELBS/Longman, 1989.
4. Encyclopedia of Analytical Chemistry: Ed. by R.A. Meyers Vol. 1-15, John Wiley, 2000.
5. D. M. Skoog, D. M. West and F. J. Holler, Fundamentals of Instrumental Analysis, 8th ed., Saunders College Publishing, 2004.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	10+10+10
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√		
Quiz -1		√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-4	L1-L09	**1**	Introduction to Analytical Chemistry	**T1, R1,R3**	**1**	**PPT Digi Class/Chock -Board**
4-7	L10-L18	**2**	Separation Techniques	**T1,T2 R1,R3**	**1**	**-do-**
7-10	L19-L27	**3**	Classical Methods of Analysis	**T1, R2,R3**	**2**	**-do-**
10-11	L28-L36	**4**	Thermal Methods of Analysis	**T1**	**3**	**-do-**
12-15	L37-L45	**5**	Electrochemical Methods of Analysis	**T1**	**4**	**-do-**

Course code: CH 413
Course title: Inorganic Chemistry-V Lab
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 2 L: T: P: 4
Class schedule per week: 04
Class: M.Sc. and I M.Sc.
Semester / Level: M. Sc. II/ I. M. Sc. VIII
Branch: Chemistry
Name of Teacher:

Syllabus

1. Semi micro qualitative analysis of mixtures containing two anions, two common cations and one rare earth elements: W, Mo, Ce, Th, Zr, V, U and Li.
2. Gravimetric determination of Fe in iron ore as Fe_2O_3.
3. Chemical Analysis of Alloy samples: Dissolution, sample preparation & Analysis. (any one)

a) Analysis of brass: Estimation of copper by gravimetry and zinc by EDTA titration.
b) Analysis of bronze: Estimation of copper by volumetry and tin by gravimetry

4. Inorganic Synthesis:

a) Nano-chemistry: Synthesis and characterization of manganese dioxide nanoparticles
b) Synthesis of pentaamminechlorocobalt(III) chloride.
c) Preparation of *cis* and *trans*-dichlorobis-(ethylenediamine)cobalt(III) chloride
d) Ligand synthesis for multimetal complex: Preparation of *bis*-(*N,N*-disalicylidene ethylenediamine)
e) Synthesis and characterization of *tris*-triphenylphosphinecopper(I) nitrate
f) Preparation of *bis*-(N, N'-disalicylalethylene-diamine)-μ-aquadicobalt(II)

Reference Books:

1. Vogel's Text book of Qualitative Chemical Analysis, J. Bassett, G. H. Jeffery and J. Mendham, ELBS, 1986.
2. Vogel's text book of Quantitative Chemical Analysis, 5thEdition, J. Bassett, G. H. Jeffery and J. Mendham, and R. C. Denny, Longman Scientific and Technical, 1999.
3. J. D. Woollins, Inorganic Experiments; VCH, Weinheim, 1994.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Course code: CH 414
Course title: Theoretical & Computational Chemistry Lab
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 2 L: 0 **T:** 0 **P:** 4
Class schedule per week: 04
Class: M.Sc. and I. M. Sc.
Semester / Level: M. Sc. II/ I. M. Sc. VIII
Branch: Chemistry
Name of Teacher:

Syllabus

1. A) Draw and clean the 2D chemical structure for given molecules (e.g.; Barbituric Acid,N-acetylneuraminic acid, Cholesterol) as per ACS format using ChemDraw Software. B) Perform the analysis of the drawn structure to report IUPAC name, molecular weight, exact mass and elemental analysis. C) Convert the 2D chemical structure into 3D structure using Chem3D software and demonstrate the various molecular models.
2. Draw the suitable conformers of 2,3-dibromobutane and demonstrate in Sawhorse, Newmann, and Fisher projection. Minimize the eclipsed and staggered conformor and evaluate the energies by molecular mechanics (MM) for both conformers.
3. Compute the physico-chemical properties such as log p, solubility, molar refractivity and NMR for a given molecule.
4. Draw the reaction mechanism for a given name reaction using ChemDraw tools in ACS (American Chemical Society) format.
5. Compute the partial atomic charges (extended Huckel) in phenol and display by color gradient.
6. Draw and demonstrate the HOMO-LUMO diagram using ethylene molecule. Minimize the energy of the given molecule and calculate HUMO-LUMO energy gap using Gaussian Software.
7. (a) Introduction about the computational chemistry software Schrodinger, understanding and use of its Graphical interface “Maestro” to prepare the molecular system for computer simulation. (b) Draw the 3D structure of a given chiral molecule (tamiflu) in Maestro workspace, clean the structure by short minimization using MM.
8. Generate the all stereochemical structure of a given molecules (tamiflu or zanamavir) using maestro interface of Schrodinger.
9. Conduct the molecular docking experiment for a given ligands with a large protein structure. Report the docking score and binding mode of ligands within the protein active site. Compare the docking result to conclude the remarks for its bindingaffinity.
10. Determine the single point energy of benzene (assume: singlet and uncharged) by density-function calculation with the B3LYP functional and a 6-31G** basis set. Optimize the geometry of the output structure form experiment-9 using BLYP/6-31G** level.
11. Run the calculation to demonstrate the electrostatic potential (ESP) of vinyl alcohol. Label atoms in the workspace with atomic properties derived from the ESP and examine the electrostatic potential (ESP) on the molecular surface.
12. Predict and describe the pKa values of organic bases such as methylamine, dimethyl amine and trimethyl amine usingChemOffice.
13. Draw and describe the 3D conformational features of *trans*-1,3-demthyl cyclohexane. Draw, demonstrate and compare the electrostatic potential map of CH_3-Cl and CH_3-Li. Explain the significance of this experiment.

Text books:

1. F. Jensen, Introduction to Computational Chemistry, Wiley, New York, 1999.
2. A. Szabo and N. S. Ostlund, Modern Quantum Chemistry, Introduction to Advanced Electronic Structure Theory, 1st ed., revised Dover, 1989. More mathematical detail for many of the ab initio electronic structure methods.

Reference book:

1. D. A. McQuarrie, Quantum Chemistry, University Science Books, Mill Valley, CA, 1983.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Course code: CH 501
Course title: Spectroscopic Elucidation of Molecular Structure
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To interpret spectra collected through different characterization tools
B.	To deduce the structure of molecules from given spectral data

Course Outcomes

After the completion of this course, students will be:

1.	Learn fundamental principal of different characterization techniques
2.	Apply the basics of structural elucidation principles in deducing the molecular structure
3.	Analyse the given spectrum to decipher the molecular structure

Syllabus

UV-Visible & IR Spectroscopy (8 Lectures)

Electronic transitions, Chromophores, Auxochromes, Bathochromic and hypsochromic shifts, Solvent effects, Woodward –Fieser Rules for dienes. enones and aromatic compounds.

Vibrational Transitions, Important group frequencies, Factors affecting I.R. group frequency, Applications of I.R. Instrumentation and recording of spectra.

Nuclear Magnetic Resonance Spectroscopy (10 Lectures)

1H-NMR: chemical shift, spin-spin interaction, shielding mechanism, chemical shift values and correlation for protons bonded to carbons and other nucleus, chemical exchange, effect of deuteration, complex spin-spin interaction between 2, 3, 4 and 5 nuclei, virtual coupling, stereochemistry, hindered rotation, simplification of complex spectra, nuclear magnetic double resonance, contact shift reagents, solvent effects, 13C-NMR: General considerations, chemical shifts, coupling constants and examples 2D-NMR: spectroscopy-COSY, NOESY, DEPT. DEPT with 3 different angles, interpretation of 2D spectra and examples.

Mass Spectrometry (9 Lectures)

Introduction, ion production, factors affecting fragmentation, ion analysis, ion abundance, mass spectro fragmentation in organic compounds, common functional groups, molecular ion peak, high resolution mass spectrometry, examples of mass spectral fragmentation of organic compounds w.r.t. their structure determination.

Electron Spin Resonance Spectroscopy & Mossbauer Spectroscopy (11 Lectures)

Hyperfine coupling, Spin polarization for atoms and transition metal ions, spin orbit coupling an significance of g-tensors, applications to transition metal complexes having one unpaired electron including biological systems and to inorganic free radicals such as PH_4, F_2^- and $(BH_3)^-$.

Mossbauer Spectroscopy: Basic principles, spectral parameters and spectrum display, applications to the study of bonding and structures of Fe^{2+} and Fe^{3+} compounds, Sn^{2+} and Sn^{4+} compounds– nature of M-L bond, Co-ordination number, structure and detection of oxidation state.

Spectra and Structure: Combined application (7 Lectures)
UV, IR, NMR and Mass spectral data to elucidate unknown compound structure.

Text books:

1. D. H. Williams, I. Fleming, Spectroscopic Methods in Organic Chemistry, McGraw-Hill Education; 6th ed. 2007.
2. R. M. Silverstein, F. X.Webster, D. J. Kiemle, Spectrometric Identification of Organic Compounds, 7th ed.; Wiley: Hoboken, NJ, 2005.
3. W. Kemp, Organic Spectroscopy, McMillan, Reprint 2009.

Reference books:

1. J. R. Dyer, Applications of Spectroscopy of Organic Compounds, Prentice Hall, Reprint 2010.
2. R. S. Macomber, A Complete Introduction to Modern NMR Spectroscopy, Wiley-Interscience; 1st ed., 1997.
3. H. Gunther, NMR Spectroscopy, Basic Principles, Concepts and Applications in Chemistry, 3rd ed., Wiley VCH, 2013.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3
Quiz -1	√		
Quiz II		√	
End Sem Examination Marks	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	M	L
CO2	H	M	L	H
CO3	H	M	L	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3	CD1
CD2	Tutorials/Assignments	CO1, 2, 3	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3	CD6
CD7	Simulation	CO2	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-2	L1-L09	**1**	UV-Vis and IR spectroscopy	**T1, T2**	**1**	**PPT Digi Class/Chock -Board**
3-6	L10-L18	**2**	NMR Spectroscopy	**T1,T2,T3 R1,R3**	**1**	**-do-**
7-9	L19-L27	**3**	Mass Spectrometry	**T2, T3**	**1, 2**	**-do-**
10-12	L28-L36	**4**	EPR and Mossbauer Spectroscopy	**T3,R1**	**3**	**-do-**
13-15	L37-L45	**5**	Structure determination from given combination of spectra	**T1,T2,T3, R1,R2**	**2**	**-do-**

Course code: CH 502 (SPL-I)
Course title: Inorganic Chemistry-VIII: Solid state and Nuclear Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the basics of nuclear chemistry
B.	To grow concept of nuclear structure
C.	To know about the nuclear reactions
D.	To know about the structure of the solids and their reactivities

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain the basics of nuclear chemistry
2.	Able to explain the nuclear stability
3.	Able to predict the nuclear reactions
4.	Able to explain the structure of the solids and their reactivities

Syllabus

Module I:Basic Nuclear Chemistry (9 Lectures)

Systematic of alpha, beta and gamma decays, Alpha decay, energy curve, spectra of alpha particles, Geiger-Nuttal law, theory of alpha decay, penetration of potential barrier, beta decay, range of energy relationship, beta spectrum, sergeants curve, Fermi theory of beta decay, matrix elements, allowed and forbidden transitions, curie plots, gamma decay, Nuclear energy levels, selection rule, isomeric transitions, Internal conversion, Auger effect.

Module II: Nuclear Structure and Stability (9 Lectures)

Nuclear Potential, Binding energy, empirical mass equation, The Nuclear Models: Shell model-salient features, forms of the nuclear potential, filling of orbitals, nuclear configuration, Liquid drop model, Fermi gas model, Collective model and Optical model.

Module III: Nuclear reactions (9 Lectures)

Introduction, production of projectiles, nuclear cross section, nuclear dynamics, threshold energy of nuclear reaction, Coulomb scattering, potential barrier, potential well, formation of a compound nucleus, Nuclear reactions, direct Nuclear reactions, heavy ion induced nuclear reactions, photonuclear reactions. Fission and Fusion reactions: Fission barrier and threshold, fission cross section, mass energy and charge distribution of fission products, symmetric and Asymmetric fission, decay chains and delayed neutrons.

Module IV: The Structure of solids (9 Lectures)

The types of matter, classification of solids, close packing of atoms; Voids in closest packings; Radius ratio rule, Structure of ionic Crystals; Ionic Crystals with stoichiometry MX, Ionic Crystals with stoichiometry MX_2, spinel structure, perovskite structure. Perfect and Imperfect Crystals, intrinsic and extrinsic defects- Point defects, line and plane defects, Vacancies- Schottky and Frenkel defects. Thermodynamics of Schottky and Frenkel defects formation, Colour centres, Non-stoichiometry and

defects. Evolution of band structure, Brillouin zone, Effective mass of electron, Intrinsic semiconductors, Hall effect, Electrical conductivity of metals, alloys & semiconductors. Fermi levels in metals & semiconductors, Direct & indirect band gap semiconductors, Photo-conductivity, Properties of junctions: metal – metal, metal – semiconductor & semiconductor – semiconductor. Application: Diode system, Photocatalytic systems

Module V: Solid State Reactions (9 Lectures)

Thermal decomposition reactions- Type I, Type II, Polymorphism, Enantiotropy & Monotropy, Order-disorder transitions, Buerger's Classification, Polytypism, Sintering, Zone refining, Crystal growth, Growth from solutions, Flame fusion method, Vapour deposition technique, Chemical transport reaction, Growth by condensation.

Text books:

1. H. J. Arnikar, Essentials of Nuclear Chemistry, 4th ed. Wiley Eastern, 1987.
2. A. R. West, Solid State Chemistry and its Applications, 2nd ed., Student Edition, Wiley, 2014.

Reference books:

1. G. Friedlander, T. W. Kennedy, E. S.Macias and J. M. Miller, Introduction of Nuclear and Radiochemistry, 3rd ed., John Wiley, 1981.
2. H. J. M. Bowen, Chemical Applications of Radioisotopes, Methuen, 1969.
3. C. N. R. Rao, New Directions in Solid State Chemistry, 2nd ed., Cambridge University Press, 1997.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√		
Quiz –I	√	√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / Refere nces	COs mapped	Methodology used
1-2	L1-L09	**1**	Basic Nuclear Chemistry: Systematic of alpha, beta and gamma decays, Alpha decay, energy curve, spectra of alpha particles, Geiger-Nuttal law, theory of alpha decay	**T1, T2, R1**	**1**	**PPT Digi Class/Chock -Board**
3-6	L10-L18	**2**	Nuclear Structure and Stability Nuclear Potential, Binding energy, empirical mass equation, The Nuclear Models	**T1, T3, R2**	**2**	**-do-**
5-6	L19-L27	**3**	Nuclear reactions Introduction, production of projectiles, nuclear cross section, nuclear dynamics, threshold energy of nuclear reaction, Coulomb scattering, potential barrier, potential well	**T1, T2, R1**	**3**	**-do-**
7-10	L28-L36	**4**	The Structure of solids The types of matter, classification of solids, close packing of atoms, Ionic Crystals with stoichiometry MX_2, spinel structure, perovskite structure. Perfect and Imperfect Crystals, Schottky and Frenkel defects. Colour centres, Non-stoichiometry and defects.	**T1, R2**	**4**	**-do-**
11-15	L37-L45	**5**	Solid State Reactions: Thermal decomposition reactions- Type I, Type II, Polymorphism, Buerger's Classification, Polytypism, Sintering, Zone refining, Crystal growth, Growth from solutions	**T1, T2, R1**	**5**	**-do-**

Course code: CH 503(SPL-I)
Course title: Molecular Spectroscopy
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To recognize the fundamental principles of optical and magnetic resonance and simple relations between experimentally observable spectroscopic quantities and molecule dependent parameters by introducing time dependent quantum mechanics.
B.	To show that spectroscopy connects matter with molecules through interaction of electromagnetic radiation.

Course Outcomes

After the completion of this course, students will be:

1.	Able to apply principles of microwave, infrared and electronic spectroscopies to identify the fingerprint region of small molecules.
2.	Able to identify the element present in the molecule along with oxidation state from their respective binding energies.
3.	Able to apply the concept of chemical shift and spin-spin coupling in both NMR and EPR spectroscopy to identify high resolution spectra of small organic molecules.
4.	Familiar with modern spectrometers and methods, which are applied in industrial and scientific laboratories in the field of synthesis and structural determination.

Syllabus

Module I: Rotational spectroscopy (9 lectures)

Classification of polyatomic molecules: Linear, symmetric rotor, spherical rotor and asymmetric rotor molecules. The Stark effect in hetero-nuclear diatomic molecules. Rotational Raman spectroscopy. Applications of microwave spectroscopy.

Module II: Vibrational spectroscopy (9 lectures)

Infrared (IR) spectroscopy, Raman spectroscopy; Polyatomic molecules: Group vibrations, Number of normal vibrations of each symmetry species, Vibrational selection rules, Vibration-rotation spectroscopy, Anharmonicity. Techniques and instrumentation-Analysis by IR spectroscopy.

Module III: Electronic spectroscopy (9 lectures)

Diatomic molecules. Selection rules. Breakdown of selection rules. Franck-Condon factors. Dissociation energies. Transition moments, assignment of electronic transitions of N_2, H_2O and formaldehyde using group theory. Qualitative ideas of solvent effects- viscosity, polarity, hydrogen bonding. Fluorescence and phosphorescence.

Module IV: Photoelectron spectroscopy (9 lectures)

Ionization processes and Koopman's theorem, Ultraviolet photoelectron spectroscopy, X-ray photoelectron spectroscopy. Auger electron spectroscopy: introduction- instrumentation- classification of various transitions- quantification- applications**.** Electron energy loss spectroscopy: Franck and Hertz experiment- instrumentation - selection rules- theory- studies on molecules- surface states- high resolution spectroscopy- adsorption and catalysis- applications.

Module V: Spin resonance spectroscopy (9 lectures)

The effect of magnetic fields on electron and nuclei, nuclear magnetic resonance (NMR): Bloch equations, Steady state (continuous wave) and Transient (pulsed) experiments, nuclear Overhauser effect, Polarization transfer, Selective Population Inversion. Electron spin resonance (ESR): g value, hyperfine structure, ESR of organic free radicals, solids, inorganic ions, simple free radicals in solutions. Mossbauer spectroscopy: principle & applications.

Text books:

1. P. W. Atkins, J.de Paula, Physical Chemistry, Oxford, London, 7th ed. 2002.
2. P. S. Sindhu, Fundamentals of Molecular Spectroscopy, New Age International (P) Ltd. Publishers, 2006.
3. C. M. Banwell, Molecular Spectroscopy, Tata McGraw Hill, 1998.
4. G. M. Barrow, Introduction to Molecular Spectroscopy, McGraw Hill, 1964.
5. M. Hollas, Modern Spectroscopy, Wiley; 4th ed., 2004.

Reference books:

1. A. Carrington and A. D. Mclachlan, Introduction to Magnetic Resonance, Methuen, 1983.
2. J. D. Graybeal, Molecular Spectroscopy, McGraw Hill, 1993.
3. H. Friebolin, Basic One- and Two-Dimensional NMR Spectroscopy 5th ed., Wiley-VCH, 2010.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	**% Contribution during CO Assessment**
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**
Assignment	√	√	√	
Quiz –I	√			
Quiz II		√	√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	H	L
CO2	H	H	M	L
CO3	H	H	H	L
CO4	H	H	M	L

Mapping of Course Outcomes onto Program Outcomes:

Mapping Between COs and Course Delivery (CD) methods			
CD	**Course Delivery methods**	**Course Outcome**	**Course Delivery Method**
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1, 2
CD3	Seminars	CO 1, 4	CD3
CD4	Mini projects/Projects	CO 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internet	CO1, 2, 3, 4	CD6
CD7	Simulation	CO 2, 3	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L09	**1**	Microwave Spectroscopy	**T1, T2 T3, T4**	**1, 4**	**PPT Digi Class/Chock -Board**
4-6	L10-L18	**2**	Infrared and Raman Spectroscopy	**T1,T3 R1,R3**	**1, 4**	**-do-**
7-9	L19-L27	**3**	Absorption and Photoluminescence Spectroscopy	**T3,T5, R2**	**1, 4**	**-do-**
10-12	L28-L36	**4**	Photoelectron Spectroscopy	**T4, T5**	**2**	**-do-**
13-15	L37-L45	**5**	NMR and ESR Spectroscopy	**T1, R1, R2, R3**	**3, 4**	**-do-**

Course code: CH 504(SPL-I)
Course title: Advanced Organic Synthesis
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand protection and deportation of different functional groups
B.	To know about important hydroboration, oxidation and reduction reagents
C.	To understand the hydroboration, oxidation and reduction mechanism
D.	To learn about some important name reaction

Course Outcomes

After the completion of this course, students will be:

1.	Able to consider protection/deportation of functional groups during organic synthesis
2.	Able to perform and compare the hydroboration, oxidation and reduction reagents
3.	Able to explain the hydroboration, oxidation and reduction mechanisms
4.	Able to use the knowledge of name reaction for research and development purpose

Syllabus

Module I: Protection and deprotection (8 Lectures)
Principle of protection and deprotection of alcohol, amine, carbonyl and carboxyl groups

Module II: Hydroboration reactions (10 Lectures)
Introduction, synthetic application of organobroranes: isomerization, formation of C-C bonds, aldehydes, ketones, trialkylcarbinols, reactions of alkenylboranes and trialkylalkynyl borates, free-radical reactions of organoborane.

Module III: Reagents for Oxidation (9 Lectures)
SeO_2, CrO_3, CrO_2Cl_2, LTA, t-BuOOH, mCPBA, $PdCl_2$, $HgSO_4$, $KMnO_4$, OsO_4, OsO_4/RuO_4, H_2O_2, $C_6H_5CO_3H$, CF_3CO_3H, I_2/Py, HIO_4, PCC, PDC, Des-Martin periodinane, IBX, NBS, $AgNO_3$, Ag_2CO_3, Ag_2O, AgO, MnO_2, $NaIO_4$ cat. Ozone, DDQ, DDQ/PbO_2.

Module IV: Reduction (9 Lectures)
Catalytic hydrogenation and hydrogenolysis of various functional groups by Pt_2O, Pd/C, raney nickel, Homogeneous hydrogenation by transition metal complexes {Rh, Ru}, dissolving metal {Li, Na in Liq. NH_3, Zn/HCl or CH_3COOH}, non-metallic reducing agent {hydrazine, Et_3SiH, Ph_2SiH_2, formic acid}, Metal hydrides-based Reduction: $LiAlH_4$, alkoxyaluminate, DIBAL-H, $NaBH_4$, $NaBH_3CN$, $LiBH_4$, $Zn(BH_4)_2$, $NaBH_4/CeCl_3$, alkoxy/alkyl borohydrides, super-hydride, selectrides, n-Bu_3SnH

Module V: Selected Name reactions (9 Lectures)
Biginelli reaction, Hantzsch reaction, Passerini reaction, Ugi reaction, McMurry olefination, Suzuki, Heck and Sonogashira coupling, Stille coupling, Mitsonobu reaction, Nef reaction, Ring closing metathesis (RCM) - Grubb's reaction, Larock Indole synthesis.

Text books:

1. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, 2nd ed., Oxford Press, 2012.
2. I. L. Finar, Organic Chemistry, Vol. I & II, 5th ed., Longman Ltd., New Delhi, 2011.
3. R. S. Monson, Advanced Organic Synthesis, Academic Press, New York, 2012.

Reference books:

1. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th ed., 7th Indian Reprint, Pearson Education, 2005.
2. Jerry March, Advanced Organic Chemistry, Wiley, 7th ed., 2013
3. Carey and Sundberg, Advanced Organic Chemistry, Springer, 5th ed.; 2000

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Quiz –I	√	√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty

2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	M	L
CO2	H	H	M	L
CO3	H	H	M	L
CO4	H	H	M	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-2	L1-L09	**1**	Protection and deprotection	**T1, T2**	**1**	**PPT Digi Class/Chock -Board**
3-5	L10-L18	**2**	Hydroboration reactions	**T1,T2,T3 R1,R3**	**1**	**-do-**
6-8	L19-L27	**3**	Reagents for oxidation	**T2, T3, R2, R3**	**1, 2**	**-do-**
9-12	L28-L36	**4**	Reduction	**T3,R1, R2,R3**	**3**	**-do-**
13-15	L37-L45	**5**	Selected name reactions	**T1,T2,T3, R1,R2, R3**	**2**	**-do-**

Course code: CH 505 (SPL-II)
Course title: Inorganic Chemistry-IX: Bio Inorganic Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To grow knowledge on elements of life
B.	To study the role of oxygen in biology and its reactivity
C.	To know about the Hydrolase and Oxido-Reductase Enzymes
D.	To study the role of metals in medicine

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain the role of different elements in biology
2.	Able to explain the oxygen management and oxygen transport mechanism in biology
3.	Able to explain role of Hydrolase and Oxido-Reductase Enzymes
4.	Able to explain the role of metals in drug

Syllabus

Module I Basic Bio-inorganic Chemistry (9 Lectures)

Elements of life, the natural selection of elements, metallo-biomolecules– enzymes and proteins, their differences, Metal ion storage and transport: Ferritin, metallothioneins, cerruloplasmin; Siderophores– enterobactin, transferin;. Na^+, K^+ pump, Ca^{2+} transport.

Module II Oxygen management and oxygen transport (9 Lectures)

Kinetics of biological and non-biological oxygenation, Reactive Oxygen Species (ROS): Super oxide dismutase - Occurance, types, active site structure and mechanism of catalytic activity, Catalase, Peroxidase - Occurance, types, active site structure and mechanism of catalytic activity Cytochrome c Oxidase, Cytochrome P– 450- Occurance, types, active site structure and mechanism of catalytic activity.
Natural Oxygen carriers: Heme Type: Myoglobins and Hemoglobins, Properties of heme and iron-porphyrins, The heme iron–dioxygen bond, Mechanism of dioxygen binding and model systems. Di-iron Type: Hemerythrins and Myohemerythrins : Early history and distribution of hemerythrins, Protein structure , The di-iron site and formulation of the O_2 binding reaction, Mechanism of dioxygen binding, Autoxidation, Cooperative hemerythrins, Dicopper Type: Hemocyanins: Protein structure and superstructure, The dicopper site, Mechanism of dioxygen binding.

Module III Hydrolase and Oxido-Reductase Enzymes (9 Lectures)

Zn Carbonic Anhydrase, Zn Carboxy peptidase, Fe Acid Phosphatase, Ni Urease, Alcohol dehydrogenase- Occurance, types, active site structure and mechanism and model system. catalytic activity of Cu proteins for biological oxidation: Tyrosinase, Galactose oxidase, Catecholase, phenoxazinone synthase.

Module IV Model Systems in Bioinorganic Chemistry (9 Lectures)

Chemistry of Vitamin B_{12} , Iron– Sulphur proteins, Cytochromes, Nitrogenase- biological nitrogen fixation, molybdenum nitrogenase, Nitrogenase model systems, Hydrogenase and model systems, Metal complexes in transmission of energy- Chlorophylls & Photosynthetic Water Oxidation.

Module V Metals in Medicine (9 Lectures)

Metal Toxicity and Homeostasis, Chelation Therapy, Vanadium-Based Diabetes Drugs, Pt based Anti-Cancer Drugs, Mechanism of cisDDP Antitumor Activity, Anti-arthritis drugs, Imaging Agents: Technetium Imaging Agents, Gadolinium MRI Imaging Agents, Gold containing drugs used in the therapy of Rheumatoid Arthritis, Lithium in psychopharmalogical drugs.

Text books:

1. I. Bertini, H. B. Gray, S. J. Lippard, J. S. Valentine,Bioinorganic Chemistry, University Science Books, Mill Valley, CA, 1994.
2. W. Kaim, B. Schwederski, A. Klein, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life: An Introduction and Guide, Wiley, 1994.
3. L. Stryer, J. M. Berg, J. L. Tymoczko, 5th ed.,W. H. Freeman & Co Ltd, 2002.

Reference books:

1. R. R. Crichton, Biological Inorganic Chemistry, 2nd ed., Elsvier, 2012.
2. R. M. Roat-Malone, Bioinorganic Chemistry: A Short Course, Wiley, 2002.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Quiz –I	√	√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-2	L1-L09	**1**	Elements of life, the natural selection of elements, metallo-biomolecules– enzymes and proteins, their differences, Metal ion storage and transport	**T1, T2, R1**	**1**	**PPT Digi Class/Chock -Board**
3-6	L10-L18	**2**	Oxygen management and oxygen transport, Reactive Oxygen Species	**T1, T3, R2**	**2**	**-do-**
5-6	L19-L27	**3**	Hydrolase and Oxido-Reductase Enzymes**,** Zn Carbonic Anhydrase, Zn Carboxy peptidase, Fe Acid Phosphatase, Ni Urease, Alcohol dehydrogenase-	**T1, T2, R1**	**3**	**-do-**
7-10	L28-L36	**4**	Model Systems in Bioinorganic Chemistry, Chemistry of Vitamin B_{12} , Iron– Sulphur proteins, Cytochromes, Nitrogenase- biological nitrogen fixation	**T1, R2**	**4**	**-do-**
11-15	L37-L45	**5**	Metal Toxicity and Homeostasis, Chelation Therapy, Vanadium-Based Diabetes Drugs, Pt based Anti-Cancer Drugs, Mechanism of cisDDP Antitumor Activity, Anti-arthritis drugs, Imaging Agents	**T1, T2, R1**	**5**	**-do-**

Course code: CH 506 (SPL-II)
Course title: Advanced Electrochemistry
Pre-requisite(s): B.Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To learn electrode kinetics, corrosion and corrosion control.
B.	To know the principle and applications of electroanalytical, Spectro-electrochemical and spectroscopic techniques.
C.	To learn about the electrochemical energy systems used as power sources and for energy storage.

Course Outcomes

After the completion of this course, students will be:

1.	Able to calculateelectrochemical kinetics parameters, exchange current density, Tafel slope.
2.	Familiar with the basic concepts of corrosion, factors which influence the corrosion and gain the knowledge about the control of corrosion in real situation.
3.	Familiar with electrochemical techniques like cyclic voltammetry, polarography, chrono methods, electrochemical impedance spectroscopy.
4.	Familiar with the reversible and irreversible cells and their applications in various fields and able to distinguish batteries, fuel cells and capacitors.

Syllabus

Module I: Electrode Kinetics (9 lectures)

Mass transfer by Diffusion and Migration – models of electrode reactions – current potential characteristics–general mass transfer equation. Kinetics of an electrode reaction, Butler-Volmer equation, diffusion overpotential. Exchange current density, Tafel plot. Polarizable and non-polarizable interfaces. Irreversible electrode processes.

Module II: Corrosion (9 lectures)

Different types of corrosion; Evans diagram, Pourbaix diagram; Corrosion current and Corrosion potential; Measurement of corrosion rate; Stern Geary equation; Mixed potential theory and prevention of corrosion.

Module III: Electroanalytical Techniques (10 lectures)

Potential Step Methods: Types of techniques, step under diffusion control, Ilkovic equation–polarographic analysis–sampled current voltammetry, reversible, irreversible processes, multicomponent systems. *Chrono Methods:* Chronoamperometry, chronocoulometry. *Pulse polarographic methods*; *Potential Sweep Methods:* Cyclic Voltammetry; *Bulk Electrolysis Techniques:* Classification of methods–Controlled Potential methods: current – time behaviour, electrogravimetry, electroseparation–Coulometric measurements: controlled current methods: characteristics, coulometric methods–Electrometric end point detection: classification, potentiometric, amperometric methods.

Module IV: Spectro-electrochemical and spectroscopic techniques (7 lectures)

Impedance Spectroscopy, Scanning Electrochemical Microscopy, Electrochemical AFM and STM, Electrochemical Quartz Crystal Microbalance.

Module V: Electrochemical Energy Systems (10 lectures)

Electrochemical power sources - theoretical background on the basis of thermodynamic and kinetic considerations. Primary cells, secondary cells- magnesium and aluminium based cells magnesium reserve batteries, Li-ion batteries. Fuel cells - classification - chemistry of fuel cells - detailed description of hydrogen/oxygen fuel cells - methanol - molten carbonate solid polymer electrolyte and biochemical fuel cells. Photoelectrochemical cells, Electrochemical supercapacitors for energy storage.

Text books:

1. J.O'M. Bockris & A. K. N. Reddy, Modern Electrochemistry, Vol. 1 & 2A and 2 B, Plenum Press, New York, 2000.
2. A. J. Bard and L. R. Faulkner, Electrochemical methods, Wiley & Sons, 2nd ed., 2001.
3. S. Glasstone, Introduction to Electrochemistry, East West Press, reprint 2007.

Reference books:

1. D. R. Crow, The Principle of electrochemistry, Chapman Hall, 4th ed. 1994.
2. H. Kissinger, Electroanalytical Techniques, John wiley, 1998.
3. P. H. Reiger, Electrochemistry, Prientice Hall, 1987.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	**% Contribution during CO Assessment**
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**
Assignment	√	√	√	
Quiz –I	√			
Quiz II		√	√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	M	H	H	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	H	H	H	L

Mapping Between COs and Course Delivery (CD) methods:

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO 2, 3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internet	CO1, 2, 3, 4	CD6
CD7	Simulation	CO1	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L09	**1**	Electrode Kinetics	**T1, T2 T3**	**1**	**PPT Digi Class/Chock -Board**
3-5	L10-L18	**2**	Corrosion	**T1,T3 R1**	**2**	**-do-**
6-10	L19-L27	**3**	Different Electroanalytical Techniques	**T1,T2, R2**	**3**	**-do-**
11	L28-L36	**4**	Spectroelectrochemical Techniques	**T1, T2**	**3**	**-do-**
12-15	L37-L45	**5**	Electrochemical Energy Systems	**T1, T2, R2, R3**	**4**	**-do-**

Course code: CH 507 (SPL-II)
Course title: Selected Topics in Organic Synthesis
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T:1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To know about advance spectroscopy of complex molecules
B.	To understand details on neighbouring group participation with mechanism
C.	To get idea about asymmetric synthesis using various catalyst
D.	To learn about retrosynthetic principle and approach

Course Outcomes

After the completion of this course, students will be:

1.	Able to understand and identify the advance spectroscopy of complex molecules
2.	Able to explain the neighbouring group participation process and its mechanism
3.	Able to use the knowledge of asymmetric synthesis during the use of various catalyst
4.	Able to consider retrosynthetic approach during research and development

Syllabus

Module I: Advanced Stereochemistry (9 Lectures)

Optical isomerism in compounds without any stereocenters (allenes, biphenyls), Enantiomerism in allenes, alkylidene cycloalkane, spiranes- configurational nomencalture, correlation of axial dissymmtry and centrodissymmetry, Stereochemistry of natural products, strychnine, podophyllotixin, Conformation and reactivity of fused polycyclic systems: perhydrophenanthrenes.

Module II: Neighboring Group Participation (9 Lectures)

Concept of neighboring group participation with mechanism, neighboring group participation by π & σ bonds, classical and non-classical carbocations, Intramolecular displacement by hydrogen, Oxygen, nitrogen, sulphur and halogen. Anchimeric assistance using Alkyl, cycloalkyl, Aryl participation, participation in bicyclic system, migratory aptitude, intimate and solvent separated ion-pair, transannular, pinacole and carbocation rearrangements and related rearrangements in neighboring group participation, NGP in elimination and addition.

Module III: Catalytic Asymmetric Synthesis (9 Lectures)

Sharpless epoxidation and dihydroxylation; asymmetric cyclopropanation; asymmetric hydrogenation, Enzyme catalyzed asymmetric synthesis, CBS reduction, Reactions using Chiral Lewis Acids and Bronsted Acids, Hydrosilyation of Carbon-Carbon Double bonds and Related Reactions, Synthesis via C-H Activation: Introduction, types of C-H activation, oxidation of alkanes, addition of C-H bond to C-C double bonds, C-H activation in natural product synthesis.

Module IV: Principles of Retrosynthesis (9 Lectures)

Methodologies in organic synthesis-basic ideas on synthons and synthetic equivalents, disconnection approach, functional group transformations and inter-conversions of simple functionalities, Disconnection Approaches, Functional Group Interconversions (FGI). Concept of synthetic efficiency: one pot, multi-component and atom economical reactions. linear and convergent synthesis.

Module V: Retrosynthetic analysis (9 Lectures)

One group disconnections, Reactions examples One group C-C and C-X disconnection, Umpolung of reactivity and protecting groups. Two group C-C disconnections, Diels-Alder reaction, 1,3-difunctionalised compounds, α, β-unsaturated carbonyl compounds, control in carbonyl condensation, 1,5-difunctionalised compounds. Michael addition and Robinson annelation, Retrosynthetic analysis and synthetic design of Tamiflu and Reserpine.

Text books:

1. D. Nasipuri, Stereochemistry of Organic Compounds: Principles and Applications; New Age International Publishers, 2018
2. M. B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanism and Structure, 7ed, Wiley, 2015.
3. W. Carruthers, I. Coldham, Some modern methods of Organic Synthesis, 4th ed., Cambridge Univ. Press, 2015.
4. S. Warren, Organic Synthesis: The Disconnection Approach, Wiley 2007

Reference books:

1. E. L. Eliel, Stereochemistry of Organic Compounds, Wilel, 2008
2. S. Warren, P. Wyatt Workbook for Organic Synthesis: The Disconnection Approach, 2nd ed., Wiley, 2010.
3. Norman and Coxon, Principle of Organic Synthesis, 3rd ed., CRC Press, 1993.
4. I. Ojima, Catalytic Asymmetric Synthesis, 3rd ed, John Wiley & Sons, New Jersey, 2010.
5. V. Sunjic, V. P. Perokovic; Organic Chemistry from Retrosynthesis to Asymmetric Synthesis, Springer, 2016

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√		
Quiz –I	√			
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	M	H	L	L
CO2	H	H	M	L
CO3	H	H	H	M
CO4	H	M	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect No.	Ch. No.	Topics to be covered	TextBook /References	COs mapped	Methodology used
1-3	L1-L09	**1**	Advanced Stereochemistry	**T1, R1**	**1**	**PPT Digi Class/Chock -Board**
3-5	L10-L18	**2**	Neighboring Group Participation	**T2, R3**	**1**	**-do-**
5-7	L19-L27	**3**	Catalytic Asymmetric Synthesis	**T1, T2 R4**	**2**	**-do-**
7-9	L28-L36	**4**	Principles of Retrosynthesis	**T4, R2, R5**	**3**	**-do-**
9-12	L37-L45	**5**	Retrosynthetic analsis	**T4, R2, R5**	**3**	**-do-**

Course code: CH 508
Course title: Advanced Characterization Lab
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Syllabus

I: Examples of organic sample characterization by UV-VIS, IR, NMR, Mass, CHN, mp and single crystal diffraction techniques.

Experiment 1: Synthesis and characterization of sugar intermediates using UV, IR, NMR (^{1}H and ^{13}C), Mass, mp and CHN.

Experiment 2: Synthesis of Nucleo-base analogs and characterization using UV, IR, NMR (^{1}H and ^{13}C), Mass, mp and CHN.

Experiment 3: Synthesis of Benzanilide and characterization using UV, IR, NMR (^{1}H and ^{13}C), Mass, mp and CHN.

II: Examples of bimolecular and polymeric materials characterization using Intense Viscosity Measurement, Molecular Weight Determination and Distribution using GPC, Light Scattering Technique, FTIR, NMR, SEM, XRD

Experiment 1: Determination of T_g and T_m of Polyvinyl chloride and methylmethacrylate polymer using TGA/DSC.

Experiment 2: Study of surface morphology of polymeric material /hybrid materials using XRD and SEM.

Experiment 3: Finding out molecular weight of PMMA using light-scattering/GPC.

III: Examples of inorganic sample characterization

Experiment 1: Thermogravimetric analysis of $CuSO_4.\ 5H_2O$

Experiment 2: Synthesis & characterization of Fluorescent Zn complexes by spectrofluoremeter.

Experiment 3: Study of surface morphology of inorganic materials using XRD and SEM.

Reference book:

1. V. R. Gowariker, N. V. Viswanathan & J. Sreedhar, Polymer Science, New Age International (P) Ltd. Publishers, 1986.
2. W. Kemp, Organic Spectroscopy, Palgrave, Reprint 2009.
3. Suryanarayana, C.; Norton, M. G. X-Ray Diffraction - A Practical Approach, Springer Publishers, 1998.
4. Lyman, C. E. et al., K.-R.Scanning Electron Microscopy, X-Ray Microanalysis, and Analytical Electron Microscopy, Springer Publishers, 1990.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Course code: CH 509
Course title: Inorganic Chemistry (SPL) Lab
Pre-requisite(s): B.Sc. (H) Chemistry
Co- requisite(s):
Credits: 2 L: T: P: 4
Class schedule per week: 04
Class: M.sc. and I M.Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Syllabus

1. Determination of conductivity of 1:1, 1:2 and 1:3 complexes.
2. Kinetics of Hg(II) catalysed reaction of $[FeCN_6]^{4-}$ with 1,10-*ortho* phenonthroline and its application in the determination of trace quantity of Hg(II).
3. Study of the conductance of $H[Co(DMGH)_2Cl_2]$ in freshly prepared aqueous solution and its change with time for studying the rate of aquation.
4. pH metric determination of Proton- Ligand and Metal-Ligand stability constants.
5. Colorimetric study of the kinetics of the reduction of azidopentaminecobalt(III) chloride by aqueous Fe(II) ion.
6. Colorimetry: Simultaneous determination of chromium and manganese in a solution by visible spectroscopy.
7. Spectrofluorometric determination of lanthanide elements in dilute solution.
8. Quantitative determination of DNA–Ligand binding using fluorescence spectroscopy.
9. Determination of magnetic moment of the lanthanides by Gouy's method.
10. Use of ligand field tetragonality on the ground state spin of Ni(II) complexes.
11. Determination of formal potential of electronically non-innocent ligands.
12. Determination of formal potential of metal complexes.

Reference books:

1. M. V. Cases, Principles of analytical chemistry, Springer, 2000.
2. D. Harvey, Modern Analytical Chemistry; Mcgraw-Hill, 2000.
3. A. J. Bard and I. Rubinstein, Electroanalytical Chemistry, CRC Press, 1998.
4. Electroanalytical Chemistry: A Series of Advances: Volume 24, A. J. Bard and C. Zoski, CRC Press, 2017.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Course code: CH 510
Course title: Physical Chemistry (SPL) Lab
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 2 L: 0 T: 0 P: 4
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Syllabus

1. To determine pH of a buffer solution using quinhydrone electrode.
2. Oscillatory reaction: Chemical oscillation & pattern formation in B-Z system.
3. To study the phase diagram of two components forming a simple eutectic.
4. To determine the molecular weight of a polymer from viscosity measurements.
5. To determine magnetic susceptibility by Guoy balance.
6. To determine the surface area of alumina by BET surface area determination method.
7. To determine the solubility product by conductivity and potentiometric methods.
8. Stability constants of complexes by the use of pH meter, potentiometric method.
9. Reversibility of an electrochemical reactions and determination of concentration of a given reducible ion-Polarography.
10. To determine the Tafel constants, the corrosion current and the linear polarisation resistance from polarisation curves.
11. Electrochemical impedance spectroscopy (EIS) study and formation of equivalent circuit diagram.
12. To determine the effect of change of temperature, concentration of reactant and catalyst and ionic strength of the media on the velocity constant of hydrolysis of an ester.

Text books:

1. B. Viswanathan, and P. S. Raghavan, Practical Physical Chemistry, Viva Books, 2010.
2. J. B. Yadav, Advanced Practical Physical Chemistry, 22nd edition, Goel publishing House, Krishna Prakashan Media Ltd. 2005.
3. V. Venkatesan, R. Veeraswamy and A.R. Kulandaivelu, Basic Principles of Practical Chemistry, 2nd ed., Sultan Chand and Sons Publication, New Delhi. 1997.
4. D. Harvey, Modern Analytical Chemistry; Mcgraw-Hill, 2000.

Reference books:

1. B. P. Levitt, Findlays Practical Physical Chemistry, 9th ed., Longman, London, 1985.
2. G. R. Chatwal and S. K. Anand, Instrumental Methods of Chemical Analysis, Himalaya Publishing House, Delhi, 2000.
3. A. M. Halpern and G. C. McBane, Experimental Physical Chemistry: A Laboratory Text Book, 3rd ed., W. H. Freeman, 2006.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Course code: CH 511
Course title: Organic Chemistry (SPL) Lab
Pre-requisite(s): B.Sc. (H) Chemistry
Co- requisite(s):
Credits:2 L: 0 T: 0 P: 4
Class schedule per week: 04
Class: M.Sc. and I. M. Sc.
Semester / Level: M. Sc. III/ I. M. Sc. IX
Branch: Chemistry
Name of Teacher:

Syllabus

1. Synthesis of alcohol from the reaction of a Grignard reagent and a ketone.
2. Synthesis of an alkene from dehydration of the alcohol prepared in previous step.
3. Multi-step reactions, (Cyclohexanone to methyl cyclohexane) using i) Grignard reaction ii) Dehydration iii) High-pressure hydrogenation.
4. Anthranilic acid from phthalic anhydride.
5. Synthesis of Nylon 6 starting from cyclohexanone.
6. Characterization of an organic compound through CHN, Mass, FTIR, NMR and single crystal X-ray diffraction.

Reference Books:

1. A. I. Vogel, Quantitative Organic Analysis, Part 3, Pearson, 2012.
2. F. G. Mann, & B. C. Saunders, Practical Organic Chemistry, Pearson Education, 2009.
3. B. S. Furniss, A. J. Hannaford, P. W. G.Smith, A. R. Tatchell, Practical Organic Chemistry, 5th ed., Pearson, 2012.
4. V. K. Ahluwalia and R. Aggarwal, Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press, 2000.
5. V. K. Ahluwalia and S. Dhingra, Comprehensive Practical Organic Chemistry: Qualitative Analysis, University Press, 2000.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Course code: CH 513 (SPL-III)
Course title: Inorganic Chemistry-X: Inorganic Photochemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. IV/ I. M. Sc. X
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the photolytic excited state
B.	To know the techniques to study the excited state
C.	To learn the photochemistry of polypyridyl complexes and porphyrins
D.	To know the application of inorganic photochemistry

Course Outcomes

After the completion of this course, students will be:

1.	To explain photochemical excited state
2.	To determine the properties of the excited state
3.	To explain the photochemical properties of polypyridyl complexes and porphyrins
4.	To explain the application of inorganic photochemistry

Syllabus

Module I Photophysical properties of excited state (9 Lectures)
Absorption spectra and electronic transitions, Assignment of electronic transitions, Charge transfer transition, Radiative decay, Non-radiative decay and the energy gap law, Classification of the excited state- MLCT, MC & LC excited state, Reactivity pattern of the excited state, Electronic excited state of d^3 and d^6 complexes, Solvent effects and dipole moment of the excited state, Acid- base reactions of the excited states.

Module II Photochemical reactions and techniques for the study of excited state (9 Lectures)
Bimolecular quenching of the excited state, Energy and electron transfer quenching, Energetics, Photoredox reactions of metal complexes - Thermal electron transfer process: Classical treatment and self exchange type, Energy transfer reactions of the excited state, Excited state acid-base reactions, Photoinduced electron transfer, Photoinduced energy transfer (Forster and Dexter mechanism), Characterization of the excited state by steady state methods and Time-Resolved methods (Flash Photolysis), Time resolved conductivity, Electron spin resonance, Photoselection, Study photo-redox and energy transfer reactions, Study of the photosubstitution reactions.

Module III Photochemistry of the Polypyridyl complexes and porphyrins (9 Lectures)
Polypyridyl ligands as chelating agents, Free ligand and metal complexes excited state, Ground and excited state redox properties, General trends in polynuclear and ortho-metallated complexes, Polypyridyl complexes of Fe, Ru, Os, Cr and Cu Photochemical applications of Polypyridyl complexes: Catalysed photodecomposition of H_2O to H_2, and O_2, Catalysed photoreduction of CO and CO_2, $Ru(bpy)_3^{2+}$ as dye for DSSC.

Module IV Photochemistry of Porphyrins (9 Lectures)
Introduction to porphyrin, Types of porphyrin and their general features, Classification based on peripheral substitution, Reduced porphyrins, Electronic spectroscopy of metalloporphyrin- Classification based on absorption and emission spectral feature, Description on metalloporphyrin ground and excited

state, Different types of excited states of porphyrins. Resonance Raman spectra of metalloporphyrins. Hypso porphyrins: luminiscent type- Cu Porphyrin, Ag Porphyrin, Phosporescent type- Au Porphyrins, Pt Porphyrins, Pd Porphyrins, Rh Porphyrins, Ru Porphyrins, Os Porphyrins; Radiationless Hypso Porphyrins: Fe and Co Porphyrins, Hyper porphyrine: d type- Cr and Mn Porphyrins, p Type-Metalloid porphyrins; Pseudo normal Porphyrins-Lanthanide porphyrins..

Module V Application of Inorganic Photochemistry (9 Lectures)

Environment cleaning: Photocatalytic reactions of volatile hydrocarbons, Photocatalytic activity of TiO_2 in cleaning air pollutants, Photocatalyst based air purifying materials.

Porphyrin and photosynthesis, Active site structure of Chlorophyl, Accessory Pigments and Extended Range of Light Absorption, Exciton Transfer; Central Photochemical Event: Light-Driven Electron Flow, The Pheophytin-Quinone Reaction Center, Functional modules of photosynthetic machinery- *Z* Scheme, Biomimetic energy production- Artificial photosynthesis, Photosynthetic cell, Dye Sensitised Solar Cell, Tandem Cell.

Text books:

1. K. Kalyanasundaram, Photochemistry of Polypyridine and Porphyrin Complexes; Academic Press Limited: London, 1992.

Reference books:

1. M. Kaneko, I. Okura, Photocatalysis: Science and Technilogy, Springer
2. E. A. B. Ebsworth, D. W. H. Rankin, S. Cardock, Structural methods in Inorganic Chemistry; 2nd ed., Wiley-Blackwell, 1991.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√		
Quiz –I	√	√		
Quiz-II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-2	L1-L09	**1**	Photophysical properties of excited state	**T1, R1**	**1**	**PPT Digi Class/Chock -Board**
3-6	L10-L18	**2**	Photochemical reactions and techniques for the study of excited state	**T1, R2**	**2**	**-do-**
7-8	L19-L27	**3**	Photochemistry of the Polypyridyl complexes and porphyrins	**T1, R1**	**3**	**-do-**
8-13	L28-L36	**4**	Photochemistry of Porphyrins	**T1**	**4**	**-do-**
13-15	L37-L45	**5**	Application of Inorganic Photochemistry	**T1, R1**	**5**	**-do-**

Course code: CH 514 (SPL-III)
Course title: Chemical Applications of Group Theory
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. IV/ I. M. Sc. X
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To apply the great orthogonality theorem to derive simple point groups and illustrate its use in the applications in crystal field theory, pericyclic reactions and molecular spectroscopy.

Course Outcomes

After the completion of this course, students will be:

1.	Able to determinethe symmetry operations of any small and medium-sized molecule and apply point group theory to the study of electrical, optical and magnetic properties and selection rules for absorption.

Syllabus

Module I: Molecular Vibrations (9 lectures)
Group theory and normal modes of vibrations of polyatomic molecules. Procedure for determining the irreducible representation of the vibrational modes for H_2O, NH_3 molecules. Selection rules for fundamental vibration transition.

Module II: Molecular Orbital (MO) Theory & its Application in Organic Chemistry (9 lectures)
Symmetry factoring of secular equations, carbocyclic system, LCAO-MO π-bonding for naphthalene & formaldehyde. Electronic excitation, Selection Rule and Configuration interaction, Three-centre bonding, Symmetry-based selection rule for cyclization reaction.

Module III: MO Theory for Inorganic & Organometallic Compounds (9 lectures)
Transform properties of atomic orbitals, hybridization scheme for σ & π bonding orbitals; MO theory for AB_n-type of molecules and regular octahedral and tetrahedral molecules.

Module IV: Ligand Field Theory (9 lectures)
Electronic structure of free atoms and ions; Splitting of levels and terms in chemical environment, Construction of energy level diagrams; Estimation of orbital energy; Selection rules and polarization; Double groups.

Module V: Crystallographic Symmetry (9 lectures)
Two-dimensional space symmetries; Three-dimensional and their symmetries; Crystal symmetry; Interrelating lattice symmetry, crystal symmetry & diffraction symmetry; Additional symmetry elements & operations; Space groups and X-ray crystallography.

Text books:

1. F. A. Cotton, Chemical Applications of Group Theory, 3rded., Wiley Eastern Limited, 1985.
2. V. Ramakrishnan and M. S. Gopinathan: Group Theory in chemistry, Vishal Publication, 1986.

Reference books:

1. P. Atkins, R. Friedman, Molecular Quantum Mechanics, 4th ed., Oxford University Press, 2005.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1
Assignment	√
Quiz -1	√
Quiz II	√
End Sem Examination Marks	√

Indirect Assessment –
1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO 1	CD1
CD2	Tutorials/Assignments	CO 1	CD1, 2
CD3	Seminars	CO 1	CD3
CD4	Mini projects/Projects	CO 1	CD4
CD5	Laboratory experiments/teaching aids	CO 1	CD5
CD6	Self- learning such as use of NPTEL materials and internet	CO 1	CD6
CD7	Simulation	CO 1	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L09	**1**	Group Theory and normal modes of vibration for polyatomic molecules	**T1, T2,R1**	**1**	**PPT Digi Class/Chock -Board**
3-5	L10-L18	**2**	Molecular Orbital (MO) Theory and its Application	**T1, T2,R1**	**1**	**-do-**
6-10	L19-L27	**3**	MO Theory for Inorganic Compound	**T1, T2,R1**	**1**	**-do-**
11	L28-L36	**4**	Ligand Field Theory	**T1, T2,R1**	**1**	**-do-**
12-15	L37-L45	**5**	Crystallographic Symmetry	**T1, T2,R1**	**1**	**-do-**

Course code: CH 515 (SPL-III)
Course title: Interdisciplinary Organic Chemistry
Pre-requisite(s): B. Sc. (H) Chemistry
Co- requisite(s):
Credits: 4 L: 3 T: 1 P: 0
Class schedule per week: 04
Class: M. Sc. and I. M. Sc.
Semester / Level: M. Sc. IV/ I. M. Sc. X
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the structure and functions of Carbohydrate, peptides, proteins, flavonoids, terpenoids and steroids in biological system. How to differentiate reducing and non-reducing sugars.
B.	Study reactions involving peptide synthesis, biosynthesis of Steroids.
C.	To understand polymer chemistry including Properties of polymers, Methods of polymerization and processing.
D.	To design safer chemicals, safer solvents and auxiliaries, energy efficient reactions for Green synthesis.

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain structure and functions of Carbohydrate, peptides, proteins, flavonoids, terpenoids and steroids.
2.	Able to explain properties of polymers, their methods of preparation and processing.
3.	Able to design safer chemicals, safer solvents and auxiliaries, energy efficient reactions for Green synthesis
4.	Able to explain the principles of green chemistry

Syllabus

Module I: Carbohydrate chemistry (10 Lectures)

Biological importance of monosaccharides (aldohexose-glucose, mannose, galactose; epimers; ketohexose–fructose,; aldopentose-riboses; deoxysugars-deoxyribose; fucose; rhamanose), polysaccharides (cellulose, glycogen, starch, chitin, agar), Glycoprotein, proteoglycan, glycosaminoglycan, muramic acid, sialic acid. Molish's test for carbohydrate, reaction of monosaccharides with nitric acid, bromine water, periodic acid and phenylhydrazine, osazone formation, reaction of deoxyribose with DPA and reaction of ribose with orcinol reagent; glycosidic linkage, disaccharides (sucrose-invert sugar, inversion of sucrose, maltose and lactose) reducing and non-reducing sugar (tests for reducing sugars, reaction with Benedict's reagent, Fehling's solution, Tollen's reagent, Seliwanoff test for ketose)

Module II: Peptide Chemistry (10 Lectures)

Example of biologically important peptides and their functions in brief (glutathione-peptide of non-protein origin), Merrifield solid-phase peptide synthesis using protection/ deprotection protocol (brief outline). Deprotection and racemization in peptide synthesis. Solution and solid phase techniques. Proteins: Definition & structure, primary, secondary, tertiary and quaternary structure (definition and example), structure of globular protein (albumin, globulin, haemoglobin & myoglobin – Structure, function and occurrence in brief) Behaviour of proteins in solutions, salting in and salting out, Denaturation and renaturation of proteins (example -RNase), absorbance of proteins, example of metalloprotein, lipoprotein.

Module III: Natural Product Chemistry (9 Lectures)

Flavonoid Chemistry: Anthocyanims, Flavonols and flavones; Quinone chemistry. Terpenoids: Structure and Methods for Structure elucidation. Biosynthesis of Terpenoids: Gibberellins. Acyclic (Squalene), Lanosterol, Ursolic acid & Oleanolic acid. Alkaloid Chemistry: Opium, Ergot, Rauwolfia and Vinca alkaloids. Cyanogenic glycosides, Indoles and Chlorophylls. Steroid chemistry: Introduction & Biosynthesis of Steroids. Phytosterols, Saponins & Sapogenins, Cardiotonic glucosides, Steroidal alkaloids: Solanum and Kurchi alkaloids.

Module IV: Polymer Chemistry (8 Lectures)

Methods of polymerization: Bulk, solution, suspension, emulsion, Addition, Melt and condensation.

Properties of polymers: Viscosity, end-group analysis, hardness, abrasion resistance, crystallinity glassy state, glass transition temperature (T_g) and melting point (T_m).

Additives in polymers: Plasticizers, stabilizers, antioxidants, fillers, pigments

Polymer processing: Compounding, calendaring, die/rotational/film casting, injection molding, extrusion molding, thermoforming, foaming and reinforcing.

Module V: Green Chemistry (8 Lectures)

Introduction to the principles of green chemistry – prevention of waste, atom economy, less hazardous chemical syntheses, designing safer chemicals, safer solvents and auxiliaries, design for energy efficiency, reduce derivatives, renewable feedstock, catalysis, design for degradation, Green synthesis, clean routes, supercritical solvents, ionic liquids, Catalysis in green chemistry.

Text books:

1. I. L. Finar Organic Chemistry Vol. II., Stereochemistry and the Chemistry Natural Products, 5th ed., Longman Ltd., New Delhi, 2011.
2. A. Ravve, Principles of Polymer Chemistry, Plenum Press, New York, Springer 3rd Edition, May 2012.
3. V. R Gowarikar, Vishwanathan Srikanth, Polymer Chemistry, Wiley Eastern, Bombay, 2000.
4. V. K. Ahluwalia, Green Chemistry: Greener Alternatives to Synthetic Organic Transformations- Narosa Publishing House.

Reference books:

1. T.K. Lindhorst: Essentials of Carbohydrate Chemistry and Biochemistry, 3rd ed., Wiley-VCH, Weinheim 2007.
2. P. D. Bailey, An Introduction to Peptide Chemistry; Wiley-Blackwell; Revised ed. edition (22 April 1992)
3. S. V. Bhat, B. A. Nagasampagi, M. Shivakumar: Chemistry of Natural Products; Narosa Publishing House; Revised edition (27 September 2013)
4. V. K. Ahluwalia, Anuradha Mishra Polymer Science:, Ane Books Pvt. Ltd.
5. M. Lancaster, Green Chemistry: In Introductory Text, RSC Publishing, 2010

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	10
Seminar before a commitee	10
Three Quizzes	10+10+10
End Sem Examination Marks	50

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√	√	
Quiz -1	√			
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	M	H	M	L
CO2	H	H	M	L
CO3	H	H	H	M
CO4	H	M	L	H

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L09	**1**	Carbohydrate Chemistry	**T1, R1**	**1**	**PPT Digi Class/Chock -Board**
4-6	L10-L18	**2**	Chemistry of Peptide and Proteins	**T1, R2**	**1**	**-do-**
7-9	L19-L27	**3**	Natural Product Chemistry	**T1, R3**	**2**	**-do-**
10-12	L28-L36	**4**	Polymer Chemistry	**T2, T3, R4**	**3**	**-do-**
13-15	L37-L45	**5**	Green Chemistry	**T4, R5**	**4**	**-do-**

OPEN ELECTIVES (OE) FOR PG PROGRAMME

Course code: CH 415
Course title: Molecular Structure by NMR & X-Ray Crystallography
Pre-requisite(s): B.Sc./ B. Pharm
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. E/ M. Pharm
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the theory and principle of NMR spectroscopy
B.	To know the applications of NMR spectroscopy
C.	To grow the knowledge on crystal structure
D.	To know the instrumental techniques on NMR spectroscopy and X ray crystallography

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain several parameters on NMR spectroscopy
2.	Able to interpret the nmr spectrum to find the molecular formula
3.	Able to explain different parameters of solid state and X-ray crystallography
4.	Able to experimentally determine the molecular structure by NMR and X-ray

Syllabus

Module-I: Introduction to Nuclear Magnetic Resonance Spectroscopy (9 Lectures)
Physical Basis of NMR Spectroscopy, 1H NMR: NMR Spectrum, Chemical Shift, Chemical Shift Scales, Integral, Chemcial Shift and Structural Relation, Spin-Spin Splitting, Coupling constant, shielding mechanism, effect of deuteration, Anisotropic effects in alkene, alkyne, aldehydes and aromatics. Parameters in NMR of important spin 1/2 nuclei (1H, 19F, 13C, 31P etc.): (a) Chemical shift (b) Spin-spin coupling (J-coupling) (c) Relaxation mechanisms (d) Nuclear Overhauser Effect

Module-II: 13C-and 2D NMR: **(9 Lectures)**
Brief introduction to ^{13}C NMR, chemical shifts, coupling constants and examples. 2D-NMR: spectroscopy-COSY, NOESY, DEPT. DEPT with 3 different angles, Basics of 2D NMR experiments (the basic 2D spectrum; 2D pulse sequences incorporating polarization transfer and coherence transfer experiments for enhancing spectral resolution and structural detail. Interpretation of 2D spectra and examples. Problems/Examples to solve unknown structure using spectral data of NMR, Mass, UV, & IR

Module-III: Crystals and crystal structures (9 Lectures)
Crystal families and crystal systems, Morphology and crystal classes, The description of crystal structures, The cubic close-packed (A1) structure of copper, The body-centred cubic (A2) structure of tungsten, The hexagonal (A3) structure of magnesium, The halite structure, The rutile structure, The fluorite structure, The structure of urea, The density of a crystal

Module-IV: Lattices, planes and symmetry (9 Lectures)
Unit cells, The reciprocal lattice, The reciprocal, Lattice planes and Miller indices, Hexagonal lattices and Miller-Bravais indices, Miller indices and planes in crystals, Directions, The symmetry of an object: Centre of symmetry, Axes of inversion, The symmetry of the Bravais lattices, The crystallographic point groups, Bragg's law, Symmetry and reflection intensities,

Module-V: Instrumentation, Software and Structure solution (9 Lectures)

NMR instrumentation; spectrometer components and their function, superconducting magnets, probe heads, NMR data processing: zero filling, window functions, etc. Spectral analysis in 1 dimension with examples, Weakly and strongly J-coupled spectra and their analysis. Pulse, FID, DELTA Software for spectrum generation. Single Crystal Diffractometer and Structure Solution, Structure determination using X-ray diffraction, Refinement, ORTEP diagram and Crystal Information File creation

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	**% Contribution during CO Assessment**
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**
Assignment	√	√		
Quiz -1		√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L9	1	Basics of NMR spectroscopy	T1, T2	1	PPT Digi Class/Chock -Board
4-6	L10-L18	2	Study of different types of NMR spectra	T1,T2,T3 R1,R3	1	-do-
7-9	L19-L27	3	Basics of X- ray crystallography	T2, T3	1, 2	-do-
10-12	L28-L36	4	Solid state and molecular symmetry	T3,R1	3	-do-
13-15	L37-L45	5	Structure determination form nmr and X-ray	T1,T2,T3, R1,R2	2	-do-

Course code: CH 416
Course title: Electroanalytical Techniques
Pre-requisite(s): B.Sc./ B. Pharm/ B.Tech
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. E/ M. Pharm
Semester / Level: PG
Branch: Chemistry
Name of Teacher:
Course Objectives

This course enables the students:

A.	To understand the theory and principle of electrochemistry
B.	To know the applications of electrochemistry
C.	To grow the knowledge on electroanalytical techniques
D.	To know the instrumental techniques on electrochemical analysis

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain different parameters on electrochemistry
2.	Able to interpret the electrochemical processes
3.	Able to design the electroanalytical techniques
4.	Able to analyze the sample by electrochemical processes

Syllabus

Module-I: Basics of electro-chemistry (9 Lectures)
Overview of electrochemical concepts and methods; two and three-electrode cell, redox reactions; cell notation; standard potentials, free energy & equilibrium constants; the SHE; the Nernst equation; activity and formal potentials; reference electrodes, etc. Ohmic and non-Ohmic behaviors; Voltage; Impedance; The electric double layer; Electrocapillarity; Current, Diffusion transport; Current-Voltage relation.

Module-II: Electrolysis (9 Lectures)
Current-Voltage relation, Chemical modified electrodes etc., Electrogravimetric analysis at constant current, constant potential and at controlled potential, Coulometric analysis, Electrochemical Cells, Types of Electrochemical Cells, Electrolytic Cells, Galvanic Cells, Electrolytic Cell Vs Galvanic Cell, Electrolytic Cell, Multi cation presence in cell, Multi anions presence in cell, Importance of Salt Bridge, IUPAC Cell Representation, Oxidation Side, Salt Bridge, Reduction Side, Preferential Discharge Theory

Module-III:Electrochemical characterization (9 Lectures)
Standard rate constant; transfer coefficient; Tafel equation; Marcus theory; Butler-Volmer equation; Tafel plots; irreversible & quasi-reversible voltammetry, etc. Two types; general methods and calibration; redox and ion-selective electrodes, etc. Definition of reversibility; charging currents; convectionless methods; chronoamperometry; Cottrell equation; linear scan and cyclic voltammetry; polarography; pulse methods; convection methods; rotating disk and ring-disk voltammetry; microelectrodes, etc. Electrochemical Impedance Spectroscopy.

Module-IV:Electrochemical sensors (9 Lectures)
Potentiometric sensors, Potentiometric biosensors, Amperometric sensors, Conductometric sensors, Applications of Field-Effect Transistors sensors, Electroanalytical chemistry in neuroscience. Electrochemistry of redox proteins. Design of third generation electrochemical sensors. Electrochemical

DNA sensors. Electrochemical Impedance spectroscopy and their application. Electrochemical immunoassay: redox and enzyme labeled immunoassay. Electrochemiluminescence and immunoassay; Electrochemical quartz crystal microbalance and its applications.

Module-V: Other electrochemical applications (9 Lectures)

Electrical Energy Storage Device, Batteries, Fuel Cells, Corrosion, Corrosion protection, Technological aspects of electrochemistry, corrosion and stability of metals, electrochemical energy conversion, electricity storage.

Textbooks:

1. A. J. Bard and L. R. Faulkner, Electrochemical Methods: Fundamentals and Applications, John Wiley and Sons., 2nd ed. 2001.
2. D. Pletcher, *A First Course in Electrode Processes*, RSC Publishing, 2nd ed. 2009.

Reference books:

1. F. Scholz, Electroanalytical methods, Springer, 2002.
2. P. Monk, Fundamentals of electroanalytical chemistry, Wiley, 2001.
3. A.P.F. Turner I. Karube, I. G. Wilson, Biosensors- Fundamentals and applications. Oxford University Press, New York, 1987.
4. Brian R. Eggins, Chemical Sensors and Biosensors, Analytical Techniques in the Sciences (ANTS), 2nd Edition, Wiley, 2002.
5. Gabor Harsanyi, Sensors in Biomedical Applications - Fundamentals, Technology and Applications, CRC Press, 2000.
6. Raluca-Ioana Stefan, Electrochemical Sensors in Bioanalysis, CRC Press, 2001.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Industrial/guest lectures
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√		
Quiz -1		√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –
1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	**L1-L9**	**1**	Basics of electro-chemistry	**T1, T2, R3, R4**	**1,2**	**PPT Digi Class/Chock -Board**
3-6	**L10-L18**	**2**	Electrolysis	**T1,T2,R1 R4,R5**	**1,2,3**	**-do-**
7-9	**L19-L27**	**3**	Electrochemical characterization	**T1,T2, R2, R3**	**2, 4**	**-do-**
10-12	**L28-L36**	**4**	Electrochemical sensors	**T1,T2,R1, R6**	**3,4**	**-do-**
13-15	**L37-L45**	**5**	Other electrochemical applications	**T1,T2,R1, R2,R5**	**4**	**-do-**

Course code: CH 417
Course title: Chemistry of Metalloenzymes
Pre-requisite(s): B.Sc./ B. Pharm/ B.Tech
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. E/ M. Pharm
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A	To understand the basic role of metals in biology
B	To know the role and mechanism of metalloenzymes in different biological catalytic process- e.g., acid -base reaction, Reactive oxygen Species (ROS) deactivation, oxidation-reduction process etc.
C	To understand the mechanism of photosynthetic energy production

Course Outcomes

After the completion of this course, students will be:

1.	Able to describe the importance of metals in biology
2.	Able to elucidate the mechanism of several biological catalysis
3.	Able to explain the process of photosynthetic energy production

Syllabus

Module-I: Basics of Bioinorganic Chemistry (9 Lectures)
Fundamentals of coordination chemistry – metal ions and their coordination behavior, ligands, electronic configurations. Elements of life, the natural selection of elements, Mapping the elements with the binding sites in biological systems, Metalloproteins and metalloenzymes -general perspectives, Amino acids and their mode of coordination, preferred geometries of metal ions in metalloproteins, Other Bioligands – Porphyrins, Nucleobases and ATP

Module-II: Enzymes dealing with oxygen and reactive oxygen species (ROS) (9 Lectures)
Oxidase: cytochrome c oxidase – structure, mechanism, electron transfer pathways and synthetic models; Amine oxidase, Galactose oxidase, Catechol oxidase
Oxygenases: Heme mono oxygenase - Cytochrome P450, Non-heme dioxygenase, tyrosinase, Catalase, superoxide dismutase and glutathione, peroxidase

Module-III: Photosynthetic oxygen evolution: (9 Lectures)
The Central Photochemical Event: Light-Driven Electron Flow; Photosystem I and II; Integration of photosystems I and II in chloroplasts- "Z scheme, Water oxidation catalyst - Active site structure, mechanism and model systems,
Concept of Artificial photosynthesis for renewable energy production

Module-IV: Acid–base, Isomerisation and alkyl group transfer catalysis:(9 Lectures)
Zn- carbonic anhydrase, carboxypeptidase, Alkaline phosphatase; Mg - ribulose bisphosphate carboxylase, Fe - Acid phosphatases, aconitase, B_{12}- dependent Isomerase and methyl transferase

Module-V: Biological Cycles (9 Lectures)
Biological nitrogen fixation: Nitrogenase, Mechanistic study, Iron–Sulfur Clusters, Fe–Protein Structure, MoFe–Protein Structure.
Biological hydrogen production: Mechanism and active site structure of Hydrogenase-Fe only hydrogenase, Ni-Fe Hydrogenase

Text books:

1. I. Bertini, H. B. Gray, S. J. Lippard, J. S. Valentine,Bioinorganic Chemistry, University Science Books, Mill Valley, CA, 1994.
2. W. Kaim, B. Schwederski, A. Klein, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life: An Introduction and Guide, Wiley, 1994.
3. L. Stryer, J. M. Berg, J. L. Tymoczko, 5th ed.,W. H. Freeman & Co Ltd, 2002.

Reference books:

1. R. R. Crichton, Biological Inorganic Chemistry, 2nd ed., Elsvier, 2012.
2. R. M. Roat-Malone, Bioinorganic Chemistry: A Short Course, Wiley, 2002.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3
Assignment	√	√	
Quiz –I		√	
Quiz II			√
End Sem Examination Marks	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty

2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3,	CD1
CD2	Tutorials/Assignments	CO1, 2, 3,	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3,	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3,	CD6
CD7	Simulation	CO2,	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L9	1	Basics of Bioinorganic Chemistry	T1, 2,T3,R2	1	PPT Digi Class/Chock -Board
4-6	L10-L18	2	Enzymes dealing with oxygen and reactive oxygen species (ROS)	T1,T2,T3 R2, R3	1	-do-
7-9	L19-L27	3	Photosynthetic oxygen evolution	T2, T3, R2	1, 2	-do-
10-12	L28-L36	4	Acid–base, Isomerisation and alkyl group transfer catalysis	T1, R4	3	-do-
13-15	L37-L45	5	Biological Cycles:	T1,T2	2	-do-

Course code: CH418
Course title: Membrane Science
Pre-requisite(s): B.Sc./ B. Pharm/ B.Tech
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. E/ M. Pharm
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

This course enables the students:

A.	To understand the concepts and applications of membrane and separation process
B.	To strengthen the fundamental concepts of separation and its applications
C.	To apply basic chemistry/science skills, conduct experiments in teams, analyze the results, and communicate these results, in a safe, professional and ethical manner leading to development of separation sciences through membranes

Course Outcomes

After the completion of this course, students will be:

1.	Able to understand concept of membranes for Separation Processes
2.	Able to classify membranes and their mechanism of function
3.	Able to know applications of membranes for gas separation
4.	Able to know applications of membranes for liquid separation
5.	Able to comprehend the working principles of OSN processes

Syllabus

Module I: Separation Process: Membranes for Separation Processes (9 lectures)
Introduction of various membrane separation processes such as gas permeation, pervaporation, reverse osmosis, microfiltration, electrodialysis, membrane reactor, etc. Membrane Preparation:Selection of polymer, solvent and nonsolvent. Methods for preparation of membranes. Basic facilities for preparation of membranes. Rate governed and equilibrium membrane separation processes- Fundamentals, Types of membranes, Modules, Flow patterns, Preparation and characterization of membranes, Melt pressing, Film stretching, Sol-gel peptization, Interfacial polymerization etc. Measurement of pore size and solute rejection properties.

Module II: Membrane Transport (9 lectures)
Reverse osmosis transport. Specification of membranes and predictability of RO membrane performance for aqueous solution systems. Reverse Osmosis- Design and operating parameters, Various transport models, Kedem-katchalsky model, Spiegler-kedem model, Solutiondiffusion model, Concentration polarization and flux decline, Design of an RO module, Forward Osmosis Membrane gas transport. Design of composite membranes for gas separation/Resistance Theory. Dialysis- Principle of dialysis, Dialysis systems, Mass transfer in 4 dialysis, Modeling of solute transport in hemodialyzer, Advantages of diffusion dialysis, Application of diffusion dialysis, Electrodialysis.

Module III: Membrane gas Separation (9 lectures)
Membranes for gas separation, Fundamental mechanism of gas transport, Knudsen diffusion, Molecular sieving, Solution diffusion, Dual sorption model, Factors affecting gas permeation, Complete mixing model, Solution of equations, Equations for multicomponent mixtures, Cross- flow model, Countercurrent Model, Polarisation Phenomena,MembraneModules and Membrane Systems Methods to reduce fouling, Module types. Module calculations and design.

Module IV: Liquid Membrane: (9 lectures)

Benefits of liquid membrane, Bulk liquid membrane, Emulsion liquid membrane, Thin sheet supported liquid membrane, Hollow fibre supported liquid membrane, Applications Facilitated Transport:- Mechanism of facilitated transport, Coupled Transport, Carrier agents, Competitive facilitated transport with two permeants, active and passive transport, Some potential applications of facilitated transport. Membrane Reactor- Membrane bioreactor, Membrane distillation.Theoretical considerations on mass transfer. Membrane devices and transport correlations. Concentration profile in hollow fibre lumen.

Module V: Organic Solvent Nanofiltration (OSN) Processes (9 lectures)

Ultra & Nano filtration, OSN-Background, Membrane Formation and Characterisation, Equipment and Scale Up, Fine Chemicals and Pharma, Process Design, OSN – Refining and Bulk Chemicals, Membrane Transport Models for OSN. Nanofiltration- Transport mechanism in NF membranes, Parameters affecting the performance of NF membranes, Fouling model, determination of various resistances.

Text Books:

1. Membrane Handbook Eds. by W. S. W. Ho and K. K.Sirkar
2. Membrane technology and applications, Baker, R.W., 2nd ed., John Wiley 2004
3. Synthetic membranes: Science, Engineering and Applications, Eds. by P. B. Bunge, H. K. Lonsdale and M. N. Depinho.
4. Ultrafiltration and Microfiltration Handbook, (2nd Edition), Munir Cheryan, CRC Press.
5. Basic Principles of Membrane Separation, Mudler J, (2nd Edition), Springer.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Industrial/guest lectures
Self- learning such as use of NPTEL materials and internet
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4	CO5
Assignment	√	√	√	√	
Quiz –I	√	√			
Quiz II			√	√	
End Sem Examination Marks	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty

2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	M	L
CO3	H	H	H	M
CO4	H	M	H	L
CO5	H	H	L	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, CO2, CO3, CO4, CO5	CD1
CD2	Tutorials/Assignments	CO2, CO3	CD1
CD3	Seminars	CO3, CO4	CD1 and CD2
CD4	Mini projects/Projects	CO1, CO2, CO3, CO4, CO5	CD3 and CD4
CD5	Laboratory experiments/teaching aids	CO2,CO3	CD5
CD6	Industrial/guest lectures	CO4	CD6
CD7	Self- learning such as use of NPTEL materials and internets	CO5	CD7
CD8	Simulation	CO1 CO2	CD8

Lecture wise Lesson planning Details.

WeekNo.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1 - L9	1	Types of membranes, mechanisms involved	1,2	1	PPT Digi Class/Chalk -Board
4-6	L10-18	2	Membrane transport systems	1,2	2	-do-
7-9	L19-27	3	Membranes for gas separation	1,2,3	3	-do-
8-12	L27-36	4	Liquid membranes	1,2,3	4	-do-
13-15	L37-45	5	Organic solvent nanofiltration processess	1,2,3	5	-do-

Course code: CH419
Course title: Environmental Monitoring and Control
Pre-requisite(s): B.Sc./ B. Pharm/ B.Tech
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. E/ M. Pharm
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

This course enables the students:

A.	To understand the concepts and applications of environmental chemistry
B.	To strengthen the fundamental concepts of environmental chemistry and then builds an interface with their applications.
C.	To apply basic chemistry/science skills, conduct experiments in teams, analyze the results, and communicate these results, in a safe, professional and ethical manner leading to better environmental conditions

Course Outcomes

After the completion of this course, students will be:

1.	Able to understand elements of ecology
2.	Able to understand and analyse air pollution monitoring and control practices
3.	Able to understand and analyse water pollution monitoring and control practices
4.	Able to understand Soil, Radiation and Noise pollution
5.	Able to comprehend waste management practices

Syllabus

Module I: Ecology & Environment (9 lectures)
Basic concepts of ecology & ecosystem, Structure and function of an ecosystem, Energy & Nutrient flow, Segments of environment, Environmental factors, Environmental transformation and degradation processes.

Module II: Air pollution monitoring and control (9 lectures)
Sampling and analysis of air pollutants, Units of pollutants, emission standards from industrial sources, control of air pollutants from mobile and stationary emission sources, Various control methods for particulate emission: gravitational settling chambers, cyclone separators, baghouse filters, electrostatic precipitators and wet scrubbers. Control of gaseous emissions, absorption by liquids, adsorption by solids, combustion. Control of Sox, NOx, CO, Hydrocarbons from mobile and stationary emission sources. Indoor air quality

Module III: Water quality and control (9 lectures)
Municipal and industrial water quality, Drinking water standards-PHED and WHO, Sampling techniques and preservation of samples, Physical examination, chemical characterization and Biological investigation,Control measures: Primary, secondary and advanced treatments, Coagulation, flocculation, sedimentation, Industrial water treatment: softening, corrosion and scale prevention

Module IV: Radiation, Noise and Odour: Measurement and control (9 lectures)
Radiation hazards: Types of radiation, sources, effects, control and disposal of nuclear waste. Noise: Sources of Noise, types of noise, noise measurement, mapping, Control measures-Anechoic chambers, Industrial noise abatement measures, Sources of odour, sampling, measurement

Module V: Soil pollution and Solid waste management (9 lectures)
Soil Pollution: Analysis of micro and macro nutrients in soil, Trace element analysis, pesticide analysis
Sources, Classification and composition of MSW, Properties of MSW, MSW management, Waste minimization, Life cycle assessment, benefits, waste reduction techniques, Reuse and recycling, Biological MSW treatment, Thermal treatment, Landfill, Integrated waste management, Case studies

Text books:

1. Environmental Pollution Control Engineering by C.S. Rao.
2. Practical Environmental Analysis by Miroslav Radojevic and Vladimir N. Bashkin, RSC.
3. Environmental Pollution Analysis by S. M. Khopker, New Age International Corporations.
4. An Introduction to Environmental Science & Engineering by Gilbert M. Masters. 5. Chemical analysis of ecological materials by S. E. Allen.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Industrial/guest lectures
Self- learning such as use of NPTEL materials and internet
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√	√	
Quiz -1	√			
Quiz II		√	√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty

2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	M	H	L	L
CO2	H	H	M	L
CO3	H	H	H	M
CO4	H	M	H	L

Mapping Between COs and Course Delivery (CD) methods			
CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, CO2, CO3, CO4, CO5	CD1
CD2	Tutorials/Assignments	CO2, CO3	CD1
CD3	Seminars	CO3, CO4	CD1 and CD2
CD4	Mini projects/Projects	CO1, CO2, CO3, CO4, CO5	CD3 and CD4
CD5	Laboratory experiments/teaching aids	CO2,CO3	CD5
CD6	Industrial/guest lectures	CO4	CD6,CD7
CD7	Self- learning such as use of NPTEL materials and internets	CO5	CD8
CD8	Simulation	CO1 CO2	CD8

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1 - L9	1	Ecology, Biogeochemical cycles, Fate of pollutants	1,2	1	PPT DigiClass/Chalk-Board
4-6	L10-18	2	Air pollution monitoring & control	1,2	2	-do-
7-9	L19-27	3	Water pollution monitoring & control	1,2,3	3	-do-
8-12	L27-36	4	Soil, noise & radiation pollution	1,2,3	4	-do-
13-15	L37-45	5	Solid waste management	1,2,3	5	-do-

Course code: CH420
Course title: Research Methodology and Data Analysis
Pre-requisite(s): B.Sc./ B. Pharm/ B.Tech
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. E/ M. Pharm
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

Syllabus

Module I : Probability Distributions (6 Lectures)

Poisson Distribution, Normal distribution, Lognormal distribution, Student's t- distribution, Chi-squared distribution, Cauchy distribution and Pareto distribution
Calculation of population mean for normal distribution
Geometric mean and geometric standard deviation for lognormal distribution
Calculation of percentiles of a particular distribution.

Module II : Sampling Designs (12 Lectures)

Random Sampling, Stratified Random Sampling, Systematic Sampling, Two-Stage Sampling, Composite and Three-Stage Sampling, Double Sampling, Guidelines for effective sample size determination, Sampling distributions of–Means, Difference of means, Proportion, Variances,estimation of parameters, Point and Interval estimates. Confidence interval estimation of – Means, Difference of means, Proportion, and Variance,estimation of Upper Confidence Limits (UCL) and Lower Confidence Limits (LCL) Formulae of UCL for Normal and Lognormal Distribution,Analysis of environmental data using ANOVA,Method of Censoring Data: Method Detection Limits,Methods to estimate mean and standard deviation in presence of below detection level (BDL) data.

Module III: Time Series Analysis and Extreme Value Theory (10 Lectures)

Introduction
Correlogram analysis
Autocorrelation and partial autocorrelation function
Trend and moving average analysis
Introduction to autoregressive and moving average models
Yule walker equations
Application of univariate models for daily average pollutant concentration series.
Introduction to extreme values
Applications-Forecasting floods, Environmental pollution
Identifying outlying observations
Families of distributions
Analysis of extreme value data
Extremes of data containing trends
Parameter estimation
Extremes of small samples
Reliability computations for extreme value distributions.

Module IV: Tests of Hypotheses and Environmental Data (7 Lectures)

Hypotheses testing procedures
Type I and Type II Errors
Level of significance
Parametric tests – Tests of significance for large samples
Special tests of significance for small samples
Generation of environmental dataType and objectives of environmental studies

Stochastic processes in the environment

Module V: Regression and Correlation Analysis and Data Analysis (10 Lectures)

Student's t-test, Goodness-of-fit tests
Chi-Squared test
Kolmogorov-Smirnov test
Nonparametric test- Sign test
Wilcoxon Signed-Rank test, Kruskal-Wallis test, Runs test;
Measurement Uncertainty, Bias, Precision and Accuracy
Variability and Errors in environmental pollution data
Outlier detection – Different tests for outlier detection
Quality assurance and quality control
Control charts: Description and Theory
Analysis of trend in the environmental data: Detecting and estimating trend, trends and seasonality

Reference

1. Berthouex Paul Mac and Linfield C. Brown, "Statistics for Environmental Engineers", Lewis Publisheres, 1994
2. Murray R. Spiegel, John Schiller, and R. Alu Srinivasan, Probability and Statistics, Second Edition, Tata McGraw-Hill Publishing Company Limited, New Delhi, 2004
3. Catillo Enrique, Extreme Value Theory in Engineering, Academic Press, Inc., Hart-Court Brace Jovanovich, Publishers.
4. Box G.E.P and Jenkins G.M., Time Series Analysis, Forecasting and Control, San Franscisco, Holden day, 1976
5. Robert R. Kinnison, Applied Extreme Value Statistics, Battelle Press, Macmillan Publishing Company, 1985.

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Industrial/guest lectures
Self- learning such as use of NPTEL materials and internet
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4
Assignment	√	√	√	
Quiz -1	√			
Quiz II		√	√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. **Student Feedback on Faculty**
2. **Student Feedback on Course Outcome**

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	M	H	L	L
CO2	H	H	M	L
CO3	H	H	H	M
CO4	H	M	H	L

Mapping Between COs and Course Delivery (CD) methods			
CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, CO2, CO3, CO4, CO5	CD1
CD2	Tutorials/Assignments	CO2, CO3	CD1
CD3	Seminars	CO3, CO4	CD1 and CD2
CD4	Mini projects/Projects	CO1, CO2, CO3, CO4, CO5	CD3 and CD4
CD5	Laboratory experiments/teaching aids	CO2,CO3	CD5
CD6	Industrial/guest lectures	CO4	CD6,CD7
CD7	Self- learning such as use of NPTEL materials and internets	CO5	CD8
CD8	Simulation	CO1 CO2	CD8

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1 - L9	1	Probability Distributions	1,2	1	PPT DigiClass/Chalk-Board
4-6	L10-18	2	Sampling Designs	1,2	2	-do-
7-9	L19-27	3	Time Series Analysis and Extreme Value Theory	1,2,3	3	-do-
8-12	L27-36	4	Tests of Hypotheses and Environmental Data	1,2,3	4	-do-
13-15	L37-45	5	Regression and Correlation Analysis and Data Analysis	1,2,3	5	-do-

Course code: CH 421
Course title: Nuclear and Radiation Chemistry
Pre-requisite(s): B.Sc./ B. Pharm/ B.Tech
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. E/ M. Pharm
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

This course enables the students:

A.	To understand the concepts and applications of radioactivity and nuclear chemistry
B.	To strengthen the fundamental concepts of chemistry and then builds an interface with their applications.
C.	To apply basic chemistry/science skills, conduct experiments in teams, analyze the results, and communicate these results, in a safe, professional and ethical manner

Course Outcomes

After the completion of this course, students will be:

1.	Able to understand radioactivity and nuclear reactions.
2.	Able to classify elements of radiation chemistry
3.	Able to know applications of radioactivity and depict the concept of kinetics
4.	Able to analyse trace elements and compounds and understand the risks involved
5.	Able to comprehend the working of nuclear power plants

Syllabus

Module I:Radioactivity (7 lectures)

Recapitulation: types of radioactive decay, Nuclear reactions: types of nuclear reactions, nuclear cross section, spallation, nuclear fusion nuclear fission-theory of nuclear fission; chain reaction, decay kinetics, radiation detection and measurement separation of isotopes, (G. M. and Scintillation Counter).

Module II: Elements of radiation chemistry: (8 lectures)

Interaction of ionising radiation with matter, units for measuring radiation absorption and radiation energy, radiation dosimetry, radiolysis of water and aqueous solutions.

Module III: Applications of radioisotopes- (10 lectures)

General principles of using radioisotopes, applications of radiotracers in various applications like energy tapping, dating of objects, neutron activation analysis, isotopic labeling studies, nuclear medicine-^{99m}Tc radiopharmaceuticals

Physicochemical constants - diffusion coefficient, surface area, solubility, stability constant.

Chemical pathways - kinetic studies, inorganic reactions, organic reaction, biosynthesis, polymerization.

Module IV: Trace analysis of elements and compounds (12 lectures)

neutron activation analysis, isotope dilution analysis. Isotopes used in nuclear fission reactions. Radioisotopes used in noninvasive imaging techniques in nuclear medicine.

Module V: Nuclear power plants: (8 lectures)

critical mass; nuclear reactors-fast breeder reactors, fuels used in nuclear reactors moderators, coolants Commissioning, working, closure of power plants, Location, on site sampling, analysis, nuclear reactors in India Environmental issues, Future prospects.

Text Books:

1. Essentials of Nuclear Chemistry, H. J. Arnikar, 4th Edition Wiley Eastern (1987).
2. Chemical Applications of Radioisotopes, H. J. M. Bowen. Buttler and Tanner (1969).
3. Introduction of Nuclear and Radiochemistry, G Friedlander, T. W. Kennedy, E. S. Macias and J. M. Miller, 3rd Edition, John Wiley (1981).

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	% Contribution during CO Assessment
Assignment	**10**
Seminar before a commitee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	CO1	CO2	CO3	CO4	CO5
Quiz (s)	√	√	√	√	
Assignment	√	√	√	√	
End Sem Examination Marks	√	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty
2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	M	H	L	L
CO2	H	M	M	L
CO3	H	M	H	M
CO4	H	M	H	L
CO5	H	H	H	M

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, CO2, CO3, CO4, CO5	CD1
CD2	Tutorials/Assignments	CO2, CO3	CD1
CD3	Seminars	CO3, CO4	CD1 and CD2
CD4	Mini projects/Projects	CO1, CO2, CO3, CO4, CO5	CD3 and CD4
CD5	Laboratory experiments/teaching aids	CO2,CO3	CD5
CD6	Self- learning such as use of NPTEL materials and internet	CO5	CD6
CD7	Simulation	CO1 CO2	CD7

Lecture wise Lesson planning Details.

WeekNo.	Lect.No.	Ch. No.	Topics to be covered	TextBook / References	COs mapped	Methodology used
1-2	L1 - L7	1	Radioactivity, Nuclear reactions	1,2	1	PPT Digi Class/ Chalk-Board
3-5	L8-15	2	Elements of radiation chemistry	1,2	2	-do-
6-8	L16-25	3	Applications of radioisotopes	1,2,3	3	-do-
9-12	L26-37	4	Trace analysis of elements	1,2,3	4	-do-
13-15	L38-45	5	Nuclear power plants	1,2,3	5	-do-

Course code: CH 422
Course title: Fuel Chemistry-1
Pre-requisite(s): B.Sc./ B. Tech.
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. Tech
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the knowledge of energy resources and fossil fuels
B.	To make a framework of renewable and non-renewable energy sources
C.	To gain the knowledge of working principle of various fuels systems
D.	To ensure the proper utilization of various fuels for both domestic and industrial application

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain the basic of fuel chemistry
2.	Able to know the importance of various fuels for development of social and industries
3.	Able to explain working principle and efficiency of different fuels
4.	Able to validate the parametric evaluation of various hydrocarbon fuels

Syllabus

Module-I: Energy Resources (9 Lectures)
Renewable and Non-Renewable Energy Resources, Basic of Biomass and Fossil fuels Resources, Introduction of Solar, Wind, Hydro, Tidal, Ocean Thermal Energy Resources, Clean Energy Resources and Monitoring of Environment.

Module-II: Fuels (9 Lectures)
Introduction, Classification of Fuels, Solid Liquid, Gaseous Fuels, Fuels and Combustion, Combustion stoichiometry, Representative parameters of conventional Resources, Calorific Value, Structure and Properties Relationship of Hydrocarbon fuels, Volatility, Melting, Density, Viscosity, Solubility, Flash Point and the Combustion temperature, Lower Heating Value and Higher Heating Value.

Module-III: Solid Natural Fuels (9 Lectures)
Introduction and Principle of Classification, Fuel Characteristics of Solid Fossil Fuels (Woods & Coals) in terms of their Constituents, Calorific Value, Ash, Moisture, Ignition and Combustion.

Module-IV: Solid Fossil Fuels (Coal) (9 Lectures)
Introduction, Uses and Utilization, Classification of Coal, Fuel Characteristics of Coal, Fundamentals of Coal Combustion, Coal Combustion Techniques, Coal Tar Distillation, Coal Liquefaction, Direct Liquefaction, Indirect liquefaction, Coal gasification, combustion stoichiometry, Flue Gas, Producer Gas, Water Gas.

Module-V: Coal Carbonization & Characterization (9 Lectures)
Introduction to Coal Carbonization, Coke Formation, Pre-Carbonization Techniques, Coal Gasification & Liquification, Chemical Composition and their Uses, Coal Metamorphism, Categorizing of coal, Size

analysis, Proximate analysis, Ultimate analysis, Gross calorific value, Net calorific value, Free Swelling Index, Estimation of Total Moisture.

Text Books:

1. Combustion, Irvin Glassman, 2nd ed., Academic Press
2. Fuels Combustion and Furnaces, John Griswold, Mc-Graw Hill Book Company Inc.
3. Fuels and Combustion: Samir Sarkar, University Press (India) Pvt Limited, India
4. Elements of Fuels, Furnaces and Refractories: O P Gupta, Khanna Publishers, India

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	**% Contribution during CO Assessment**
Assignment	**10**
Seminar before a committee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**
Assignment	√	√		
Quiz -1		√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty

2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L9	1	Basics of energy resources	T1, T3	1	PPT Digi Class/Chock -Board
3-8	L10-L18	2	Fundamental of fuel chemistry	T1,T2,T4	1	-do-
8-9	L19-L27	3	Basics of Solid Natural Fuels	T2, T3	1, 2	-do-
9-10	L28-L36	4	Fossil Fuels and Coal combustion	T3,R1	3, 4	-do-
10-12	L37-L45	5	Coal Carbonization and Characterization	T1,T2,T3, R1,R2	2	-do-

Course code: CH 423
Course title: Fuel Chemistry-2
Pre-requisite(s): B.Sc./ B. Tech.
Co- requisite(s):
Credits: 3 L: 3 T: 0 P: 0
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M. E./M. Tech
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

Course Objectives

This course enables the students:

A.	To understand the knowledge of petroleum liquid fuels
B.	To know the basic of gaseous fuels
C.	To gain the knowledge of processing and utility standard of petroleum liquid and solid fuels
D.	To ensure the proper utilization of various liquid and gaseous fuels for both domestic and industrial applications

Course Outcomes

After the completion of this course, students will be:

1.	Able to explain the basic of petroleum liquid and gaseous fuels
2.	Able to know the compositional characteristics of various liquid/gaseous fuels for application
3.	Able to explain efficiency based characterization of different liquid/gaseous fuels
4.	Able to validate the parametric standard of liquid/gaseous fuels

Syllabus

Module-I: Liquid and Gaseous Fuels (9 Lectures)
Basic Introduction of Liquid Fuels, Gaseous Fuels, Natural Gas and Light Hydrocarbons gaseous fuels, Fuels containing Biomass/Biogas and Hydrogen energy.

Module-II: Liquid Fuels (9 Lectures)
Liquid Fuels Resources, Classifications, Characterization Method of crude oils, Refinery Techniques and Operations, Industrial process design, Utilization of Petroleum Products, Synthetic liquid fuels.

Module-III: Gaseous Fuels (9 Lectures)
Different Types of Gaseous Fuels, Resources and Characteristics of Gaseous Fuels, Principles of Manufacturing of Gaseous Fuels from Coal and Oil, Kinetics and Mechanism of Gasification, Production of Industrial Fuel Gases, Rich Gases such as SNG, Purification, Storage and Transportation of Gaseous Fuels.

Module-IV: Liquid lubricants (9 Lectures)
Introduction, Principle and Basic mechanism of action of additives, Antioxidants, Detergents and Dispersants, Anti- Corrosion Additives, Anti-Foam Additives, Emulsifiers, Viscosity Modifiers, Viscosity- Temperature Curve, Anti-Wear and Lubricity Additives, Extreme Pressure Additives, biocides.

Module-V: Significance Fuel additives **(9 Lectures)**

Effect of Fuels and Lubricants on Environment, Properties Regenerated Lubricating Oil and Recycling Technology for Used Oil.

Text and Reference Books:

1. Modern Petroleum Technology,Vol 1, Upstream,Ed. by Richard A. Dave, IP, 6th ed., John Wiley & Sons. Ltd.
2. Modern Petroleum Technology,Vol 2, Downstream,Ed. by Alan G. Lucas, IP, 6th ed., John Wiley & Sons. Ltd.
3. Modern Petroleum Technology,Vol 1, Upstream,Ed. by Richard A. Dave, IP, 6th ed., John Wiley & Sons. Ltd.
4. Modern Petroleum Refining Processes, B.K.Bhaskar Rao, 4th ed., Oxford & IBH Publishing Co.Pvt. Ltd

Course Delivery methods
Lecture by use of boards/LCD projectors/OHP projectors
Tutorials/Assignments
Seminars
Mini projects/Projects
Laboratory experiments/teaching aids
Self- learning such as use of NPTEL materials and internets
Simulation

Course Outcome (CO) Attainment Assessment tools & Evaluation procedure

Direct Assessment

Assessment Tool	**% Contribution during CO Assessment**
Assignment	**10**
Seminar before a committee	**10**
Three Quizzes	**10+10+10**
End Sem Examination Marks	**50**

Assessment Components	**CO1**	**CO2**	**CO3**	**CO4**
Assignment	√	√		
Quiz -1		√		
Quiz II			√	
End Sem Examination Marks	√	√	√	√

Indirect Assessment –

1. Student Feedback on Faculty

2. Student Feedback on Course Outcome

Mapping between Objectives and Outcomes

Course Outcome #	Program Outcomes			
	PO1	PO2	PO3	PO4
CO1	H	H	L	L
CO2	H	H	H	L
CO3	H	H	H	L
CO4	M	H	H	L

Mapping Between COs and Course Delivery (CD) methods

CD	Course Delivery methods	Course Outcome	Course Delivery Method
CD1	Lecture by use of boards/LCD projectors/OHP projectors	CO1, 2, 3, 4	CD1
CD2	Tutorials/Assignments	CO1, 2, 3, 4	CD1,CD2
CD3	Seminars	CO 2, 3	CD3
CD4	Mini projects/Projects	CO3, 4	CD4
CD5	Laboratory experiments/teaching aids	CO 1, 2, 3	CD5
CD6	Self- learning such as use of NPTEL materials and internets	CO1, 2, 3, 4	CD6
CD7	Simulation	CO2, 4	CD7

Lecture wise Lesson planning Details.

Week No.	Lect. No.	Ch. No.	Topics to be covered	Text Book / References	COs mapped	Methodology used
1-3	L1-L9	1	Basics Liquid and Gaseous Fuels	T1, T4	1	PPT Digi Class/Chock -Board
3-6	L10-L18	2	Fundamental of Liquid Fuels	T1,T2,T3	1	-do-
6-8	L19-L27	3	Basics of Gaseous Fuels	T2, T2	1, 2	-do-
8-10	L28-L36	4	Liquid lubricants	T1,R4	3, 4	-do-
10-12	L37-L45	5	Significance Fuel additives	T3, T4	2	-do-

Course code: CH 424
Course title: Fuel Chemistry Lab
Pre-requisite(s): B.Sc./ B. Tech.
Co- requisite(s):
Credits: 1.5 L: 0 T: 0 P: 1.5
Class schedule per week: 03
Class: M. Sc./ I. M. Sc/ M.E./M. Tech
Semester / Level: PG
Branch: Chemistry
Name of Teacher:

Syllabus

- Determination of Flash and Fire points of Liquid fuels
- Determination of Viscosity of Petroleum Liquid Fuels using Redwood Viscometer
- Spectroscopic characterization of Liquid Fuels
- Determination of Carbon residue Liquid fuels-A
- Determination of Carbon residue Liquid fuels-A
- Determination of Cloud and Pour point of Liquid fuels
- Determination of Proximate Analysis of coal
- Determination of Ultimate Analysis of coal
- Determination of Calorific value: of Gaseous fuels using Junkers Gas Calorimeter
- Determination of Calorific value of coal using bomb calorimeter
- Pyrolysis & Degradation of Coal Sample.
- Determination of Aniline point of given fuels.

Assessment Tool	% Contribution
Progressive Evaluation	**60 (Day to day performance: 30, Quiz: 10, Viva: 20)**
End Sem Examination	**40 (Experiment Performance: 30, Quiz: 10)**

Text Books & Reference Books:

1. Fuels and Combustion: Samir Sarkar, University Press (India) Pvt Limited, India.
2. Elements of Fuels, Furnaces and Refractories: O P Gupta, Khanna Publishers, India
3. Fuels, Furnaces and Refractories: R C Gupta, PHI Learning Private Limited, India
4. A Text Book of Engineering Chemistry by Shashi Chawla, Dhanpat Rai & Sons, India.