M.Sc. Chemistry Syllabus

(As per NEP 2020)

Assam University, Silchar

M.Sc. Chemistry Course Structure

First Semester

Paper code	Description	Credit	Hours/week	Marks
CHM-500	Orientation	Nil		
CHM-501	Inorganic Chemistry –I (CC)	4	4	100
CHM-502	Organic Chemistry –I (CC)	4	4	100
CHM-503	Physical Chemistry –I (CC)	4	4	100
CHM-504	Applied Chemistry (SEC)	3	3	100
CHM-505	Laboratory course in Inorganic Chemistry (ALIF)	3	6	100
CHM-506	CCEC	2	2	100
Total		**20**	**23**	**600**

Second Semester

Paper code	Description	Credit	Hours/week	Marks
CHM-551	Inorganic Chemistry –II (CC)	4	4	100
CHM-552	Organic Chemistry –II (CC)	4	4	100
CHM-553	Physical Chemistry –II (CC)	4	4	100
CHM-554	Quantum Chemistry and Molecular spectroscopy (IDC)	3	3	100
CHM-555	Laboratory course in Organic Chemistry (ALIF)	3	6	100
CHM-556	Chemistry in Everyday Life (VBC)	2	2	100
Total		**20**	**23**	**600**

Third Semester

Paper code	Description	Credit	Hours/week	Marks
CHM-601	Applications of spectroscopy methods-I (CC)	4	4	100
CHM-602	Analytical and Computational chemistry (IDC)	4	4	100
CHM-603	Inorganic Chemistry-III / Organic Chemistry –III / Physical chemistry –III (ECC)	4	4	100
CHM-604	Laboratory course in Physical Chemistry (ALIF)	3	6	100
CHM-605	Dissertation (Research Project, Part I)	5	10	100
Total		**20**	**28**	**500**

Fourth Semester

Paper code	Description	Credit	Hours/week	Marks
CHM-651	Applications of spectroscopy methods-II (CC)	4	4	100
CHM-652	Chemistry of Advanced Materials (CC)	4	4	100
CHM-653	Inorganic Chemistry-IV / Organic Chemistry –IV / Physical chemistry –IV (ECC)	4	4	100
CHM-654	Dissertation (Research Project, Part II)	8	16	200
Total		**20**	**28**	**500**

CC- Core Course; ECC –Elective Core Course; IDC-Interdisciplinary Core Course, ALIF- Apprenticeship/Laboratory/Internship/Field; SEC-Skill Enhancement Course, VBC- Value Based Course; CCEC- Compulsory Community Engagement Course

CHEMISTRY, CHM-501: INORGANIC CHEMISTRY-I
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

UNIT – I: Symmetry and Structure:
Symmetry elements and symmetry operations, symmetry groups with examples from inorganic compounds, groups of very high symmetry, molecular dissymmetry and optical activity, molecular symmetry for compounds having coordination number 2 to 9, Molecular dissymmetry and polarity, matrix representations of symmetry operators and their products.

UNIT – II: Chemical Bonding:
VSEPR model, hybridization. Molecular orbital of hetero diatomic, triatomic and polyatomic molecules/ions (including Td, Oh, and D_4h coordination complexes) with special reference to CO, HCl, CO_2, NH_3 and SF_6. Spectroscopic electronegativity, concept of chemical hardness (η). Walsh diagrams (triatomic systems).

UNIT – III: Selected topics on non-transition elements:
Concept of cluster, Wade's rule, Styx number, PSEPT, Synthesis, properties and structures of boranes, carboranes, metallo-carboranes, silicates, zeolites and clay, S - N and P – N Compounds, Non-Stoichiometric oxides, Polymorphism of carbon, phosphorus and sulphur, Isopoly and Heteropoly anions.

UNIT – IV: Bioinorganic chemistry:
Essential and trace elements of life, basic roles of metal ions in biological systems, bioenergetic principle and role of ATP, alkali metal complexes with macrocyclic ligands (crown ethers, cryptates and spherand), membrane structure and transport across biological membrane: Na^+-K^+ -ion pump, biological defense mechanism, ionophores, valinomycin.

UNIT – V: Kinetics and Mechanism of Inorganic reactions:
Mechanism of ligand replacement reactions, ligand displacement reactions in octahedral and square planar complexes, trans-effect, isomerisation and racemisation in tris-chelate complexes, electrons transfer reactions, Cross-section and Marcus-Hush theory. Stereochemical non-rigidity and fluxionality (concept, examples, techniques of detection)

Essential readings:

1. F. Basolo and R. Johnson, Coordination Chemistry, Science Rewiews, Northwood, 1987.
2. R. Debock and H. B. Gray, Chemical structure and bonding, Benjamin/Cummings, Menlo Park, 1980.
3. N. N. Greenwood and A. Earnshaw, Chemistry of the elements, Pergamon, Oxford, 1984.
4. H. G. Heal, The Inorganic Heterocyclic Chemistry of Sulfur, Nitrogen and phosphorus.
5. D. F. Shriver, P.W. Atkins and C.H. Landgord, Inorganic Chemistry, 3rdEdn, Oxford University Press, 1998.
6. J. D. Atwood, Inorganic and Organometallic reaction mechanisms, 2nd Edn. 1997, VCH Publishers, New York.
7. S. E. Manahan, Environmental Chemistry, Lewis Publishers.
8. C. Baird, W. H. Freeman, Environmental Chemistry.
9. G. L. Miessler and D. A. Tarr, inorganic Chemistry, Pearson. 2009.
10. J. D. Lee, Concise Inorganic Chemistry, Chapman & Hall Ltd., 1991
11. G. Wulfsberg, Inorganic Chemistry, Viva Books Pvt. Ltd. 2002.
12. A. K. Das, Fundamental concepts of inorganic chemistry, Vol III, Second Edn. CBS, 2010.
13. G. N. Mukherjee and A. Das, Elements of Bioinorganic Chemistry, U. N. Dhar & Sons Pvt. Ltd.,1993
14. J. E. Huheey, E. A. Keiter, R. L. Keiter, Inorganic Chemistry-Principles of Structure and Reactivity, Addison –Wsley Publishing Company, 1993

Additional Reading:

1. W. L. Jolly, Inorganic Chemistry, 1976, McGraw Hill, New York.
2. J. E. Fergusson, Inorganic Chemistry and the Earth: Chemical Resources, Use and Environmental Impact, Vol. 6, Pergamon Press, Oxford, 1982.
3. S. F. A. Kettle, Symmetry and Structure, Wiley, New York, 1985.
4. D. C. Harris and M.D. Bertolucci, Symmetry and Spectroscopy, Oxford University Press, 1978.

CHEMISTRY, CHM-502: ORGANIC CHEMISTRY-I
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

UNIT – I: Nature of bonding in organic molecules:
Delocalised chemical bonding-conjugation, resonance, **hyperconjugation**, tautomerism. Aromaticity in benzenoid and non-benzenoid compounds. Huckel's rule, energy level of -molecular orbitals, annulenes, antiaromaticity, homo-aromaticity. Crown ether complexes and cryptands, cyclodextrins, catenanes and rotaxanes. Hydrogen bonds, nonbonding intermolecular forces. Effect of structure on reactivity – resonance and field effects, steric effect, quantitative treatment. The Hammett equation and linear free energy relationship, substituent and reaction constants.

UNIT – II: Basic concepts of stereochemistry:
Conformational analysis of cycloalkanes, decalins, effect of conformation on reactivity. Chirality, molecules with more than one chiral centres, methods of resolution, optical purity, enantiotopic and diastereotopic atoms, groups and faces. Optical activity in the absence of chiral carbon (biphenyls, allenes and spiranes), chirality due to molecular dissymmetry. Methods of asymmetric synthesis including chiral pool, chiral auxiliary, chiral reagents; enantio and diastereo selective and specific synthesis. Inclusive of substrate control and reagent control strategieseg, Sharpless epoxidation, Catalytic asymmetric sulfoxidations, and di-hydroxylations with AD-mix-α and β, asymmetric epoxidation of unfunctionalised olefins.

UNIT – III: Substitution reactions (aliphatic and aromatic):
Review of SN2, SN1, SNi along with mixed SN^1 and SN^2 and SET mechanisms. Carbocation: Classical and non-classical: Generation, stability and classification and as reaction intermediates. The neighbouring group mechanism, neighbouring group participation by π and σ bonds (anchimeric assistance). Nucleophilic substitution at an allylic, aliphatic trigonal and at vinylic carbon. Leaving group and ambident nucleophile, regioselectivity. Diazonium coupling, Ipso substitution, Vilsmeir Haak reaction, Gattermann-Koch reaction. The Sommelet-Hauser, and Smiles rearrangements.

UNIT – IV: Carbonyl and related groups:
Nucleophilic addition, hetero atoms (N, O) Hydride donors as nucleophiles, carbanion additions, addition elimination and stereo selective aldol type of condensations. Enolates, emines and enamines: their roles in chemoselective and regioselective C-C bond formations. Alkylation of enolates, emines and enamines and their stereochemical outcomes. Vinylogous or conjugate additions. Substitution by hydrides and acylation of carbon, carbonyl cyclization reactions and cleavage of carbonyl compounds. Addition of Grignard reagents, organozinc and organolithium reagents to carbonyl and unsaturated carbonyl compounds- stereochemical aspects including Cram's rule.

UNIT – V: Addition and elimination reactions:
Addition Reaction: Mechanistic and stereochemical aspects of addition reactions involving electrophiles, nucleophiles and free radicals, regio- and chemoselectivity, orientation and reactivity. Wittig, modified Wittig reaction.
Introduction to Elimination reactions: Formation of alkenes by eliminations with proton loss and by other elimination reactions including 6-membered cyclic substrate. Formation of other double bonds (C = N, C = O) and triple bonds by elimination reactions. Stereochemistry of elimination reactions. Pyrolytic syn-Elimination reactions of esters, xanthates and sulfoxides.

Essential readings:

1. L. N. Ferguson – The modern structural theory of organic chemistry, Prentice Hall of India (1973).
2. L. Pauling – Nature of the chemical bond, Cornell University Press (1960).
3. T.W.G. Solomons – Organic chemistry, John Wiley (1992).
4. D. Nasipuri – Stereochemistry of Organic compounds, Wiley Eastern (1994).
5. Seyhan Ege – Organic chemistry (Structure and reactivity, 3rd Edn., 1998), AITBS Publishers, Delhi.
6. F. A. Carey and R. J. Sandberg, Plenum.
7. P. Y. Bruice, Organic Chemistry, Pearson Education, inc 2002.

Additional readings:

1. J.C. Stowell, Intermediate organic chemistry John Wiley.
2. T.W.G. Solomons, Organic chemistry and study guide to accompany organic chemistry, 5thEdn., John Wiley.
3. J.B. Hendrickson, D.J. Cram and G. Hammond – Organic chemistry, McGraw Hill (1970).
4. E.L. Eliel – Stereochemistry of carbon compounds, McGraw Hill, Book Company Inc. (1960).
5. J. March – Advance organic chemistry; Reactions mechanism and structures, 4th Edn. , Wiley Eastern.
6. J. Clayden, N. Greeve, S. Warren and P. Wother – Organic Chemistry, OUP, New Delhi-200001.
7. M. B. Smith – Organic Synthesis, McGraw Hill 1994.

CHEMISTRY, CHM-503: PHYSICAL CHEMISTRY – I
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional:30, Pass Marks:12

Unit– I: Chemical Kinetics – I
Arrhenius equation, statistical derivation of activated complex theory. Comparison of absolute reaction rates with those of collision theory. Thermodynamic formulation of reaction rates. Reactions in solution. Comparison of gas and liquid phase reactions. Primary and secondary salt effects (kinetic salt effect). Effects of solvent (concept only) and ionic strength on rate constants.

Unit- II: Chemical Kinetics – II
Complex reactions, Mechanisms of chain, photochemical and oscillatory reactions, homogeneous catalysis, Kinetics of enzyme reactions, study of fast reactions by flow methods, relaxation methods, flash photolysis and the nuclear magnetic resonance method.

Unit – III: Surface Phenomena
Surface tension and surface free energy, interfacial tension, adsorption of solids, Gibbs adsorption isotherm, BET adsorption isotherm: estimation of surface area of solids.
Photoelectron Spectroscopy: Basic principles of UV-photoelectron, X-ray photoelectron spectroscopy and Auger spectroscopy, their applications for chemical analysis of solid surfaces.

Unit – IV: Micelles
Surface active agents, classifications of surface-active agents, micellization, hydrophobic interactions, critical micelle concentration (CMC), factors affecting the CMC of surfactants, thermodynamics of micelle formation- phase separation and mass action models, kinetics of micelle formation, solubilization, reverse micelles, micro-emulsions, Kraft phenomenon.

Unit – V: Solid State
Crystal structures, Bragg's law, and applications.
Crystal defects: Perfect and imperfect crystals, types of defects (Schottky and Frenkel defects) colour centres, vacancies and interstitials.
Electronic properties and band theory: Metals, insulators and semiconductors electrical properties of solids, electronic structure of solids, band theory.

Essential reading:

1. P. W. Atkins – Physical Chemistry, 7th Edn. Oxford (2000).
2. I. N. Levine, Physical Chemistry, 4th Edn., McGraw Hill, New Delhi, (1995).
3. Solid state Chemistry AR West, John Wiley NY 1987
4. G. K. Vemulapally, Physical Chemistry, Prentice Hall, India, 1997.
5. K. J. Laidler, Chemical Kinetics, Harper & Row.
6. RP Rastogi and Mishra, Chemical thermodynamics, PHI New Delhi

Additional reading:

7. V. Fried, U. Blukis and H. F. Hameka – Physical Chemistry Macmillan (1975).
8. K. J. Laidler & J. H. Meiser, Physical Chemistry, Houghton Mifflin Company, Bonton, 1998.
9. I. N. Levine, Physical Chemistry, McGraw Hill, New York, 1988.
10. Y. A. Gersimov, Physical Chemistry, Mir Publishers, Moscow, 1985.
11. J. Rajaram & J. Kuriakose, Kinetics and Mechanism of Chemical Transformations, McMillan India, 1993.

CHEMISTRY, CHM-504: APPLIED CHEMISTRY
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

UNIT I: Green synthesis: Introduction, the need of green chemistry, principles of green chemistry, Atom economy, E-factor, planning of green synthesis, tools of green chemistry (Solvents, reagents etc), Green reactions, Aldol condensation, Cannizaro reaction and Grignard reaction- comparison of the above with classical reactions- Green preparations, Applications phase transfer catalysts, Introduction to Microwave organic synthesis, Green alternatives to some common reactions, Industrial synthesis of Ibuprofen. Biodegradable polymers and plastics

Unit II: Materials in catalysis: Introduction to catalysis- activity, selectivity, stability. Classification of catalysts: homogeneous and heterogeneous catalysts. Homogeneous catalysis in industrial processes- rhodium catalysts in hydroformylation of propene, carbonylation of methanol; palladium catalyst in Wacker oxidation process, Suzuki coupling reaction, metallocene-based olefin polymerization, asymmetric hydrogenation and epoxidation. Heterogeneous catalysis in industrial processes- production of inorganic chemicals, organic chemicals; refinery processes; catalysts in environmental protection, fine chemical synthesis. Biocatalysis. Electrocatalysis.

Unit III: Synthetic drugs: Synthesis and mechanism of action for the following taking one example each: (A) any tetracyclic antibiotics, beta-lactum and S- containing antibiotics.
(B) Anti-cancer agents under invasive and non-invasive cancer therapy- basic mode of action/pharmacokinetics or pharmacodynamics. Some examples of commercially available drugs.(C) Anti-viral agents involving pyrimidine derivatives and photo-active anti-viral agents that are on clinical use. Few examples.

Unit IV: Data analysis: Errors in chemical analysis, precision and accuracy, mean and standard deviation, systematic and random errors, linear regression; covariance and correlation coefficient, Significant figures.

Unit V: Renewable Energy
Solar energy: Sun as a source of energy, Solar radiation, Importance, Storage of solar energy, Different types of Solar cells. Bio-Energy: Energy from biomass Sources of biomass, Different species, Conversion of biomass into fuels, Energy through fermentation, Pyrolysis, and gasification. Hydrogen Energy: Production and Storage, Applications.

Essential reading:

1. P.T. Anastas and J.C.Warner, *Green chemistry*, Oxford
2. Handbook Of Industrial Catalysts: Fundamental And Applied Catalysis by LLOYD L , SPRINGER
3. Alka L.gupta, "*Medicinal Chemistry*," Pragati Prakasan Meerut.
4. AhluwaliaV.K.,Madu Chopra "*Medicinal Chemistry*," Ane books.
5. Vogel's Textbook of Quantitative Chemical Analysis, 5th Edn, G H Jeffery, J Bassett, J Mendham and R C Denney.
6. Solar Energy- Fundamentals, design, modeling & applications, G.N. Tiwari, Narosa Pub., 2005.
7. Fundamentals of Renewable Energy Resources by G.N.Tiwari, M.K.Ghosal, Narosa Pub., 2007.
8. Principles of Energy conversion, A. W. Culp Jr.,, McGraw Hill, 1996
9. Non-Conventional Energy Resources by Shobh Nath Singh, Pearson India., 2016.

Additional reading:

1. Non-Conventional Energy Resources by B.H. Khan, Tata McGraw Hill Pub., 2009.
2. Principles of Instrumental Analysis, Douglas A. Skoog, Donald M. West, F. James Holler, Timothy A. Nieman, 1997.
3. Fundamental Concepts In Heterogeneous Catalysis by Jens K. Norskov , Felix Studt , Frank Abild-Pedersen , Thomas Bligaard, John Wiley & Sons Inc.
4. Advanced Materials in Catalysis by James L. Burton and Robert L. Garten, Academic Press Inc., 1977

CHEMISTRY, CHM-505: LABORATORY COURSE IN INORGANIC CHEMISTRY
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

1. **Semi-micro qualitative analysis ;**
   Complete systematic analysis of Inorganic mixtures containing six ions including two of the following elements: W, Mo, Au, Pt, Pd, Se, Te, V, Ti, Zr, U, Th and Ce and the interfering anion (arsenates/phosphate/borate/fluoride).

2. **Quantitative estimation** (involving volumetric-redox and complexometry, gravivimatric and Spectrophotometric methods) of constituents in two and three component mixtures and alloys.

3. **Preparation of the following compounds** : related complementary work and physical studies (at least 8 preparations are to be completed by turn)

   a) Reinecke Salt.
   b) Potassium tris-oxolato chromate (III) trihydrate
   c) Potassium tris-oxolato ferrate (III) trihydrate.
   d) Tris (acetylacetonato) iron (III).
   e) Tris (acetylacetonato) chromium (III).
   f) Chloro pentaamino cobalt (III) chloride.
   g) Mercury tetrathiocyanatocobaltate(II).
   h) Linkage isomers of Nitro and Nitrito-pentammine cobalt (III) chloride.
   i) Cis, trans –dichloro bis(ethylenediammine) cobalt (III) chloride.
   j) N, N' disalicylalethylene – diammine nickel (II).
   k) Bis(N, N' disalicylalethylene-diamine)-μ- aquadicobalt(II)

4. Physical studies includes magnetic susceptibility conductance measurements, infrared, UV-Visible Spectroscopy and cyclic voltammetry.

Essential readings:

1. A.I. Vogel, Macro and Semicro qualitative Inorganic Analysis, Orient Longman, 1969.
2. J. Basset, R.C. Denney, G.H. Jeffery and J. Memdham, Vogel's Text Book of quantitative Inorganic Analysis, ELBS, 4th Edn., 1978.
3. H. H. Willard, L. L. Merrit and J.A. Dean, Instrumental methods of analysis, East-West Press, 4th Edn, 1974.
4. G.W. Parshall (Ed. In chief), Inorganic Synthesis, Vol 15, McGraw Hill, P. 48, 1974.
5. D. D. Sood, S. B. Mohaharand, A. V. R. Reddy, Experiments in Radiochemistry Theory and Practice, IANCAS Publications, 1994.
6. W.L. Jolly: Synthesis and characterization of inorganic compounds Prentice Hall Inc.

CHEMISTRY, CHM-551: INORGANIC CHEMISTRY – II

Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

Unit – I: **Magnetic properties of transition metal complexes**:
Brief review of different types of magnetic behaviors, spin-orbit coupling, quenching of orbital angular moments, temperature independence paramagnetism. Term symbols for metal ions, crystal field theory and its application to explain magnetic properties of coordination compounds, spin crossover. Magnetic interactions in poly nuclear systems, types of exchange interactions, canting, spin frustration.

Unit – II: **Electronic structure of transition metal complexes**:
Electronic absorption spectra of octahedral and tetrahedral complexes, orgel diagrams, selection rules, band intensities and band widths, spectra of high spin octahedral and tetrahedral complexes for various d^n configurations, spectrochemical series. Adjusted crystal field theory, Nephelauxetic series, Molecular orbital theory of complexes (qualitative principles involved in complexes with no π- bonding and with π-bonding), Charge-transfer transitions of inorganic coordination compounds (different type).

Unit – III: Aspects **of transition elements lanthanides and actinides**:
Elements of first transition series and their comparison with the second and third series, general periodic trends, chemistry to the various oxidation states of first row transition metals and their comparison based on electronic configuration. The splitting of f-orbitals in octahedral field, Lanthanide contraction, Lanthanide shift reagent, oxidation states complexes, magnetic and optical properties of lanthanides and actinides.

Unit – IV: Transition **metal π-acid complexes**:
Structure, bonding, synthesis and reactivity of complexes with CO, OS_1, N_2, NO group V donor ligands and extended π-system ligands (phen, bipy), metal carbonyl hydrides and metal carbonyl clusters: LNCC and HNCC Wale's rule and the Capping rule.

Unit – V: Aspects **of Bioinorganic chemistry**:
Iron-sulphur proteins: Rubredoxin and ferredoxins, metalloporphyrins, Heme Proteins: Hemoglobin, Myoglopin and Cytochrome C, Non-heme proteins: Hemerythrin and Ferritin, Hemocyanin, Nitrogen fixation and introgenases, photosynthesis PSI and PSII.

Essential Readings:

1. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, Wiley Eastern Ltd., 3rd. Edn., 1972, 6th edn 1999.
2. J. E. Huheey, E. A. Keiter and R. J. Keiter, Principles of Structure and reactivity, Harper Collins College Publishers, 4th Edn., 1993.
3. A. Earnshaw, Introduction to Magnetochemistry, Academic Press, New York, 1968.
4. M. N. Hughes, The Inorganic Chemistry of Biological Processes, Wiley, 1981.
5. E. I. Ochiai, Bioinorganic Chemistry – An Introduction, Allyn and Bacon, Inc., 1977.
6. Asim K. Das, Bioinorganic Chemistry, Books & Allied (P) Ltd., Kolkata
7. P K Bhattacharya, Metal ions in Biochemistry, Narosa, New Delhi
8. N. Gupta, and Monal Singh, Essential of Bio-inorganic chemistry, Pragati Prakashan.

Additional Readings:

1. B.F.G.Johnson Transition metal clusters, John Wiley 1980
2. T. Moeller, Inorganic Chemistry – A modern Approach, John Wiley, 1982.
3. BN Figgs Introduction to ligand field theory Wiley Eastern Ltd, 1976
4. ABP Lever Inorganic electronic spectroscopy
5. RL Carlin Magnetochemistry Springer Verlag New York 1986
6. O. Kahn, Molecular Magnetism, VCH, New York, 1993
7. R. L. Datta and A. Syamal, Elements of Magnetochemistry, 2nd Edn, East-west press, New Delhi, 1993

CHEMISTRY, CHM-552: ORGANIC CHEMISTRY
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

UNIT I: Reductive reaction:
A) Introduction to catalytic hydrogenation, reduction of functional groups, Raney Nickel desulphurization. Heterogeneous catalytic hydrogenation (Wilkinson's catalyst) **B) Dissolving metal reduction**, acyloin condensation. **C) Reduction of carbonyl compounds with metal hydrides**, stereochemistry and mechanism of reduction reaction of other functional groups by metal hydrides, Merwein Pondorf Verley reduction, Hydroboration and related reactions including alkyl borane. Tributyl tin hydride (including its coupling reactions). D) Reduction with Hydrazine and its derivatives: The Wolf-Kishner reduction and related reduction of tosylhydrazone, reduction with diimide.

Unit II:Oxidation Reactions
A) Oxidation with Chromium and Manganese compounds: Oxidation of alcohol, aldehydes, carbon cabon double bonds and carbon–hydrogen bonds in organic molecules, pyridinium chloro chromates (PCC) oxidations. **B) Oxidation with peracids and other peroxides**: Oxidation of carbon-carbon double bonds Sharpless asymmetric oxidation, oxidation of carbonyl compounds, Baeyer–Villigar oxidation. **C) Other methods of oxidation**: Prevost and Woodward, Swern, Moffatt, DMSO-SO_3 complex, Dess-Martin periodinane, iodobenzene diacetate and periodates, thallium nitrate, Ruthenium tetraoxide.

UNIT – III: A)Carbocations: Rearrangements involving carbocations, (Meerwein, Pinacol-pinacolone, Tiffeneau-Demjanov, Dienone phenol, Fries) **B)Carbenes**: Singlet and triplet species- their characteristics, generation, and reactions involving cycloadditions, C-H insertion, nucleophilic reactions and rearrangements(including Wolf,Diazo-ketone reactions including Arndt-Eistert), their stereochemical outcomes of reactions. **C) Nitrenes**: generation structure reactions, and rearrangements (aziridine formation, C-H insertion, Hoffman Curtius and Schmidt) D) **Benzyne**: generation structure, reactions.

Unit IV: Free Radicals and Photochemistry: Photosensitization, energy transfer reactions photo-dissociation, gas phase photolysis, photochemistry of alkynes, intramolecular reactions of the olefinic bonds, geometrical isomerism, rearragements of 1,4 (di-pi-methane) and 1,5 dienes, photochemistry of carbonyl compounds including Patterno Buchi (oxitane formation),Norrish Types I and II (intramolecular reactions of carbonyl compounds) intermolecular cycloaddition reactions and photooxygenation and reduction and rearrangements, (Barton, photo Fries).

Unit V: Pericyclic Reactions:
Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene and allyl systems. Classification of pericyclic reactions. Woodward – Hoffmann correlation diagrams. FMO and PMO approach. Electrocyclic reactions – conrotatory and disrotatory motions, 4n, 4n + 2 and allyl systems. Nazarov Cyclization, cycloadditions – antarafacial and suprafacial additions, 4n and 4n + 2 systems, 2 + 2 addition of ketenes, 1,3 dipolar cycloadditions and cheleotropic reactions. Sigmatropic rearrangements – suprafacial and antarafacial shifts of H, sigmatropic shifts involving carbon moieties, 3,3- and 5,5- sigmatropic rearrangements. Claisen, Cope, aza and oxy-Cope rearrangements. Ene reaction.

Essential reading:

1. Advanced Organic Chemistry-Reactions, Mechanism and structure, Jerry March, John Wiley
2. Organic Chemistry, R.T. Morrison and R.N. Boyd, Prentice Hall.
3. Modern Organic reactions, H. O. House, Benjamin.
4. Principle of organic synthesis, R.O.C. Norman and J.M.Coxon, Blackie Academic & Professional.
5. Pericyclic Reactions, S.M. Mukherji, Macmillan, India.
6. P. Y. Bruice, Organic Chemistry, Pearson Education, inc 2002.

Additional reading:

1. Organic Chemistry Michael B. Smith 2000
2. Reaction Mechanism in Organic Chemistry, S. M. Mukherji and S. P. Singh, Macmillan.
3. Stereochemistry of Organic Compounds, D. Nasipuri, New Age International.
4. Stereochemistry of Organic Compounds, P.S. Kalsi, New Age International.
5. Principles of organic synthesis R.O. C. Norman and Coxon ELBS
6. Advanced Organic chemistry, F.A. Carry and R.J. Sundberg, Plenum.
7. Structure and Mechanism in Organic Chemistry, C.K. Ingold, Cornell University Press.

CHEMISTRY, CHM-553: PHYSICAL CHEMISTRY – II
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

Unit – I : Equilibrium Electrochemistry
Activity coefficients of electrolytes, mean activity coefficient, theoretical calculation of activity coefficients Debye-Huckel theory, Debye Huckel limiting law, Ions and Electrodes, electrochemical potential, interfacial potential difference, electric potential at interfaces. Electrochemical cells: EMF and electrode potentials, concentration – dependence of EMF, membrane potentials, thermodynamic data from cell EMF.
Ion solvent interactions : The Born model, entropy and enthalpy of ion-solvent interactions.

Unit – II : Dynamic Electrochemistry
Processes at electrodes: double layer at interface, different models of double layers, rate of charge transfer, over potential, aspects of current-voltage relations, ButlerVolmer equation, Tafel plot, i-v curves, deviations from equilibrium.
Electrochemical processes: Dissolution and deposition at electrodes – currents affecting potential of a cell, power generation and storage process fuel cells – power shortage.
Corrosion: Thermodynamics of corrosion, kinetics of corrosion, and inhibition of corrosion.

Unit – III: Equilibrium Thermodynamics – I
Brief review of the concepts of laws of thermodynamics: state and path functions, exact and inexact differentials, zeroth and first law, isothermal and adiabatic processes.
Second law: Thermodynamic view of the entropy, Carnot Cycle, Clausius inequality, Helmholtz and Gibbs free energies, Maxwell's relations.
Third law: Nernst heat theorem, Residual entropies.

Unit- IV: Equilibrium Thermodynamics – II
Thermodynamics of ideal and real gases and gas mixtures, mixing of gases, fugacities of gases and their determination, chemical potentials of liquids and liquid mixtures.
Thermodynamics of ideal and non-ideal binary solutions, excess functions for non-ideal solutions, regular solutions. Thermodynamic criteria for chemical equilibria, equilibrium constant of chemical reactions, dependence of equilibrium constant on temperature and pressure.
Phase equilibrium, derivation of the Gibbs phase rule. Partial molar properties, the Gibbs – Duhem equation, the chemical potential and its significance.

Unit-V: Non-Equilibrium Thermodynamics:
Thermodynamic functions for non-equilibrium states, entropy production and entropy flow, transformations of the generalized fluxes and forces, phenomenological equations, Microscopic reversibility and Onsager's reciprocity relations, electrokinetics phenomena, diffusion, electric conduction, the stationary non-equilibrium states.

Essential reading:

1. Physical chemistry, P.W. Atkins, OUP, 7th edition 2000
2. Modern Electrochemistry Vol. I and Vol. II, J.O.M. Bockris and A.K.N. Reddy, Plenum.
3. Micelles, Theoretical and applied Aspects, Y. Moroi, Plenum, 1992.
4. A whiff on photoelectron spectroscopy, P.K. Ghosh

Suggested reading:

1. Physical chemistry, G.K.Vemulapalli, PHI 1998
2. Principles and applications of electrochemistry DR Crow, 3rd edn Chapman and Hall 1988
3. Experimental approach to electrochemistry NJ Selley, Edward Arnold London 1977
4. Experimental approach to electrochemistry NJ Selley, Edward Arnold London 1977

CHEMISTRY, CHM-554: QUANTUM CHEMISTRY AND MOLECULAR SPECTROSCOPY
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

UNIT - I: Angular Momentum, Schordinger Wave Equation and its Applications

Hamiltonian, Hermitian and Unitary Operators, Some important Theorems, Schordinger equation - Particle in a box and its application, Potential Energy Barrier and Tunneling Effect, One-dimensional Harmonic Oscillator, Rigid Rotator.

Angular Momentum – Commutation Relations, Hydrogen atom-wave functions of hydrogen atoms, Zeeman Effect, Spin-Orbit Coupling.

UNIT – II: Theory of Orbitals and Chemical Bonding

Approximate Methods: Perturbation theory and Variation theorem and their application.

Born-Oppenheimer approximation, LCAO-MO and VB treatment of the Hydrogen molecule and Hydrogen molecule like ions, Comparison of Molecular Orbital and Valence Bond Methods.

Hybridization, Pi-electron approximation, Simple Huckel Treatment of Ethylene, Allyl and Butadiene Systems, Calculating the energies of Cyclic Polyenes, Symmetry Adapted Linear Combinations (SALC).

Unit – III: Electronic and Microwave Spectroscopy

Electronic Spectra: Introduction to Electronic spectra, Born-Oppenheimer approximation, Franck – Condon principle, Change of shape on excitation, Jablonski diagram: Fluorescence and Phosphorescence

Microwave Spectra: Rigid and Non-rigid rotator models, Rotational energies of diatomic molecules: Moment of inertia and bond length, Centrifugal distortion, Effect of isotopic substitution

Unit – IV: Infra-Red and Raman Spectroscopy

Vibrational Spectra: Harmonic and Anharmonic oscillators, Fundamental frequencies, Overtones, Morse potential, Hot bands, Vibration-rotational spectra of HCl, PQR branches, Characteristic stretching frequencies of common functional groups and their dependence on chemical environment.

Raman Spectra: Molecular polarizability – Raman Effect, Pure rotational Raman spectra of linear molecules, Vibrational Raman spectra – Raman activity of vibrational, Rule of mutual exclusion.

Unit – V: Magnetic ResonanceSpectroscopy

Interaction of magnetic moments with external magnetic field and the relevant Zeeman levels, Selection rules, Chemical shifts and Origin of chemical shifts, Spectral features due to spin-spin interaction in NMR Classification of NMR spectra. Concept of pulses and Relaxation techniques, Principles of 2D NMR.

ESR Spectra: Position of ESR adsorption, the g-factor fine structure of ESR absorption, Hyperfine structure. Mechanism of Hyperfine Coupling and McConnell's Relation.

Identification of pure ESR transitions and NMR transitions in the energy level diagram, Hyperfine interaction, Calculation of zero order, first-order and second-order energies and the relevant energy level diagrams, Identification of allowed and forbidden transitions.

ESSENTIAL READING:

1. D.A. McQuarrie – Quantum Chemistry, Oxford University Press (1983).
2. P.W. Atkins et al Molecular Quantum Mechanics, OUP, 1998.
3. R. K. Prasad, Quantum Chemistry, New Age International, New Delhi, 1997.
4. Introduction to Molecular Spectroscopy, G.M. Barrow, McGraw Hill.
5. Introduction to Magnetic Resonance, A. Carrington and A.D. Maclachalan, Harper & Raw.
6. Basic Principles of Spectroscopy, R. Chang, McGraw Hill.

CHEMISTRY, CHM-555: LABORATORY COURSE IN ORGANIC CHEMISTRY
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

1**. Qualitative Analysis**:
Separation, purification and identification of compounds of binary mixture (one liquid and one solid, two solids) using TLC and column chromatography, chemical tests (Semi micro/Spot test/Capillary method), UV and IR Spectra to be used for functional group identification.

2. **Chromatography**: TLC and column chromatography (CC). Separation and identification of mixture of two or three compounds by chromatography, determination of RF values.

3. **Organic Synthesis: (Any four)**
Acetylation: Acetylation of cholesterol and separation of cholesteryl acetate by column chromatography. **Oxidation**: Adipic acid by chromic acid oxidation of cyclohexanol.
Grignard reaction: Synthesis of triphenylmethanol from benzoic acid. **Aldol condensation**: Dibenzal acetone from benzaldehyde. **Sandmeyer reaction:** p-Chlorotoluene from p-toluidine. Acetoacetic ester condensation synthesis of ethyl-n-butylacetoacetate by A.E.E. condensation. **Cannizzaro reaction**: 4-Chlorobenzaldehyde as substrate. **Friedel Crafts Reaction:** β-Benzoyl propionic acid from succinic anhydride and benzene. **Aromatic electrophilic substitutions**: Synthesis of p-nitroaniline and p-bromoaniline. **Benzilic acid rearrangement**: Benzilic acid from benzoin, Benzoin—Benzil—Benzilic acid .**Synthesis of heterocyclic compounds - Skraup synthesis**: Preparation of quinoline from aniline, **Fisher – Indole synthesis**: Preparation of 2-phenylindole from phenylhydrazine. **Enzymatic Synthesis:Enzymatic reduction:** reduction of ethyl acetoacetate using Bakers' yeast to yield enantiomeric excess of S(+) ethyl-3-hydroxybutanoate and determine its optical purity. Biosynthesis of ethanol from sucrose. Synthesis using microwaves. Alkylation of diethyl malonate with benzyl chloride. Synthesis using phase transfer catalyst. Alkylation of diethyl malonate or ethyl acetoacetate with an alkyl halide.

4. Extraction of Organic compounds from Natural sources: (Any two)
Isolation of caffeine from tea leaves. Isolation of nicotine dipicrate from tobacco. Isolation of cinchonine from cinchona bark. Isolation of piperine from black pepper. Isolation of lycopene from tomatoes. Isolation of β-carotene from carrots. Isolation of oleic acid from olive oil involving the preparation of complex with urea and separation of linoleic acid). Isolation of eugenol from cloves. Isolation of (+) limonine from citrus rinds

5. **Quantitative Analysis: (any two)**
Determination of the percentage or number of hydroxyl groups in an organic compound by acetylation method. Estimation of amines/phenols using bromate bromide solution or acetylation method. Determination of lodine and Saponification values of an oil sample. Determination of DO, COD and BOD of water sample.

7. **Estimations:** Ascorbic acid, Aspirin, Caffeine.

8. **Use of Computer in organic chemistry**: Simple operations like Drawing of structures, Optimization etc.

ESSENTIAL READINGS:

1. F. Brians, J. H. Antony, P. W. G. Smith and R. T. Austin, Vogel's text book of practical organic chemistry, ELBS, 5th Edn. 1991.
2. R. K. Bansal, Laboratory manual of organic chemistry, 3rd Edn. Wiley Eastern Limited, 1994.
3. D. H. Williams and Ian Fleming, Spectroscopic methods in organic chemistry, TMH Edition, 1988.
4. A. Buzarbarua, A Text Book of Practical Plant Chemistry, S. Chand and Company Ltd., 2000.
5. S. Sadasivam and A. Manikam, Biochemical Methods, Wiley Eastern, 1992.
6. D. L. Pavia, G. M. Lampman and G. S. Kriz, Introduction to Spectroscopy, 3rd Edn. Harcourt College Publishers, 2007.

ADDITIONAL READINGS:

1. A.Y. Sathi, A first courses in food analysis: New Age International (P) Ltd. Publishers, New Delhi, 1999.
2. M. R. Silverstein, C. G. Bassler, C. Horril, Spectroscopic Identification of Organic compounds, John Wiley and Sons, 1991.
3. P. S. Kalsi, Spectroscopy of Organic Compounds, New Age International Publishers Ltd., 1995.
4. I. L. Finar, Organic Chemistry Vol. 2, ELBS with Longman, 1975.
5. H. T. Clarke, A Hand book of Organic analysis Edward Arnold Ltd 1960.

CHEMISTRY, CHM-556: Chemistry in Everyday Life
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

Unit-I History of Chemistry with reference to Indian context

Old traditions of Chemical sciences in India, Ayurvedic Chemistry, Alchemy in India, Chemistry in medical schools of ancient India, Metal and Metallurgy, Fiber, cloth, Paper, ink, and dying chemistry of ancient India, Discoveries and Inventions in the context of state of art and impact, Development of chemistry during the industrial revolution.

Unit-II Hazards and Peaceful use of Chemistry
Historical background, types of weapons of mass destruction (WMD) – Nuclear, Radiological, Chemical and Biological. Chemical warfare agents: Classes, Designation, persistency. Hazards and peaceful uses. Chemical Weapon Convention (CWC).

UNIT- III Chemical waste management: Introduction, Waste chemicals- solid chemicals, liquid chemicals, compressed gas, oxidisers. Classification of chemical Waste- Hazardous Waste, Non-hazardous waste, Universal waste. Chemical waste management- accumulation of wastes, waste containers, storage, labelling and disposal, dilution and evaporation, elementary neutralisation, chemical spill and PPE waste, nanoparticle waste. Waste minimization- recycling, scaling and substitution, mixing waste streams, inventory management.

Unit-IV Laboratory safety measures
A) Chemical safety and Environment: chemicals and the society. Case studies. Bhopal Gas tragedy, and other major industrial accidents.
B) Safety in the use of chemicals in the Chemistry laboratory: prevention of accidents. International Chemical Safety Cards (ICSC); Disposal of hazardous wastes like halogen waste, non-halogen wastes, heavy metal wastes and nano materials.

Unit-V Elementary food chemistry

Food- definition and general classification and elementary idea of each type, Cellular basis of foods (animal, plant, and microbial sources), Enzymes: basic principles and roles in food production, processing, and quality attributes, Minerals in food : Trace elements in eggs, cereals, vegetable and fruits, toxic trace elements, Food additives : Vitamins, aminoacids, minerals. Aroma compounds as food flavours, sugar substitute: sorbitol, saccharin, cyclamate. Food colors: types and compositions, Proteins and meat, Carbohydrates, Lipids and emulsions: chemical and biochemical influences on structure, color, flavor, and texture, Browning reactions: chemical and biochemical influences on color, flavor, and texture in fresh and processed foods, Preservation of foods : General principles of food preservation. Physical and chemical methods of food preservation

ESSENTIAL READINGS:

1. Singh, M. V. and Shrivastava, B. B. Science and technology in ancient India, (Centrum Press, New Delhi, 2011).
2. Chattopadhyay, D. P. History of Science and Technology in Ancient India, (Firma KLM Kolkata, 1986).
3. Ray, P. C. History of Chemistry in ancient and medieval India, (Indian Chemical Society, Kolkata, 1956).
4. Freeman H.M. (1988) Standard Handbook of Hazardous Waste Treatment and Disposal, New York, McGraw-Hill
5. George Techobanoglous et al, Integrated Solid Waste Managemen, McGraw - Hill, 2014
6. Central Public Health and Environmental Engineering Organization (CPHEEO) (2000) Manual on Municipal Solid Waste Management, New Delhi, Controller of Publications.
7. Laboratory Safety for Chemistry Students, Robert H. Hill Jr. and David C. Finster, Wiley, 2016
8. Basic Food Chemistry, Frank A. Lee, Springer, 1983
9. An elementary course of food chemistry, Zella P. Egdahl, Maxwell press

ADDITIONAL READINGS:

Tchobanoglous G., Theisen H. and Vigil S. (1993) Integrated Solid Waste Management: Engineering Principles and Management Issues, New York, McGraw-Hill.
E-resource: https://www.bu.edu/ehs/ehs-topics/environmental/chemical-waste/chemical-waste-management-guide/

CHEMISTRY, CHM-601: APPLICATIONS OF SPECTROSCOPIC METHODS -I
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

Unit I: MASS SPECTROMETRY:
Introduction, ion production- EI, CI, FD, FAB, ESI and MALDI, factors affecting fragmentation, ion analysis, ion abundance. Mass spectral fragmentation of organic compounds: common functional groups, molecular ion peak, metastable peak, McLafferty rearrangement. Nitrogen rule. Structure determination.

Unit-II ULTRAVIOLET AND VISIBLE SPECTROSCOPY:
Various electronic transitions (185-800nm), effect of solvent on electronic transitions, ultraviolet bands for carbonyl compounds, unsaturated carbonyl compounds, dienes and conjugated polyenes. Fiser – Woodward rules for conjugated dienes and carbonyl compounds, ultraviolet spectra of aromatic and heterocyclic compounds. Steric effect in biphenyls.
Optical Rotatory Dispersion (ORD) and Circular Dichroism (CD): Principle, circular birefringence, Determination of absolute configuration of organic compounds

Unit III: INFRARED SPECTROSCOPY:
Characteristics vibrational frequencies of alkanes, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenols and amines. Detailed study of vibrational frequencies of different functional groups. Effect of hydrogen bonding and solvent effect on vibrational frequencies, overtones, combination bands and Fermi resonance.

Unit IV: NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY - I
Continuous wave (CW) NMR spectroscopy, Fourier-Transform (FT) NMR spectroscopy, Chemical shift in NMR spectroscopy and determination of organic structure from spectra, spin-spin coupling, shielding mechanism, rules of spectral analysis, virtual coupling, hindered rotation, karplus curve-variation of coupling constant with dihedral angle, simplification of complex spectra, nuclear magnetic double resonance, solvent- induce shifts, The effect of chirality, nuclear overhauser effect (NOE) and its applications.

Unit V: NUCLEAR MAGNETIC RESONANCE SPECTROSCOPY - II
A) ^{13}C NMR SPECTROSCOPY: General consideration, chemical shift (aliphatic, olefinic, alkyne, aromatic, heteroaromatic and carbonyl carbon) coupling constants. The applications of multipulse techniques like INEPT, DEPT, DEPTQ. Spin decoupling methods – homonuclear and heteronuclear decoupling.
B) 2D NMR Spectroscopy – 2D NMR, the spectra of the "other nuclei", Correlations through chemical bonds: Homonuclear and heteronuclear spin correlation- COSY, NMR spectral analysis from COSY (problems), NOESY-Interpretation of stereochemistry of organic molecules. Basics of HSQC and HMBC.
C) Elucidation of structure of organic compounds from UV-Visible, IR, NMR and MS Data.

Essential reading:

1. Kemp, Organic Spectroscopy, 3rd Edn, MacMillan, Hong Kong, 1991.
2. D. H. Williams and I. Fleming, Spectroscopic Methods in Organic Chemistry, 4th Edn. Tata McGraw-Hill, New Delhi, 1991.
3. D. L. Pavia, G. M. Lampman and G. S. Kriz, Introduction to Spectroscopy, 3rd Edn. Harcourt College Publishers, 2007.
4. R. M. Silverstein and F. Webster, Spectroscopic Identification of Organic Compounds, 6th Edn. John Wiely, New York, 1998.
5. K. Beimann, Mass Spectroscopy-Application to Organic Chemistry, McGraw-Hill, New York, 1962.
6. J. Barker, Mass Spectroscopy, 2nd Edn. John Wiely, New York, 2000.

Additional reading:

1. J. R. Dyer, Application of Adsorption Spectroscopy of Organic Compounds, 2nd print, Prentice-Hall, New Jersey, 1971.
2. H. Duddeck and W. Dietrich, Structure Elucidation by Modern NMR A Workbook, 2nd revised and enlarged edition. Springer-Verlag, New York, 1992

CHEMISTRY, CHM-602: ANALYTICAL AND COMPUTATIONAL CHEMISTRY
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

Unit - I: Purification and Separation Techniques
Normal and reversed phase liquid chromatography, partition, adsorption, and ion exchange chromatography, gas chromatography, high performance liquid chromatography. Hyphenated technique e. g. GC-MS, HPLC-ICPMS

Unit -II: Electrochemical methods of analysis:
Polarography: Linear scan polarography, Dropping mercury electrode (DME), Ilkovic equation. Voltammetry: Hydrodynamic voltammetry, amperometry, cyclic voltammetry, Coulometry and their applications.

Unit -III: Thermal and Nuclear methods of analysis:
Thermal methods of analysis: Thermogravimetry (TG), Differential thermal analysis (DTA), Differential Scanning Calorometry (DSC): Principles, instrumentation, applications.
Nuclear methods of analysis: Neutron activation analysis (NAA) and X-ray Fluorescence spectroscopy (XRF): Principles, instrumentation, applications. Atomic absorption spectroscopy (AAS): Principles, instrumentation, methodology and applications.

Unit IV: Introduction to computer and computing:
Basic structure and functioning of a computer (with demonstration), Algorithm, Flowchart, Development of small computer codes (in FORTRAN or C) involving simple formula in chemistry such as van der Waal's equation, pH, kinetics and radioactive decay.

Unit V: Concepts in Computational Chemistry:
Scope of computational chemistry, Potential energy surface, Force fields, concept of Basis set (STO-3G, 3-21G, 6-31G, 6-31G*, 6-31G**), The Born-Oppenheimer approximation, potential energy surfaces, local and global minima, Hartree-Fock approximation, Kohn-Sham Equation and Density Functional Theory.
(Demonstration of the key concepts using suitable software package)

Essential Reading:

1. Fundamentals of Analytical Chemistry, D.A. Skoog, D.M. West and F.J. Holler, W.B. Saunders.
2. Analytical Chemistry-Principles, J. H. Kennedy, W.B. Saunders.
3. Analytical Chemistry-Principles and Techniques, .G. Hargis, Prentice Hall.
4. Principles of Instrumental Analysis, D.A. Skoog, W. B. Saunders.
5. Instrumental methods of chemical analysis by B K Sharma Goel publishing House Ltd
6. Essentials of Nuclear chemistry HJ Arnikar, Wiley eastern.
7. D. A. McQuarrie, *Quantum Chemistry* (University Science Books, Mill Valley, CA,).
8. P. W. Atkins. *Molecular Quantum Mechanics*, Oxford Univ. Press

Additional reading:

1. Analytical chemistry, G.D. Christian, J. Wiley.
2. Quantitative Analysis, R. A. Day, Jr. and A.L. Underwood, Prentice Hall.
3. Environmental Solution Analysis, S. M. Khopkar, Wiley Eastern.
4. Basics Concepts of Analytical Chemistry, S.M. Khopkar, Wiley Eastern.
5. Handbook of Instrumental Techniques for Analytical Chemistry, F.Settle, Prentice Hall.
6. Principles of Instrumental Analysis, D.A. Skoog and J.L. Loary, W.B. Saunders.
7. Analytical chemistry of macroscopic and supramolecular compounds S M Khopkar, Narosa 2002.
8. Christopher J. Cramer, *Essentials of Computational Chemistry: Theories andModels*, 2nd Ed. Wiley & Sons, New York

CHEMISTRY, CHM-603: INORGANIC CHEMISTRY – III
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional:30, Pass Marks:12

UNIT – I:Organometallic Chemistry:
Introduction to organometallic chemistry: definition and classification (on basis of ligand type). Synthesis, structure, bonding of sigma bonded transition metal complexes: Alkyls, Aryls, Acyls. Reactions of (σ-organyls): Homolytic cleavage, Reductive elimination, Electrophilic cleavage, β-metal hydrogen Elimination, α-elimination.
Synthesis, structure, bonding and reactivity in metal – carbon multiple bonded complexes: Alkylidenes, Alkylidynes.

UNIT – II: **Homogeneous catalysis:**
Coordinative unsaturation, oxidative addition reactions, insertion reactions, reaction of coordinated ligand and activation of small molecules by complexation, cayalytic reactions of alkenes (isomerization, hydrogenation, hydroformylation, hydrosilylation and polymerization).

UNIT – III: **Symmetry group theory and its applications:**
Matrix representation of groups, reducible and irreducible representation, the Great Orthogonality Theorem, character tables. Application of group theory: Transformation properties of atomic orbitals, hybridization scheme of σ and π - bonding, hybrid orbitals as LCAO. M.O. theory for AB_n – type molecules e.g. BF relationship of MO and the hybridization treatment, determinations of symmetry types of the normal modes for AB types of system, selection rules, for fundamental vibrational transitions (Infrared and Raman).

UNIT- IV: Nuclear and Radiochemistry:
Radiation detection and measurement, ionization chamber, Geiger-Muller counter, proportional counter, scintillation counter, solid state active and passive detectors, detection of neutrons. Nuclear reactions: Energetics, Q-value, cross-sections types of nuclear reactions, nuclear fission and fusion chain reactions.

UNIT- V: Supramolecular chemistry:
Concepts of language a) **Molecular recognition**: Molecular receptors for different types of molecules including arisonic substrates, design and synthesis of coreceptor molecules and multiple recognition.
b) Supramolecular reactivity and catalysis. c)Transport processes and carrier design.
d) Supramolecular photochemistry. e) Supramolecular devices: Supramolecular electronic, ionic and switching devices.
f) Some examples of self-assembly in supramolecular chemistry.

Suggested Reading:

1. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, Wiley Eastern, 6th Edn. 1999.
2. F. A. Cotton, Chemical Application of Group Theory, Wiley Eastern, 2nd Edn. 1972.
3. G. Friedlander, J. W. Kenendy and J. M. Miller, Nuclear and Radiochemistry, Wiley Int. 2nd Edn. 1964.
4. H. J. Arnikar, Essentials of Nuclear Chemistry, Wiley Eastern, 1988.
5. R. H. Crabtree, The organometallic chemistry of transition metals, John Wiley, 2ndEdn., 1994.
6. J. M. lehn, Supramolecular Chemistry- Concepts and Perspectives, VCH, Winheim, 1995
7. P. D. Beer, P. A. Gale and D K. Smith, Supramolecular Chemistry, Oxford Scince Publications, 1999.
8. K. Ariga and T. Kunitake, Supramolcular Chemistry,-Fundamentals and Applications, Springer, 2006.

Additional Readings:

A. Yamamoto, Organotransition metal chemistry, Wiley, 1986.

CHEMISTRY, CHM-603: ORGANIC CHEMISTRY – III
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional:30, Pass Marks:12

UNIT – I: Reagents in Organic Synthesis:
Use of following reagents in organic synthesis and functional group transformations; Complex metal hydrides, Gilman's reagent, lithium dimethylcuprate, lithium disopropylamide (LDA), dicyclohexylcarboimide, 1,3-Dithiane (reactivity umpolung), trimethyl silyliodide, DDQ, DCC, DIBAL, Hoffmann – Loffler-Fretag, Miyamura, Stille, Negishi, Kamada Peterson synthesis, Selenium dioxide and Baker yeast. Organocatalysis

UNIT – II: Heterocyclic Chemistry
A) Synthesis and reactions of 5-membered heterocycles with one (Furan, Pyrrole, Thiophene) and two heteroatoms (imidazole, thiazole and pyrazole, oxazole) containg O,S and N. B) Synthesis and reactions of Pyridine, Quinoline and Isoquinoline,

UNIT – III: Multistep organic synthesis: a) Multicomponent reactions: Strecker synthesis, Biginelli synthesis, Multicomponent reactions using alkyl isocyanides: Passerini and Ugi-4-component synthesis. **b)** Domino/cascade reactions. **c) Solid phase synthesis:** solid phase polypeptide synthesis, Merrifield Resin synthesis, Solid phase oligonucleotides synthesis**. d) Combinatorial synthesis**

UNIT – IV: Chemistry of Natural Products: A) **Carbohydrates:** Natural products derived from carbohydrates- sialic acides, vitamin C. O, S, N- glycosides. Cardiac glycosides, Digitoxin, Heparin. deoxysugars, aminosugars, D-glucosamine and mesoinositol, chitin and heparin. **B) Alkaloids**: Structure elucidation and synthesis. of Ephedrine (±) and Quinine, **C) Terpinoids** Classification, nomenclature, occurrence, isolation, isoprene rule. Structure determination, stereochemistry, biosynthesis and synthesis of the following representative molecules: Menthol, Santonin and β-Carotene.

UNIT – V: Biogenesis:

A) Steroids: Cholesterol (natural synthesis), Hormones: Testosterone, Estrone, Progesterone. B) **Lipids and Proteins:** Essential Fatty acids. Role of lipids in life processes: Significance of stereochemistry in fats, essential fatty acids, membranes / phospholipids. Peptides, **C) Enzymes:** Mechanism of Enzyme Action, examples of some typical enzyme mechanisms for chymotrypsin, lysozyme. **d) Nucleic acids**: Purine and pyrimidine bases of nucleic acids, base pairing via H-bonding. Structure of ribonucleic acids (RNA) and deoxyribonucleic acids (DNA) double helix model of DNA and its importance. Chemical and enzymatic hydrolysis of nucleic acids. Overview of replication of DNA, transcription RNA and genetic code.

Essential reading:

1. L.A. Paquette-Modern Heterocyuclic Chemistry, W.A. Benzamin Inc., 1968.
2. L. Finar, Organic Chemistry, Vol.II ELBS, 1986.
3. E.E. Cohn and P.K. Stumpf, Outlines of Biochemistry, Wiley Eastern, 1987.
4. H.R. Mahaler and E.H. Cordes, Biological Chemistry, Harper International, 1989.
5. Van Der Plas, Ring Transformation of Heterocyclics, Vol.I &II, Academic press, 1976.
6. T.L. Gilchrist, Heterocyclic Chemistry, Longman, 1989.
7. F.A. Carry and R.J. Sundberg Advanced Organic chemistry Part B: Reactions and Synthesis, Springer

Additional reading:

1. Robert F. Weavwer, Molecular Biology, McGraw Hill, New Delhi, 1999.
2. Lubert Stryer, Biochemistry, Freeman, USA, 1989.
3. Michael B. Smith, Organic Synthesis, McGraw Hill, 1994.
4. J. Clayden, N. Greeves, S. Warren and P. Wothers, Organic Chemistry, OUP, New Delhi, 2001.
5. Albert L.Lehninger, David L. Nelson, Michael M. Cox, Principles of Biochemistry, CBS, 2nd Edn. 1999.

CHEMISTRY, CHM- 603: PHYSICAL CHEMISTRY – III
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional:30, Pass Marks:12

UNIT – I : Statistical Thermodynamics : Part – I
Thermodynamic probability and entropy, Ensembles – Postulates of ensemble averaging, canonical ensemble, grand canonical ensemble, micro canonical ensemble and their thermodynamics. Partition Functions – General relations for independent distinguishable and indistinguishable molecules (Boltzmann statistics), derivation and evaluation of translational partition function n using particle in a box model for ideal gases, derivation and evaluation of rotational partition function using rigid rotator model for ideal diatomic molecules, rotational partition function for linear and non-linear molecules (derivation not required).

UNIT – II : Statistical Thermodynamics : Part – 2
Derivation and evaluation of vibrational partition function for ideal diatomic gases using harmonic oscillator model, electronic partition function. a) Chemical equilibria in ideal gases : Reference state of zero energy for calculation of partition function of a system, expression for equilibrium constant in terms of partition functions, applications to some chemical equilibria. b) Some illustrations: Equations of state for ideal gases, Theories of specific heat capacity for solids (Einstein's model), ideal lattice gas (Langmuir absorption isotherm) theory of absolute reaction rates.

UNIT – III : Statistical Thermodynamics : Part – 3
Maxwell- Boltzmann statistics, Fermi-Dirac statistics, ideal Fermi-Dirac gas (Electrons in metals). Bose-Einstein statistics, ideal Bose-Einstein gas (helium). Statistical mechanics of imperfect gases, derivation of the virial equation of state for a ono-component gas, siginificance of virial coefficients, evaluation of second virial coefficient.

UNIT – IV : Macromolecules :
Average molecular weights – number average and weight average molecular weights, determination of molecular weights (viscosity, osomotic pressure, light scattering and sedimentation methods). polymerization reaction-free radical mechanisms, rates of polymerization reaction, cationic, anionic and emulsion polymerization in solution, optical and geometrical isomerism.

UNIT – V : Reactions on Surfaces :
Simple Langmuir isotherm (adsorption with dissociation, competitive adsorption) statistical treatment of ideal adsorption and non-ideal adsorption, chemical reactions on surfaces (General discussion, Unimolecular surface reactions-inhibition and activation energies. Biomolecular surface reactions two adsorbed molecules, one adsorbed molecule and a gas molecule, two gases adsorbed inhibition, example of C_2H_4 –H_2.

Suggested readings:

1. T. L. Hill Statistical Thermodynamics Addision Wesley 1960
2. D.A. Mcquarie Statistical Thermodynamics , Viva Books Pvt Ltd 2003
3. JM Seddon and JD Gale Thermodynamical and statistical mechanics RSC 2001
4. LK Nash Elements of Classical and statistical thermodynamics Addision –wesley 1970
5. M. C. Gupta Statistical Thermodynamics WEL 1995
6. Introduction to Polymer Science, V.R. Gowarikar, N.V. Vishwanathan and J. Sridhar, Wiley Eastern.
7. K.J.Laidler Chemical Kinetics Harper and Row

Additional reading:

1. Principles of Polymer Science P.Bahadur, N.V.Sastry Narosa 2002
2. An introduction to Statistical Thermodynamics Robert H Gasser, N. Graham Richards WSC, 1995
3. J Raja Ram and JC Kuriakose Kinetics and mechanism of Chemical transformations McMillan 1993

CHEMISTRY, CHM-604: LABORATORY COURSE IN PHYSICAL CHEMISTRY
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

1. Determination of energy of activation for hydrolysis of an ester, using an acid catalyst.
2. To determine the relative strength of two acids by studying the rate kinetics.
3. Study of the reaction between acetone and iodine in the presence of an acid.
4. Determination of the partial molal volume of a solute in solution.
5. Determination of specific rotation of sucrose and rate constant of its hydrolysis, using a polarimeter.
6. Determination of strengths of strong and weak acids in a given mixture, using the pH meter.
7. Determination of strengths of strong and weak acids in a given mixture, using the potentiometer meter.
8. Determination of strengths of strong, weak acids and cupric chloride/sulfate in a given mixture, conductometrically.
9. Determination of strengths of halides in a mixture, potentiometrically.
10. Determination of the hydrolysis constant of ammonium chloride and the dissociation constant of ammonium hydroxide potentiometrically.
11. Determination of the p_{Ka} of an indicator spectrophotometrically.
12. To determine the concentration of Cu(II) ion in a complex spectrophotometrically.
13. Determination of the molecular composition of ferric-salicylate complex by Job's methods
14. To study the adsorption of acetic acid on activated charcoal at room temperature.
15. Determination the radius of the molecule viscometrically.
16. To determine interfacial tension of water in contact with benzene/toluene at room temperature.
17. To determine the molecular weight of a polymer viscometrically.
18. To study the effect of ionic strength on the reaction between persulfate ion and iodide ion.
19. To construct the phase diagram of the system consisting of chloroform, acetic acid and water.
20. To determine the enthalpy of neutralization of strong acid and strong base.

Suggested reading:

1. Experiments in Physical Chemistry J.C.Ghosh Bharati Bhavan 1974,New Delhi
2. Advanced experimental chemistry (Physical) J.N.Gurtu, & NR Kapoor, S.C. Company 1980
3. Laboratory manual in Physical chemistry WJ Popiel, ELBS 1970
4. Advanced Practical in Physical Chemstry JB Yadav, Pragati prakasan Meerut
5. Practical Physical Chemistry, A. M. James and F. E. Prichard, Longman.

Additional reading

6. Findley's practical Physical Chemistry, B. P. Levitt, Longman.
7. Experimental Physical Chemistry, R. C. Das and B. Behera, Tata McGraw Hill.

CHEMISTRY, CHM-605: RESEARCH PROJECT WORK PART I

Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

Research project work part I: A/B/C

A = Inorganic

B = Organic

C = Physical

CHEMISTRY – 651: APPLICATIONS OF SPECTROSCOPIC METHODS -II
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

Unit-I: Infrared and Raman spectroscopy:
Structural studies involving IR and Raman Spectroscopy of coordination compounds containing the following molecules/ions and ligands. NH_3, H_2O, OH, SO_4^{-2}, ClO_4^-, COO^-, NO_2, CN^-, SCN^-, NO, O_2, PR_3, Halides, DMSO, azopyridine, oxime, quinine, acetylacetone, aminoacids.
Optical Electronic spectroscopy of metal complexes: Structural elucidation (cis, trans *etc*.). Calculation of 10Dq values. Interpretation of spectral bands of octahedral and tetrahedral metal complexes.

Unit – II: Electron spin resonance spectroscopy:
Basic principles, comparison of NMR & ESR, ESR-instrumentation, spin Hamiltonian, g-value, ESR spectrum, hyperfine splitting, g-anisotropy, zero field splitting. Application in detection of organic free radicals, number of signals and intensities. Spectra of transition metal complexes, metal hyperfine anisotropic spectra, determination of metal oxidation states, ENDOR.

Unit- III: Nuclear magnetic resonance spectroscopy: Basic principles, chemical shift, spin-spin coupling, integration, Applications of ^1H, ^{13}C, ^{31}P and ^{19}F -NMR spectroscopy in the structural assessment of inorganic compounds.

Unit – IV: Mass Spectroscopy:
Principle of electron-impact induced mass spectrometry and FAB, qualitative and semiquantitative theories including QET, concept of metastable ions transitions, Stevensons's rules. Applications to metal compounds containing carbonyl, alkyl, cyclopentadienyl and acetylacetonate.

Unit-V: Mossbauer Spectroscopy: Gamma ray emission and absorption by nuclei, Mossbauer effect, Isomer shift, Quadrupole splitting, magnetic interaction, application to iron and tin compounds.

Essential reading:

1. K. Nakamato, IR and Raman Spectra of Inorganic and Coordination Compounds, 4th Edn. John Wiley, 1986.
2. R. S. Drago, Physical Methods in Chemistry, Saunders College Publishers, 1977.
3. M. R. Litzow and T R Spelding, Mass Spectroscopy of Inorganic & Organometallic Compounds, Elsevier,73

Additional reading:

1. A.B. P. Lever, Inorganic Electronic Spectroscopy, 2nd Edn. Elsevier.
2. H. Duddeck and W. Dietrich, Structure Elucidation by Modern NMR A Workbook, 2nd revised and enlarged edition. Springer-Verlag, New York, 1992.
3. NMR, NQR, EPR and Mossbauer Spectroscopy in Inorganic Chemistry, R.V. Parish, 1990, 1st edition, Ellis Harwood.

Chemistry 652: CHEMISTRY OF ADVANCED MATERIALS
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

Unit- I: **Introduction to Nanomaterials:**
Introduction - definition of nanoscience, nanochemistry -classification of the nanomaterials, Synthesis of Nanomaterials: Top-Down and Bottom-up approaches. Characterization Techniques: Electron Microscopy, Spectroscopy, XRD. Properties of nanomaterials:Size-effect: melting point, electrical properties, optical properties, magnetic properties, catalytic properties. Few selective examples of recent emerging applications: Solar cell, green- and environmental-nanotechnology, nanoecotoxicology.

Unit- II: Photosensitizers in Photodynamic Therapy: Modified Jablonski Diagram, Type I and Type-II mechanism for generation of ROS, Prophyrin analogues, Nanomaterials in PDT. First, second and third generation Photosensitizers and their development.

Unit -III: **Mesogens**

Introduction - Difference between liquid crystal, solid and liquid. Order parameters, Classification of liquid crystals. Thermotropic liquid crystals, shape anisotropy, nematic, cholestreric and smectic mesophases. Important applications of liquid crystals.

Unit-IV: Supramoleculer Chemistry
Applications of Supramolecule: Molecular sensors- Electrochemical and optical sensors, Switches and molecular machinery, Photochemical devices, MRI contrast, Anti cancer agents, Cosmetics and food industries.

Unit- V: Pharmaceutical Chemistry
Concept and definition of Pharmacophore, Drug Discovery, Design and Development. Structure-activity relationships: Strategies in drug design. QSAR and combinatorial synthesis. Optimization of drug-target interactions and access to drug targets. ADMET of drugs. Pro-drugs and drug delivery systems. Elementary ideas on Biomimicking systems: Cyclodextrins as enzyme mimics, ion channel mimics.

Essential Readings:

1. Introduction to Nanoscale science and Technology, (Ed) Massimiliano Di Ventra, Kluwer Academic.
2. Nanomaterials CNR Rao, Wiley-VCH
3. M.J.O.Connell, Carbon Nanotubes: Properties and Application, CRC Press, 2006
4. Nanostructures and Nanomaterials,Synthesis, Properties Applications, by G.Cao, Imperial College Press, 57 Shelton Street, Covent Garden, London WC2H 9HE, 2004
5. C.N.R.Rao, A.Muller, A.K.Cheetham, Nanomaterial Chemistry: Recent developments and new directions, Wiley, 2007.
6. T. Pradeep, Nano: The Essentials, Tata McGraw-Hill, New Delhi, 2007.
7. Nanoparticle Technology Handbook, Masuo Hosokawa, Kiyoshi Nogi, Makio Naito, Toyokazu Yokoyama, Elsevier 2007
8. Yury Gogotsi , Nanomaterials Handbook, CRC press, 2008

Additional reading:

1. J.W.steed, D.R.Turner, K.Wallace, Core Concept in Supramolecular Chemistry and Nanochemistry, Wiley, 2007
2. H.S. Nalwa, Handbook of Nanostructured Materials and Nanotechnology, Academic Press, 2000.
3. M.S. Dresselhaus, G. Dresslhous, P.C. Eklund, Science of Fullerenes and Carbon Nanotubes, Academic Press, San Diego, USA, 1996.
4. M.S. Dresselhaus, G. Dresslhous, P. Avouris, Carbon Nanotubes: Synthesis, Structure, Properties and Application, Springer, Berlin, Germany, 2001.
5. P. J. Bruke, Nanotubes and Nanowires, Spring, 2004
6. Advanced semiconductor and organic nano technique part I, II, III Hadis Morkoc, Elsevier

CHEMISTRY – 653: INORGANIC CHEMISTRY – IV
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

UNIT – I: Organometallic Chemistry
Synthesis, structure, bonding (qualitative treatment only) and reactivity of π-Coordination of C-C multiple bonds: Alkene, Di and Polyenes, Allenes, Alkynes, Carbocyclic Polyene ligands: Allyls, Pentadienyls, Cyclopropenyls, Cyclobutadienes, cyclopentadienyl, Arenes. Multidecker sandwitch compounds.

UNIT – II: Photochemistry of metal complexes:
Excited states and excited state processes**:** Ligand field states, charge transfer states, thexi and DOSENCO states, photophysical processes (radiative and nonradiative transitions). Photochemical reactions: L-F excited states and Cr(III) complexes, LMCT states and MLCT states. Survey of photoreactions of complexes of d-transitions elements. Applications of photochemical reactions of coordination compounds: Synthesis and catalysis chemical actinometry photochromism.

UNIT – III: Radiochemical method of analysis:
Tracers in chemical analysis. The tracer technique, isotopic exchange and other tracer reactiobns, analytical applications, Hot atom chemistry. Methods of radiochemical separation: Carriers, precipitation, ion-exchange, solvent extraction, electrochemical method isotope dilution technique and its applications.

UNIT – IV: Bioinorganic chemistry:
Copper: Ceruloplasmin, cytochrome oxidase and superoxide dismutase, Tyrosine. Cobalt: carbonic anhydrase, carboxy peptidase and metallothioneins, interchangeability of zinc and cobalt in enzymes. Magnesium, : Complexes with ATP and ADP, active transport of ions across membrane, Catalase and calcium in living cell and transport and regulation. Metal ion detoxification.

UNIT – V: Design and Synthesis of ligands and complexes.
Intermolecular interactions, Crystal Design Strategies, Crystallization and crystal growth, Polymorphism, Coordination polymers: properties and applications.

Essential Readings:

1. H. J. Emeleus and A. G. Sharpe, Modern Aspects of inorganic chemistry, 4th Edn. Rout ledge and Kegan Paul, London, 1973.
2. R. W. Hay, Bio-Inorganic Chemistry, Halsted Press, 1984.
3. F. wells, Structural Inorganic Chemistry, 5th Edn. OUP, Oxford, 1984.
4. W. E. Addison, Structural Principles in Inorganic Compounds, Longmans, London, 1974.
5. S. J. Lippard and J. M. Berg, Principles of Bioinorganic Chemistry, University Science Books.
6. G. R. Desiraju, J. J. Vittal and A. Ramanan, Crystal Engineering, IISC Press, World Scientific, 2011.

Additional reading:

1. J. M. Lehn, Supramolecular Chemistry, VCH.
2. R. C. Mehrotra and A. Singh, Organo-metallic Chemistry, New Age International.
3. R. West, Solid State Chemistry and its Application, Wiley, New York, 1984.
4. E.A.V. Ebsworth, D.W.H. Rankin and S. Cradock, Structural Methods in Inorganic Chemistry, Blackwell Scientific Publishers, Oxford, 1987.
4. D. M. Adams, Inorganic Solids, Wiley-Interscience, New York, 1974

CHEMISTRY – 653: ORGANIC CHEMISTRY – IV
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional: 30, Pass Marks: 12

UNIT – I: A) Organometallic Chemistry:
Bonding of transition metal in organo-metallic complexes. Fluxionality, epolarization of reactive or unstable molecules. Insertion reactions. Formation of C-C bonds with the aid of organo-Ti, Ce, B, Si and Zn compounds and their stereochemical or chemoselective applications. Role of organo-Cd, Hg and Pd compounds in organic synthesis.
B) Ylids: Phosphorous, Nitrogen and Sulphur Ylids and stereochemistry of compoundscontaining Phosphrous, Sulfur and Nitrogen.

UNIT – II:Disconnection Approach (Retro Synthesis): An introduction to Synthons and synthetic equivalents, disconnection approach,functional group interconversions. One group C-X and two group disconnections in 1,2-, 1,3-,1,4-& 1,5- difunctional compounds , Retro- synthesis of Alkene,acetylenes and aliphatic nitro Alcohols and carbonyl compounds, amines , the importance of the order of events in organic synthesis, chemoselectivity, regioselectivity. Diels-Alder reaction, Aldol condensation, Michael addition and Robinson annulation. Retro- synthesis of aromatic Heterocycles and 3, 4, 5 and 6 membered carbocyclic and heterocyclic rings. Reversal of polarity (Umpolung).

UNIT –III: Heterocyclic Synthesis-:
a) Diazines: Synthesis and general reactivity of pyridizine, pyrimidine and pyrazine.b) Benzo-Fused Five Membered Heterocycles: Synthesis and reactions including medicinal applications of Indole, benzopyrroles, benzofurans and benzothiophenes. c) Six-membered heterocycles with two or more heteroatoms: Synthesis and reactions of triazines, tetrazines and thiazines.

UNIT – IV: Medicinal Chemistry-I: Chemistry of *Drug Design*
Development of new drugs, procedures followed in drug design, concepts ofprodrugs and soft drugs. Theories of drug activity, Quantitative structure activityrelationship (QSAR). Elementary treatment of drug receptor interactions, Structure-Based Drug Design,Transporters and Enzymes as drug targets, Lipophilicity, LD-50.

UNIT – V: Medicinal Chemistry-II: Application
A) GeneralAccounts on Antibiotics: Preparation or synthesis of semi synthetic penicillin, conversion of penicillin into cephalosporin.
B) Anti-neoplastic drugs: Cancer chemotherapy, Treatment schemes, pharmacokinetics/pharmacodynamics and mode of action of mechloraethamine, cyclophosphamide, structure and role of Mephalan, uracils, mustards, Study of the role of (i) Flavones: Tangeritin (synthesis is not required), Vinca Alkoloids: Vincristine (synthesis is not required)
C) Study of the recent developments in cancer therapy viz., Photodynamic Therapy (PDT) at cellular and tissue levels, selectivity of PD treatment,and Hyperthermia.

Essential reading:

1. F. Hill, Organotransition Metal Chemistry, Royal Society of Chemistry, 2002.
2. R. C. Mehrotra and A. Singh, Organometallic Chemistry: A unified approach, 2nd Edn., New Age International Pvt. Ltd, New Delhi, 2000.
3. J. Pearson, Metalloorganic Chemistry, John Wiely, 1985.
4. R. E. Ireland, Organic Synthesis, Prentice-Hall, 1969
5. K. C. Nicholson and E. J. Sorenson, Classics in Total Synthesis, VCH, 1996.
6. E.E. Cohn and P.K. Stumf, Outlines of Biochemistry, Wiley Eastern, 1987.
7. J.D. Bulock, The Biosynthesis of Natural products, McGraw Hill, New Delhi, 1986.
8. T.L. Gilchrist, Heterocyclic Chemistry, Longman, 1989.
9. Jould and Mills, Heterocyclic Chemistry, Blackwell, 1988.
10. Alka L.gupta, "***Medicinal Chemistry***," Pragati Prakasan Meerut.
11. AhluwaliaV.K.,MaduChopra "***Medicinal Chemistry***," Ane books.

Additional reading:

1. F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry, Parts A and B, Plenum Press, 1990.
2. Robert F. Weaaver, Molecular Biology, 1999, McGraw Hill New Delhi.
3. Lubert Stryer, Biochemistry, 1989, Freeman, USA.
4. Albert L. Lehninger, David L. Nelson, Michael M. Cox, Principles of Biochemistry, CBS Publishers and Distributors, 2nd Edn.1999.

CHEMISTRY – 653: PHYSICAL CHEMISTRY – IV
Max. Marks: 100, External: 70, Pass Marks: 28, Sessional:30, Pass Marks:12

UNIT – I : Photophysical Processes in Excited State:
Types of photophysical pathways, Radiationless transitions, Fluorescence emission, Triplet state and phosphorescence emission, Fluorescence quenching, Stern-Volmer equation, Concentration quenching and excimer formation, Quenching by foreign substrates, Exciplex formation.

UNIT – II: Solvent and Environmental Effects on Fluorescence:
Solvent polarity effect; Derivation and application of Lipper-Mataga (LM) equation, effect of viscosity, temperature effects; Additional factors that effect fluorescence emission; effect of solvent mixtures: specific and non-specific interactions.
Biochemical applications of environment sensitive fluorescent probes.

UNIT – III : Solid State :
A) Physical properties of solids : i) Thermoelectric effects : Thomson, Peltier. Seebeck and Hall effects, dielectric materials, ferro-pyro and piezo electricity and its applications. Ii) Optical properties ; absorption, photoconductivity and luminescence. B) Electrically conducting organic solids : Organic metals, conjugated systems, electrically conducting polymers, organic charge-transfer complexes, organic super conductors.

UNIT – IV : Liquid State :

Cohesion of liquids and internal pressure, intermolecular forces and pair potential functions – hardsphere and Lennard-Jones potential functions. Partition function for liquids : Classical partition function, cell theory of liquids considering hard-sphere potential function, concept of communal energy and communal entropy, radial distribution function method for liquids : Clausius virial theorem, equation of state in terms of radial distribution function.

UNIT – V: Chemical Dynamics:
Dynamics of gas phase reactions: : Hydrogen-bromine reaction, pyrolysis of hydrocarbons, pyrolysis of acetaldehyde, decomposition of ozone, decomposition of nitrogen pentoxide. Dynamic of unimolecular reactions, Lindemann-Hinshelwood and the Rice-Ramsperger-assel-Marcus (RRKM) theories of unimolecular reactions, chemical reaction dynamics, steady state kinetics, kinetic and thermodynamic control of reactions.

Essential reading:

1. Physical chemistry, P.W. Atkins, 7th edn 2000, OUP
2. Rastogi and Mishra an introduction Chemical Thermodynamics, VPH, 1980
3. Liquid state Pryde, Hutchinson&co 1966
4. Solid state chemistry ARWest,
5. Chemical Kinetics, K. J. Laidler, McGraw Hill.
6. Foundation of chemical Kinetics S. W. Benson MGH, 1982

Additional reading:

1. Theoretical electrochemistry Antropov Mir Publishers 1980
2. Kinetics and Mechanism of Chemical Transformations, J. Rajaram and J.Kuriacose, McMillan.
3. Micelles, Theoretical and applied Aspects, V. Moroi, Plenum.
4. Modern Electrochemistry Vol. I and Vol. II, J.O.M., Bockris and A.K.N. Reddy, Plenum.
5. Theoretical electrochemistry, Glasstone, AEN 1960
6. Introduction to Polymer Science, V.R. Gowarikar, N.V. Vishwanathan and J. Sridhar, Wiley Eastern

CHEMISTRY 654: RESEARCH PROJECT WORK, PART II

Max. Marks: 200, External: 140, Pass Marks: 56, Sessional: 60, Pass Marks: 24

Research project work part II: A/B/C

A = Inorganic

B = Organic

C = Physical

……..end……..

Program objectives

- To impart an advance level theoretical and practical knowledge in the major fields of inorganic, organic, physical, analytical, material and computational chemistry.
- To engaged in research projects for gaining wide spectrum of subject knowledge and research experience.
- To focused on skill enhancement in the core chemistry with practical expert hands which will make students employable in academia and industries.
- To make responsible citizen to serve the nation

Program outcomes

After completing M.Sc. Chemistry program, students will be able to

1. understand, analyze and interpret various chemical phenomena and process
2. develop skill in planning and conducting advanced chemical experiments as well as accurately record and analyze the results of such experiments
3. develop new molecules or innovative techniques with industrial and societal applications
4. develop a research culture and implementation of the policies to tackle the burning global issues.
5. engage in independent learning in the broadest context of scientific advancement
6. generate new scientific insights or to the innovation of new applications of chemical research
7. communicate the principles and practice of chemical sciences in a clear and concise manner to both science community and society
8. address issues of environment, health and development from a chemical perspective
9. to act with integrity and good ethics in their profession and their obligation to society.

Course Code: CHM -501

Title of the Course: INORGANIC CHEMISTRY-I (CC)

Course Objectives: To understand molecular symmetry, chemical bonding, structure of coordination compounds, cluster, ring and chain compounds of main group elements, inorganic reaction mechanism, environmental and bioinorganic chemistry.

Course Learning Outcomes (CLOs):

After completion of this course successfully, the students will be able to……	
UNIT – I	get basic ideas of molecular symmetry and structure
UNIT-II	understand about chemical bonding
UNIT – III	learn about cluster, ring and chain compounds of main group elements
UNIT-IV	addressthe environmental issues from a chemical perspective and able to explain the function of various elements in biological systems.
UNIT – V	obtain theoretical understanding of how inorganic reactions take place

Course Code: CHM -502

Title of the Course: ORGANIC CHEMISTRY – I (CC)

Course Objectives: To understand the structure, stereochemistry and reaction pathways of organic molecules.

Course Learning Outcomes (CLOs):

After completion of this course successfully, the students will be able to……	
UNIT – I	get a basic idea about the nature of bonding in organic molecules and the role of structures in interpreting organic reactions.
UNIT-II	an exposure about the stereochemistry of molecules and different techniques of asymmetric synthesis.
UNIT – III	get an idea about the mechanistic pathway of various substitution reactions.
UNIT-IV	study the property and reactions of carbonyl functionality.
UNIT – V	learn the mechanistic pathways of organic chemistry under the terms of addition and elimination reactions

Course Code: CHM-503

Title of the Course: PHYSICAL CHEMISTRY-I (CC)
Course Objectives: To know the fundamental of chemical kinetic processes and its application in photoelectron spectroscopy

Course Learning Outcomes (CLOs):

After completion of this course successfully, the students will be able to……	
UNIT-I	Impart knowledge on the fundamentals of chemical kinetics
UNIT-II	Study the kinetics of different types of reactions and methodologies
UNIT-III	Impart knowledge on the surface phenomena and photoelectron spectroscopy
Unit-IV	Understanding surface chemistry and its application
UNIT-V	Learning crystal structure and electronic properties of solids

Course Code: CHM – 504

Title of the Course: APPLIED CHEMISTRY (SEC)

Course Objectives: To have an exposure in the understanding and mechanisms of organic oxidations, reductions, the generation and reactions of organic reaction intermediates, organic photochemistry and pericyclic reactions.

Course Learning Outcomes (CLOs):

After completion of this course successfully, the students will be able ……	
UNIT – I	learn the concept of green chemistry and applications of green chemistry for development of eco- friendly reaction in organic synthesis.
UNIT-II	to be introduce about the application of materials as Homogeneous catalysis, heterogeneous catalysis and bio-catalysis.
UNIT – III	get an idea about synthetic procedure, mechanism of action and pharmacokinetics of some synthetic anticancer, antibiotics and antiviral drug.
UNIT-IV	be introduced about the fundamentals of data analysis in chemical experiment.
UNIT – V	get information about different type of renewable energy, like solar energy, hydrogen energy, bio energy etc..

Course Code: CHM -505

Title of the Course: LABORATORY COURSE IN INORGANIC CHEMISTRY (ALIF)

Course Objectives: To analyze chemical composition of various salts, quantitative estimation of metal ions and anions, synthesis and structure analysis of inorganic complexes.

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……	
UNIT-I	analyze common chemicals for their identity and composition
UNIT-II	estimate different metal ions and anions quantitatively in mixtures and alloys
UNIT-III	gather experience on the synthesis of coordination complexes
UNIT-IV	analyze structure of inorganic complexes from spectral data
UNIT-V	have hands-on experience/practical knowledge in performing experiments

Course Code: CHM-551

Title of the Course: INORGANIC CHEMISTRY-II (CC)
Course Objectives: Understanding magnetic and electronic properties of coordination compounds, chemistry of transition metals, lanthanides and actinides, π-acid complexes, bio-inorganic model systems.
Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……	
UNIT – I	understand the magnetic properties of coordination compounds
UNIT-II	understand the electronic properties of coordination compounds
UNIT – III	know the chemical properties and applications of lanthanides and actinides
UNIT-IV	understand the structure, bonding, and reactivity of □-acid complexes
UNIT – V	design and develop new bio-inorganic model systems

Course Code: CHM-552

Title of the Course: ORGANIC CHEMISTRY-II (CC)
Course Objectives: To have an exposure in the understanding and mechanisms of organic oxidations, reductions, the generation and reactions of organic reaction intermediates, organic photochemistry and pericyclic reactions.

Course Learning Outcomes (CLOs).

After completion of this course successfully, the students will be able ……	
UNIT – I	get the fundamentals of reduction reaction of organic molecules by reducing agent.
UNIT-II	study the different approachs of oxidation reaction.
UNIT – III	learn how organic reaction intermediates can be generated and reacted.
UNIT-IV	gain an understanding of photochemical processes in organic synthesis.
UNIT – V	study the fundamentals of Pericyclic Reactions.

Course Code: CHMCC-553

Title of the Course: PHYSICAL CHEMISTRY-II (CC)

Course Objectives: To understand the fundamental of electrochemistry and different electrochemical processes with basic idea on both equilibrium and non-equilibrium thermodynamics

Course Learning Outcomes (CLOs) After completion of this course successfully, the students will be able to……

UNIT-I	Fundamentals of electrochemistry and electrochemical cells
UNIT-II	Studying the dynamics of electrochemistry and electrochemical processes
UNIT-III	Basic idea on fundamental laws of thermodynamics
Unit-IV	Understanding and its applications of equilibrium thermodynamics
UNIT-V	Introduction to non-equilibrium thermodynamics

Course Code: CHMCC-554

Title of the Course: QUANTUM CHEMISTRY AND MOLECULAR SPECTROSCOPY (IDC)

Course Objectives: To learn the fundamentals of quantum mechanics and its applications to study the molecular spectroscopy
Course Learning Outcomes (CLOs): After completion of this course successfully, the students will be able to……

UNIT-I	Understanding fundamental of quantum chemistry and their applications
UNIT-II	Chemical bonding and their applications in quantum chemistry
UNIT-III	Introduction to electronic and microwave spectroscopy
Unit-IV	Understanding the fundamentals of Infrared and Raman spectroscopy
UNIT-V	Fundamentals and its applications of NMR spectroscopy

Course Code: CHM – 555

Title of the Course: LABORATORY COURSE IN ORGANIC CHEMISTRY (AILF)

Course Objectives: To conduct fundamental organic chemistry experiments to enable to work in academia and industry.

Course Learning Outcomes (CLOs):

After completion of this course successfully, the students will be able to……	
UNIT-I	learn how to separate and analyze the component of mixtures and use of spectroscopy technique for analysis of unknown compounds.
UNIT-II	learn to separate the mixture of organic compounds by TLC and Column chromatography.
UNIT-III	hands on training for synthesis some important organic molecules applying methodologies of some well-known name reactions.
UNIT-IV	learn to isolate some bio-active natural products from the crude bio-organic materials.
UNIT-V	hands on training for quantitative analysis of phenol and water sample.

Course Code: CHM-556

Title of the Course: Chemistry in Everyday Life (VBC)

Course Objectives: To learn the ancient indian chemistry, their development and the importance of chemistry in everyday life

Course Learning Outcomes (CLOs):

After completion of this course successfully, the students will be able to……	
UNIT-I	get knowledge about the ancient Indian chemistry, applications in everyday life and medicines, development of modern chemistry
UNIT-II	know the types of chemical warfare agents, their hazards, and avenues to peaceful uses in humankind
UNIT-III	understand the industrial chemical wates and biomedical wastes and their management for environmental values
UNIT-IV	know about the values of laboratory and chemical industry safety measures, prevention of accidents, international chemical safety cards
UNIT-V	get idea about the general food chemistry, food additives and preservation

Course Code: CHM- 601

Title of the Course: APPLICATIONS OF SPECTROSCOPIC METHODS –I (CC)

Course Objectives: Structural evaluation of organic compounds by spectroscopic study like, IR, NMR and Mass spectroscopy.

After completion of this course successfully, the students will be able ……	
UNIT – I	to get basic idea and application of mass spectroscopy
UNIT-II	to learn the principle and application of UV-Visible spectroscopy for structure evalution.
UNIT – III	to learn applications of IR spectroscopy in organic molecules.
UNIT-IV	to be introduced about Continuous wave (CW) and Fourier-Transform (FT) NMR spectroscopy.
UNIT – V	to get basic idea of ^{13}C NMR spectroscopy and 2D NMR spectroscopy.

Course Code: CHM -602

Title of the Course: ANALYTICAL AND COMPUTATIONAL CHEMISTRY (IDC)

Course Objectives: Introduction to analytical techniques such as purification and separation, electrochemical analysis, thermal analysis and nuclear analysis and concept in computational chemistry

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……	
UNIT – I	concept on various purification and separation techniques and their applications in compound analysis
UNIT-II	understanding different electrochemical methods and their application for various chemical analysis
UNIT – III	principle, instrumentation and applications of various thermal analysis and neutron activation analysis (NAA) and X-ray fluorescence spectroscopy (XRF)
UNIT-IV	basic structure and functioning of a computer and computer coding involving simple formula in chemistry
UNIT – V	concepts in computational chemistry consisting of various approximation and theory

Course Code: CHM -603

Title of the Course: INORGANIC CHEMISTRY-III (ECC)

Course Objectives: Impart knowledge on organometallic compounds and their catalytic applications, Group Theory and its application in spectroscopy, nuclear radiation and measurement and supramolecular chemistry.

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……	
UNIT – I	understand the synthesis, structure, bonding, reactivity of various organometallic compounds
UNIT-II	understand homogeneous catalysis relevant to chemical and polymer industries.
UNIT – III	learn the basics of group theory and its application in chemistry. This knowledge may help them to learn other topics in chemistry like spectroscopy and coordination chemistry etc.
UNIT-IV	learn various nuclear radiations and their detection and measurement techniques
UNIT – V	provide insight into the various supramolecular interactions, molecular recognition, transport, translocation, self-assembly and molecular devices

Course Code: CHMCC -603

Title of the Course: ORGANIC CHEMISTRY – III (ECC)

Course Objectives: To understand the properties, isolation, chemical synthesis of some bio- active natural product, lipids, proteins, enzymes, and heterocyclic compound. Also, to build a concept on the role of different reagents and green approach in organic synthesis.

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able……	
UNIT – I	acquire knowledge on how different reagents can be applicable in organic transformations.
UNIT-II	get an idea about the chemical synthesis and reactions of some important heterocyclic compounds.
UNIT – III	be aware of the essence and learn the concept of green chemistry and its applications in organic synthesis.
UNIT-IV	learn the isolation process, properties and chemical synthesis of some bio-active natural products.
UNIT – V	get basic idea about biogenesis process.

Course Code: CHMCC-603

Title of the Course: PHYSICAL CHEMISTRY-III (ECC)

Course Objectives: An in-depth study of the statistical mechanics, chemistry of macromolecules and adsorption processes on solid surfaces
Course Learning Outcomes (CLOs): After completion of this course successfully, the students will be able to……

UNIT-I	Introduction to fundamentals of statistical thermodynamics
UNIT-II	Application of statistical thermodynamics using partition function
UNIT-III	Understanding the distribution functions and their applications in different statistics
Unit-IV	Macromolecules and its applications
UNIT-V	Physical insight into different adsorption processes on solid surface reactions

Course Code: CHM-604

Title of the Course: LABORATORY COURSE IN PHYSICAL CHEMISTRY (ALIF)

Course Objectives: Fundamental physical chemistry experiments to understand and utilize these works both in academic as well as in industrial applications.
Course Learning Outcomes (CLOs) After completion of this course successfully, the students will be able to……

1. Study the theories and principles of common physical chemistry experiments
2. Sample preparation and understanding to perform the experimental procedures
3. Data collection, analysis of the results, plotting of graphs and representation of the result scientifically
4. Maintaining the laboratory record book in a scientific manner

Course Code: CHM-605

Title of the Course: Dissertation (RESEARCH PROJECT -Part I)
Course Objectives: Impart basic knowledge on research problems and literature survey, designing new experiment.

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……

(1) understand research problems

(2) execute literature search on a research topic

(3) design new experiments to address research problems

Course Code: CHM -651

Title of the Course: APPLICATIONS OF SPECTROSCOPIC METHODS –II (CC)

Course Objectives: Structural evaluation of inorganic compounds by spectroscopic study like, IR, NMR, ESR, Mass and Mossbauer spectroscopy.

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……	
Part A : Inorganic Chemistry	
UNIT – I	analyze spectroscopic information to find structural information of molecules
UNIT-II	assess structure of inorganic compounds using magnetic resonance spectroscopy (ESR)
UNIT – III	assess structure of inorganic compounds using magnetic resonance spectroscopy (NMR)
UNIT – IV	learn principle of mass spectroscopy and structure elucidation of inorganic compounds
UNIT – V	learn principle of Mossbauer spectroscopy and structure elucidation of inorganic compounds

Course Code: CHM-652

Title of the Course: CHEMISTRY OF ADVANCED MATERIALS (CC)

Course Objectives: To bridge the fundamental ideas of chemistry to modern research and industry-related topics
Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……	
UNIT – I	be introduced to materials at the nanometer length scale with reference to synthesis, characterization, properties and applications
UNIT-II	understand the mechanism of photosensitization with emphasis to porphyrin complexes and their applications in photodynamic therapy
UNIT – III	study the physicochemical properties of liquid crystals and supramolecules and their representative applications
UNIT-IV	learn the basic chemistry behind drug discovery, design and development
UNIT – V	know the hazard of chemical warfare agents and avenues to peaceful uses

Course Code: CHM -653

Title of the Course: INORGANIC CHEMISTRY-IV (ECC)

Course Objectives: To study organometallic compounds with multiple M-C bond and C-C bonded ligands, photochemical reactions of coordination compounds, application of radiochemical methods, bio-inorganic enzyme chemistry, crystal engineering and applications.

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……	
UNIT – I	understand the structure, bonding and reactivity of □-Coordination of C-C multiple bonds
UNIT-II	understand the basics of photochemistry and applications of photochemical reactions of coordination compounds
UNIT – III	get information of different radiochemical method of analysis
UNIT-IV	design new catalysts, new reactions and properties based on the fundamental insights received about different enzymes
UNIT – V	understand the molecular crystal design, formation and explore their applicability

Course Code: CHM - 653:

Title of the Course: ORGANIC CHEMISTRY – IV (ECC)

Course Objectives: To get idea about the various applications of organic chemistry in the light of strategies and control.

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able ……	
UNIT – I	gain exposure to the applications of organometallic chemistry in organic strategies.
UNIT-II	get an idea about the disconnection approach of organic molecules to frame a chemical synthesis.
UNIT – III	acquire knowledge of the mechanistic pathways of the synthesis and reactions of some benzofused heterocyclic compounds having applications in medicinal chemistry.
UNIT-IV	develop the concept of the basic principle of drug designing and medicinal chemistry.
UNIT – V	gain an understanding of the chemotherapeutic and non-invasive cancer photodynamic therapy strategies through the concept of the synthetic approach and application of antineoplastic drugs/prodrugs.

Course Code: CHM-653

Title of the Course: PHYSICAL CHEMISTRY-IV (ECC)

Course Objectives: An advanced knowledge about the physical properties and their processes
Course Learning Outcomes (CLOs): After completion of this course successfully, the students will be able to……

UNIT-I	Understanding different photophysical processes in excited state
UNIT-II	Study on solvent and environment effects on emission spectra and its applications
UNIT-III	Study of the physical properties with emphasis to its applications in solid state
Unit-IV	Study of different processes with emphasis to its applications in liquid state
UNIT-V	Understanding different chemical dynamic in gas phase reactions

Course Code: CHM-654

Title of the Course: Dissertation (RESEARCH PROJECT, Part II)

Course Objectives: Impart basic knowledge on designing new experiment, their analysis and interpretation of results.

Course Learning Outcomes (CLOs)

After completion of this course successfully, the students will be able to……

1. design new experiments to address research problems
2. conduct experiments in a scientific way
3. analyze and interpret the results
4. write research article

****

***