

**SCHEME OF INSTRUCTION AND SYLLABI
(EFFECTIVE FROM 2017 –2018)**

**M.Sc. in CHEMISTRY
with Specialization in**

ANALYTICAL CHEMISTRY



**DEPARTMENT OF CHEMISTRY
NATIONAL INSTITUTE OF TECHNOLOGY, WARANGAL-506 004
TELANGANA STATE, INDIA**

**M.Sc. CHEMISTRY
with Specialization in
ANALYTICAL CHEMISTRY**

I SEMESTER

PROPOSED SCHEME of INSTRUCTION

S. No	Course Code	Course Name	Instruction Hrs			Credits
			L	T	P	
1	CY5101	Fundamentals of Analytical Chemistry	4	0	0	4
2	CY5102	Main Group and Transition Metal Chemistry	4	0	0	4
3	CY5103	Reaction Mechanisms and Stereochemistry	4	0	0	4
4	CY5104	Thermodynamics and Electrochemistry	4	0	0	4
5	CY5105	Inorganic Chemistry Laboratory	0	0	3	2
6	CY5106	Computational Chemistry Laboratory	0	0	3	2
7	CY5107	Organic Chemistry Laboratory – I	0	0	3	2
8	CY5108	Physical Chemistry Laboratory – I	0	0	3	2
Total Credits					24	

II SEMESTER

PROPOSED SCHEME of INSTRUCTION

S. No	Course Code	Course Name	Instruction Hrs			Credits
			L	T	P	
1	CY5151	Principles of Molecular Spectroscopy	4	0	0	4
2	CY5152	Solid State Chemistry and Group Theory	4	0	0	4
3	CY5153	Photochemistry and Pericyclic Reactions	4	0	0	4
4	CY5154	Chemical Kinetics and Quantum Chemistry	4	0	0	4
5	CY5155	Analytical Chemistry Laboratory	0	0	3	2
6	CY5156	Organic Chemistry Laboratory – II	0	0	3	2
7	CY5157	Physical Chemistry Laboratory – II	0	0	3	2
8	CY516X	Elective I	0	0	3	3
9	CY5191	Seminar	0	2	0	1
Total Credits					26	
<i>*List of courses for Elective I : Elective I shall be chosen by the students from the following list</i>						

Elective-I (CY516X)	CY5161	Chemistry of Heterocyclics and Biomolecules
	CY5162	Organometallic Chemistry
	CY5163	Chemical Education and Research

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III SEMESTER
PROPOSED SCHEME of INSTRUCTION

S. No.	Course Code	Course Name	Instruction Hrs			Credits
			L	T	P	
1	CY6201	X-ray and Microscopic Methods of Analysis	4	0	0	4
2	CY6202	Physical Methods of Chemical Analysis	4	0	0	4
3	CY6203	Instr. Methods of Chemical Analysis Laboratory-I	0	0	6	4
4	CY6204	Quantitative Analysis Laboratory	0	0	6	4
5	CY621A	ELECTIVE – II*	3	0	0	3
6	CY612B	ELECTIVE –III*	3	0	0	3
7	CY6241	SEMINAR	0	2	0	1
Total Credits						23

**List of courses for Electives II and III: Electives II and III shall be chosen by the students from the following list*

Elective-II (CY621A)	CY6211	Environmental Chemistry
	CY6212	Nanomaterials: Synthesis and Characterization
	CY6213	Chemical, Electrochemical and Biosensors
	CY6214	Bioinorganic Chemistry
	CY6215	Stochastics in Chemical Analysis
Elective-III (CY612B)	CY6121	Bioanalytical Chemistry
	CY6122	Computational Chemistry
	CY6123	Applications of Chemical Spectroscopy
	CY6124	Chemistry of Dyes

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IV SEMESTER

PROPOSED SCHEME of INSTRUCTION

S. No	Course Code	Course Name	Instruction Hrs			Credits
			L	T	P	
1	CY6251	Advance Chromatographic Methods	4	0	0	4
2	CY6252	Instr. Methods of Chemical Analysis Laboratory-II	0	0	3	2
3	CY626A	ELECTIVE-IV	3	0	0	3
4	CY627B	ELECTIVE-V	3	0	0	3
5	CY618C	ELECTIVE-VI	3	0	0	3
6	CY6192	COMPREHENSIVE VIVA – VOCE	0	0	0	2
7	CY6199	TERM PROJECT	0	6	0	4
Total Credits						21
<i>**List of courses for Electives IV, V and VI: Electives IV, V and VI shall be chosen by the students from the following list</i>						
Elective-IV (CY626A)	CY6261	Chemical and Electrochemical Systems of Energy				
	CY6262	Surface Analytical Techniques				
	CY6263	Supramolecular Chemistry				
Elective-V (CY627B)	CY6271	Advance Electroanalytical Methods				
	CY6272	Tandem and Hyphenated Analytical Methods				
	CY6273	Advances in Industrial Catalysis				
Elective-VI (CY618C)	CY6181	Emerging topics in Organic Synthesis				
	CY6182	Advance Optical and Magnetic Resonance Spectral Methods				
	CY6183	Quality Assurance and Quality Management in Chemical Industry				
	CY6184	Polymorphism: Chemistry and Industrial Applications				

M.Sc. CHEMISTRY (ANALYICAL CHEMISTRY)
SYLLABII OF ALL THEORY AND LABORATORY SUBJECTS

SEMESTER-I						
(Common for Both Organic and Analytical Chemistry Streams)						
Code	Fundamentals of Analytical Chemistry	L	T	P	C	56
CY5101	(Core)	4	-	-	4	Hours
<p>Errors and Statistical Treatment of Data: Accuracy and Precision; Errors and Error Distributions; Statistical Treatment of Data; Finite Data Analysis; Standard Deviation; Criteria for Rejection of Data; Method of Least Squares</p> <p>Thermoanalytical Methods: Types; Thermogravimetry; Differential Thermal Analysis (DTA); Differential Scanning Calorimetry (DSC)</p> <p>Separation Techniques: Heterogeneous Equilibria; Solvent Extraction; Solid Phase Extraction; Ion Exchange Chromatography (Planar and Column.)</p> <p>Electroanalytical Methods: Conductometry; Potentiometry; Electro-Gravimetry; Coulometry; Voltammetry; (Polarography); Amperometry</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> <i>Quantitative Analysis</i>, Day and Underwood, PHI, 6thEdn., 2009 <i>Fundamentals of Analytical Chemistry</i>, Skoog D.A, West D M, Holler, F J and Crouch S R, Saunders College Publishing, 8thEdn., 2004. <i>Modern Analytical Chemistry</i>, David Harvey, McGraw Hill, 2000. <p>Reference Books:</p> <ol style="list-style-type: none"> <i>Analytical Chemistry: Principles</i>, J.H. Kennedy, CLI, 2011 						
Code	Main Group and Transition Metal Chemistry	L	T	P	C	56 hrs
CY5102	(Core)	4	-	-	4	
<p>Review of CFT and its applications, Molecular orbital theory: Determination of stoichiometry of metal complexes by Jobs methods: Magnetic Properties of the complexes: Organometallic Compounds: Metal carbonyls, Metallocenes: Inorganic Reaction Mechanisms: Main group Chemistry: Structure and bonding in polyhedral boranes and carboranes, Synthesis and reactivity of organo-lithium, -beryllium and -magnesium compounds; Preparation and reactivity of aluminiumorganyls; carbalumination, hydroalumination. Bio-inorganic Chemistry: Electronic and Magnetic Aspects of Dioxygen Binding; Metallo-Enzymes- Nitrogenase, Catecholase, Peroxidase, Mutase Enzymes.</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> <i>Inorganic Chemistry - Principles of Structures and reactivity</i>, James E. Huheey, 3rdEdn., Harper International Edition, New York, 1992. <i>Coordination Chemistry</i>, D. Banerjee, Asian Books Private Ltd, 2ndEdn., 2007. <i>Principles of Bioinorganic Chemistry</i>, Stephen J. Lippard & Jeremy M. Berg, 2ndEdn., Panima Publishing Corporation, New Delhi, 2005. <i>An Introduction to Organometallic Chemistry</i>, P.W. Parkins, R.C. Poller, Mac Milan Publishers, 1996. <i>Elements of Magnetochemistry</i>, R.L. Datta and A. Syamal, S. Chand and Co. Ltd., 1982. <i>Concise Inorganic Chemistry</i>, J.D. Lee, Blackwell Publishing, 5th edition, 2006. <p>Reference Books:</p>						

1. *Mechanism of Inorganic Reactions*, F. Basalo and R. G. Pearson, WileyEastern Ltd., New Delhi, 2ndEdn, **1967**.
2. *Inorganic Chemistry*, D. F. Shriver and P. W. Atkins, ELBS, London, 3rdEdn.,**1999**.
3. *Advanced Inorganic Chemistry*, F. A. Cotton and G. Wilkinson, John Wiley & Sons, New York, 6thEdn.,**1999**.
4. *Inorganic Chemistry*, Keith F. Purcell and John C. Kotz, W. B. Saunders Com. HongKong, **1987**.
5. *Inorganic Reaction Mechanisms*, Martin L. Tobe and John Burgess, Longmans 1stEdn., **1999**.

Code	Reaction Mechanisms and Stereochemistry (Core)	L	T	P	C	56 hrs
CY5103		4	-	-	4	

Structure and reactivity:

Nomenclature, General rules as applied to bicyclic compounds, spiro and heterospiro compounds. Nature of reaction energy and kinetic considerations - types of organic reactions, reactive intermediates: formation and stabilization, concept of tautomerism.

Nucleophilic Substitutions:

SN_1 , SN_2 , SN_1^i , SN_2^i , SN_i , SN_i^i internal return ion pair intermediates, solvent effects, competition between SN_1 and SN_2 mechanism. Linear free energy relationships, Hammett equation, Taft treatment of polar effects in aliphatic compounds. Neighboring group participation of O, S, N, halogens, aryl groups, alkyl and cycloalkyl groups in nucleophilic substitution reactions. Sigma, Pi bond participation in acyclic and bicyclic systems (Non-classic carbocations).

Aromatic substitution reactions:

Electrophilic, nucleophilic through benzyne, orientation of aromatic substitution (Deuterium isotopic effect) at a saturated carbon, Partial rate factors, Selectivity relationships, General ideas about SE_1 , SE_2 , mechanisms.

Elimination reactions: E_1 , E_1CB , E_2 mechanisms, orientation in elimination reactions-Saytzeff and Hoffman elimination, cyclic eliminations, stereochemistry of elimination in acyclic and cyclic systems, elimination versus substitution reactions, formation of carbon-carbon double bonds via elimination reactions; pyrolytic, syn and anti-elimination.

Addition Reactions: Addition to carbon multiple bonds - Addition reactions involving electrophiles, nucleophiles and free radicals, cyclic mechanisms, orientation and stereochemistry, hydrogenation of double and triple bonds, hydroboration, (versions of Birch reduction. Michael reaction, addition of oxygen and Nitrogen; (b) Addition to carbon-hetero atom multiple bonds: Mannich reaction, addition of Grignard reagents, Wittig reaction.

Stereochemistry and stereoisomerism: Introduction, Molecular symmetry in organic molecules, Symmetry elements (C_n , C_i and S_n) and symmetry operations, Molecular symmetry and chirality, Classification of chiral molecules based on symmetry, Classification of chiral molecules based on energy criterion.

Configuration and Conformational analysis: D,L and R,S nomenclature; erythro and threo, E,Z nomenclature for unsaturated systems, Re and Si faces, Prochirality, Racemization and racemic modifications, Resolution of racemic modifications. Conformational isomerism and analysis of substituted cyclic systems, Stereochemistry of Decalins.

Stereochemistry of heteroatomic molecules and axial chirality:

Stereochemistry of nitrogen containing compounds with a tetra co-ordinate chiral center, Stereochemistry of the compounds containing $-C=N$ and $-N=N-$, Stereochemistry of allenes, spiranes and biphenyls (Atropisomerism),

Principles of chemical reactivity: Kinetic control and thermodynamic control, Partial and absolute asymmetric synthesis, Introduction to stereo selective syntheses, Concept of dynamic enantiomerism

Text Books:

1. *Reaction Mechanism in Organic Chemistry*, S.M. Mukherjee and S. P. Singh, Macmillan India Limited, 2009.
2. *Organic Chemistry*, Francis A. Carey, Tata McGraw Hill publishing company Limited, New Delhi 5thEdn.,2007.
3. *A guide book to mechanism in Organic Chemistry*, Peter Sykes, ELBS 6thEdn.,2002.
4. *Some Modern Methods of Organic Synthesis*, W. Carothers, Cambridge University Press, Cambridge, 4thEdn.,2007.

Reference Books:						
1. <i>Advanced Organic Chemistry Reactions, Mechanism & Structure</i> , Jerry March, 4 th Edn., Wiley, 2006 .						
2. <i>Organic Synthesis</i> , Michael B. Smith, McGraw-Hill, 2 nd Edn., 2002						
Code	Thermodynamics and Electrochemistry	L	T	P	C	56 hrs
CY5104	(Core)	4	-	-	4	
<p>First, Second and III Laws of Thermodynamics: Thermodynamic Reversibility, Heat Capacities and Heats of Reactions; Entropy Changes in Chemical Reactions; Thermodynamic Equations of State; <i>Free Energy and Partial Molar Properties</i>: Gibbs-Helmholtz Equations; Fugacity and Activity; Phase Equilibria; Partial Molar Quantities; <i>Third Law of Thermodynamics</i>: Absolute Entropy of Solids, Liquids and Gases; Cryoscopic Evaluation of Absolute Entropy of Solids</p> <p>Statistical Thermodynamics: Statistical Treatment of Entropy, Maxwell-Boltzmann, Bose-Einstein and Fermi-Dirac Statistics; Partition Functions and Their Calculation; Sackur-Tetrode Equation.</p> <p>Electrolytic Conductors: DHO Theory Inter-Ionic Atmosphere; Activity and Activity Coefficients; Nonaqueous Electrolytes; Solid Electrolytes; Conducting Melts</p> <p>Electrodes, Electrode Potentials and Electrode Processes: Theories of Electrical Double-Layer; Electrokinetic Phenomena; Thermodynamics of Electrochemical Cells; Ion-Selective and Chemically Modified Electrodes; Polarisation of Electrodes; Principles of Voltammetry; Rechargeable Batteries; Fuel Cells; Photovoltaic Cells</p> <p>Corrosion and Its Prevention: Types of Corrosion; Theories of Corrosion; Corrosion Prevention Methods; Pourbaux Diagram</p>						
Text Books:						
1. <i>Physical Chemistry</i> , R. S. Berry, S. A. Rice and J. Ross, (2 nd Edn), Oxford, 2007 .						
2. <i>Physical Chemistry</i> , P. Atkins and Julia de Paula, (9 th Edn), Oxford, 2011 .						
3. <i>Physical Chemistry</i> , R. J. Silbey, R.A. Alberty and M. G. Bawendi, Wiley (4 th Edn), 2006 .						
4. <i>Thermodynamics for Chemists</i> , S. Glasstone, East-West, 2007						
Reference Books:						
1. <i>Fundamentals of Electrochemistry</i> , Vladimir S Bagotsky, Wiley (2 nd Edn), 2011 .						
2. <i>Electrochemistry</i> , Carl H Hamann, A. Hamnett and W. Vielstich, (2 nd Edn) Wiley VCH, 2007 .						
Code	Inorganic Chemistry Laboratory-I	L	T	P	C	42 hrs
CY5105		-	-	3	2	
<p>Estimation of ofa mixture of acids, Fe²⁺ in hematite, available chlorine from bleaching powder, Ca²⁺ and Mg²⁺, Ca²⁺ from milk powder by volumetric method. Chemistry of blue printing, colorimetric method, semi gravimetric method, Gravimetric method, Separation of mixture of anions and cations by paper chromatographic method, Quantitative separation and determination of Cu²⁺ by gravimetric and Zn²⁺ by volumetric method.</p>						
Manuals/Text Books:						
1. <i>Inorganic Chemistry and Analysis through Problems and Exercises</i> , A.D. Kumar and A.D. Kumar, New Age International, 2007						
2. <i>Inorganic Chemistry Laboratory Manual</i> , K. Laxma Reddy, Vishnushanker, Chem. Assn., 2010						
Reference Books:						
<i>Vogels' Quantitative Inorganic Chemistry</i> , Pearson, 2012						
Code	Computational Chemistry Laboratory	L	T	P	C	42 hrs

CY5106		-	-	3	2	
<p>Computer Hardware and Software: Physical Components of Desktop Computer and Assembly; Operating Systems; Open-Access and Commercial OS</p> <p>MS-Office for Chemical Applications: MS-Word for Chemical Documentation; MS-PowerPoint for Virtual Chemical Animations; MS-EXCEL for Data Processing, Graphical Representations and Curve-Fitting</p> <p>Golden Software Surfer and Grapher: Contour and Surface3-d Plots of $z=f(x,y)$ Functions; Gridding of $z=f(x,y)$ kind Data Sets</p> <p>Molecular Structure and Labware Drawing Software: ISIS Draw; ACD-Labs; ChemDraw</p> <p>Molecular Modeling and Quantum Calculations: Use of ChemSoftChemOffice; Origin, Sybyl, etc for Molecular Modeling, Conformational Analysis, Spectral and Physicochemical Data Predictions; Orbital Energy and Bonding Calculations</p> <p>Virtual Chemistry Experiments and Online Chemical Resources: Accessing to Online Chemical Resources</p> <p>Manuals/Text Books:</p> <ol style="list-style-type: none"> <i>Computational Chemistry: A Practical Guide for Applying Techniques to Real World Problems</i>, David Young, Wiley, 2001 <i>Computational Chemistry Laboratory Manual</i>, A. Ramachandraiah, Chem. Assn., 2010 <p>Reference Books:</p> <ol style="list-style-type: none"> <i>Molecular Modeling</i>, Andrew Leach, Pearson, 2012 <i>Applications of Microsoft Excel in Analytical Chemistry</i>, F. Holler and C. Stanley, Brooks Cle, 2013 						
Code	Organic Chemistry Laboratory-I	L	T	P	C	42 hrs
CY5107		-	-	3	2	
<p>List of Experiments: Determination of physical constants (melting and boiling points) Purification Techniques: Crystallization, Decolourization, fractional crystallization, Sublimation, Simple distillation, Fractional distillation, Vacuum distillation and Steam distillation, Isolation and purification of products by chromatographic techniques: TLC & Column Chromatography, (4 classes), Solubility tests for organic compounds</p> <p>Text Books:</p> <ol style="list-style-type: none"> <i>Practical Organic Chemistry-G. Mann & B.C Saunders, ELBS Edition and Longman Group Limited, 2002.</i> 						
Code	Physical Chemistry Laboratory-I	L	T	P	C	42 hrs
CY5108		-	-	3	2	
<p>Heat of Neutralisation; Solubility Product of Sparingly Soluble Salts and ΔG° of Ionisation; Integral Heat of Solution and Heat of Hydration</p> <p>Verification of Nernst Distribution Law; Determination of Formation Constant of a Complex Ion; Evaluation of Λ_0 and Verification of DHO Equation</p> <p>Evaluation of E° value of Electrodes; Evaluation of Consecutive Deprotonation Equilibrium Constants; Evaluation of Halfwave Potentials and Diffusion Coefficients</p> <p>Construction of Phase Diagram of Binary System and Evaluation of Eutectic Point</p> <p>Evaluation of Heat of Decomposition and Heat of Phase Transformation</p> <p>Kohlrausch Law and Λ_0 of Weak Electrolytes</p> <p>Evaluation of pK_a of Weak Acids; Effect of pH, Conductance and Dissolved Oxygen on Buffers and Buffer Capacity; Physical Adsorption Isotherm</p>						

Rate and Extent of Corrosion; Molecular Linear Properties of Homologous Compounds:
Refractor; Determination of Partial Molar Volumes; Evaluation of Heat of
Decomposition and Heat of Phase Transformation

Manuals/Text Books:

1. *Laboratory Manual for Physical Chemistry Practicals*, B. V. AppaRao, A. Ramachandraiah and I. Ajit Kumar Reddy, Chemistry Association, **2016**
2. *Physical Chemistry Practical*, S. K. Maity and N. K. Ghosh, New Central Book Agency, **2012**
3. *Practical Physical Chemistry*, B. Viswanathan and P. S. Raghavan, Viva Books, **2012**
4. *Advanced Practical Physical Chemistry*, J. B. Yadav, Krishna Prakasan Media, **2015**

SEMESTER-II						
(Common for Both Organic and Analytical Chemistry Streams)						
Code	Principles of Molecular Spectroscopy	L	T	P	C	56 hrs
CY5151	(Core)	4	-	-	4	
<p>Microwave Spectroscopy: Introduction to Interaction of Radiation with Matter; Molecular Quantum Properties; Rotation of Molecules, Rigid and Non-rigid Rotors; Quantum Aspects of Molecular Rotational Energy and Selection Rules of Transitions; Diatomic and Polyatomic Molecules, Instrumentation; Applications of Microwave Spectroscopy.</p> <p>Infrared and Raman Spectroscopy: Molecular Symmetry and Fundamental Modes of Vibrations, Quantum Aspects of Molecular Vibrational Energy and Selection Rules of Vibrational Transitions; Vibrational Rotational Spectra; Instrumentation; Applications; Raman Effect; Quantum Mechanical Description; Rotational and Vibrational Raman Spectra; Mutual Exclusion and Complementarity</p> <p>Electronic (UV-Vis-NIR) Spectroscopy: Franck-Condon Principle, Types of Electronic Transitions; Instrumentation; Applications; Woodward Rules</p> <p>Nuclear Magnetic Resonance (NMR) Spectroscopy: Magnetic Nuclei and Nuclear Spin; NMR Spectral Phenomenon, Relaxation Mechanism; <i>¹H NMR Spectroscopy:</i> Chemical Shift; Instrumentation; Spin-Spin Coupling; Nuclear Overhauser Effect; 2-D NMR Spectroscopy (COSY) ; INDOR and NOE Methods.</p> <p><i>¹³C NMR Spectroscopy:</i> Fourier Transform NMR; Off-Resonance and Spin-Decoupled ¹³C NMR Spectroscopy ; Applications; Magnetic Resonance Imaging (MRI); <i>NMR Spectroscopy of ¹⁹F, ¹⁵N and ³¹P nuclides.</i></p> <p>Electron Spin Resonance (ESR) Spectroscopy: Electron Spin and Its Magnetism; 'g'-Factor; ESR Spectral Phenomenon; Instrumentation; Applications; Electron Spin-Nuclear Spin Coupling; ENDOR;</p> <p>Mass Spectrometry: Trajectories of Charged Bodies in Electrical and Magnetic Fields; Molecular Fragmentation; Resolution by Magnetic, Quadrupole and Time of Flight Methods; Applications; Hyphenated Techniques.</p>						
Text Books:						
1. <i>Fundamentals of Molecular Spectroscopy</i> , Banwell and McCash, Tata McGraw Hill, 4 th Edn.,2010.						
2. <i>Modern Spectroscopy</i> , Michael Hollas, Wiley, 4 th Edn.,2004.						
3. <i>Infrared and Raman Spectra of Inorganic and Coordination Compounds</i> , Nakamoto, Wiley Inter Science, 6 th Edn.,2009.						
4. <i>Organic Spectroscopy</i> , William Kemp, Macmillan, 3 rd Edn.,2009.						
Code	Solid State Chemistry and Group Theory	L	T	P	C	56 hrs
CY5152	(Core)	4	-	-	4	
<p>The crystal structure: Symmetry in crystal systems, Point Groups and Space Groups, Space Lattice and Unit cell, Bravais Lattices, Lattice Energy of an Ionic crystal, Miller Indices. Imperfection in a crystal: Point defects and Line Defects. Types of crystals. X-ray diffraction: Single crystal and Powder Method: The Debye Scherrer Method, Electron diffraction, Neutron diffraction. Energy Band Theory: Conductors, Semiconductors and Insulators. Superconductivity: Low Temperature superconductivity, High Temperature Super conductivity, BCS theory.</p> <p>Properties: Electrical Properties, Magnetic properties and Optical & dielectric properties.</p>						

Inorganic Polymers: Introduction, Polyphosphazine: Preparation, properties, applications. Sulphur based polymers: Polymeric sulphur and Polymeric sulphurnitride, chalcogenide glasses, threshold switching and Memory switching. Polysiloxanes or silicone polymers or silicones: Preparation, Properties, types, uses.

Molecular Symmetry: Symmetry Operations and Elements of Symmetry: Rotational Axis of Symmetry, Plane of Symmetry, Improper Rotational Axis of Symmetry (Alternate Axis of Symmetry), Center of Symmetry (Inversion Symmetry); Symmetry and Stereoisomerism; Symmetry Criteria for Optical Activity; Symmetry Restrictions on Dipole Moment.

Group Theory and Molecular Point Groups: Group Theory and Properties of a Mathematical Group; Molecular Symmetry Elements Forming to a Group; Point Groups and Classification of Molecules into Point Groups (with Examples); Point Groups, Sub-Groups and Classes; Group Multiplication Tables; Matrix Representations of Symmetry Operations; Reducible and Irreducible Representations; Construction of Character Tables; Decomposition of Reducible Representations and the Direct Product; Mulliken Symbolism; Rules of Irreducible Representations; Standard Reduction Formula; Orthogonality Theorem.

Application of Symmetry and Group Theory: Symmetry of Normal Modes of Vibrations of Molecules; Cartesian Coordinate and Internal Coordinate Methods; Selections Rules and Molecular Polarization; Infrared and Raman Activity; Internal Coordinates and Redundancy; Orbital Selection Rules and Electronic Spectra of Simple Atoms and Molecules.

Text Books:

1. *Solid State Chemistry*, D.K. Chakrabarty, , New Age International (P) Limited, Publishers, Second Edition, **2010**.
2. *Principles of Physical Chemistry*, B.R. Puri, L.R. Sharma and M.S. Pathania, Vishal Publishing Co., **2011**.
3. *Solid State Chemistry, An Introduction*, Lesley Smart, Elaine Moore, 2ndEdn.,**2004**.
4. *Symmetry and Spectroscopy of Molecules*, K. Veera Reddy, New Age International, Hyderabad, **1999**.
5. *Symmetry and Group Theory in Chemistry*, Mark Ladd, Marwood Publishers, London, **2000**.
6. *Molecular Symmetry and Group Theory*, Robert L. Carter, John Wiley & Sons, **1998**.

Code	Photochemistry and Pericyclic Reactions	L	T	P	C	56 hrs
CY5153	(Core)	4	-	-	4	

Organic Photochemistry:

Photochemical energy, Frank Condon Principle, Jablonski diagram, Singlet and Triplet states, Dissipation of photochemical energy, Photosensitization, Quenching, Quantum efficiency and Quantum yield, Experimental methods of photochemistry, Photochemistry of carbonyl and non-carbonyl compounds.

Photo Chemical Reactions:

Norrish type I and Norrish type II cleavages, Paterno-Buchi reaction. Photoreduction, Photochemistry of enones, Rearrangement of α , β unsaturated ketones and cyclohexadienes, Photochemistry of p-Benzoquinones, Photochemistry of unsaturated systems - Olefins, cis trans Isomerisation and dimerization, Acetylenes dimerisation, Dienes - Photochemistry of 1,3 butadienes (2+2) additions leading to cage structures, Photochemistry of cyclohexadienes, Photochemistry of aromatic compounds.

Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3 Butadiene, 1,3,5- Hexatriene, Allyl system, Classification of pericyclic reactions, FMO approach, Woodward-Hoffman correlation diagram method and Perturbation of molecular (PMO) approach for the explanation of pericyclic reactions under thermal and photochemical conditions.

Pericyclic Reactions: 1) Electrocyclic Reactions; Conrotatory and disrotatory motions in (4n) and (4n+2), allyl systems and secondary effects. 2) Cycloadditions; Antarafacial and suprafacial additions, Notation. of cycloaddition of (4n) and (4n+2) systems, Secondary effects of substitutes on the rates of cycloaddition reaction and chelotropic reactions, 3) Sigmatropic

Reactions; Suprafacial and antarafacial shifts, retention and inversion of configurations, Claisen and Cope rearrangements.

Aromaticity and Antiaromaticity: Localized and delocalised covalent bond, Concept of resonance and aromaticity, Huckel's rule for aromaticity in benzenoid and non-benzenoid compounds, Anti-aromaticity and homo-aromaticity, Aromaticity of various rings like annulenes, heteroannulenes, sydnones and Fullerenes (C₆₀).

Text Books:

1. *Advanced Organic Chemistry Reactions, Mechanism & Structure*, Jerry March, 4th Edition, Wiley, 2006.
2. *Molecular reactions and Photochemistry*, Charles Dupey and O. Chapman, Prentice Hall, 2006.
3. *Reaction Mechanism in Organic Chemistry*, S.M. Mukherjee and S. P. Singh, Macmillan India Limited, 2009.
4. *Pericyclic reactions*, S.M. Mukherjee, Macmilan India Limited, 2009.
5. *Heterocyclic Chemistry*, Thomas L. Gilchrist, 3rd Edition, Pearson Education, 2007.
6. *Heterocyclic Chemistry-II*, J.A. Joule, K. Mills and G.F. Smith, 3rd Edition, Stanley Thornes, 2007.
7. *Heterocyclic Chemistry*, Raj K. Bansal, 5th Edition, New Age International (Pvt.Ltd.), 2006.

Reference Books:

1. The modern structural theory in Organic Chemistry, L. N. Ferguson, Pretice Hall, 2008.
2. Physical Organic Chemistry by Jack Hine, Mc. Graw Hill, 2007.
3. Mechanisms and Theory in Organic Chemistry by T.H. Lowery and K.S. Rich Gardson, 2006.

Code	Chemical Kinetics and Quantum Chemistry	L	T	P	C	56 hrs
CY5154	(Core)	4	-	-	4	

Chemical Kinetics and Catalysis Reaction Rates and Rate Equations; Kinetics of Complex and Fast Reactions and Their Reaction Mechanisms; Kinetics of Auto-oxidation Reactions; Photochemical and Oscillatory Reactions; *Theories of Reaction Rates:* Unimolecular and Bimolecular Reactions. Potential Energy Diagrams. *Kinetics of Reactions in Solution:* Effect of Solvent, Salt and Substituent on Reaction Rates; Linear Free Energy Relationships; *Catalysis:* Homogeneous Catalysis: Acid-Base Catalysis; *Enzyme Catalysis:* Rate –Substrate Concentration Profile of Enzymatic Reactions. Michealis - Menten Model; Inhibition of Enzymatic Reactions.

Surface Chemistry and Heterogeneous Catalysis: Adsorption Isotherms; Surface Area Determination by BET Method; Kinetics of Heterogeneous Reactions. Catalysis by Solid Oxides; Nanocatalysis.

Emergence of Quantum Mechanics: Incompatibility of Classical Explanation of Blackbody Radiation, Photoelectric Effect, Franck-Hertz Experiment; Colours of Gold Colloids

Matter Waves and Schrodinger Equation: de Broglie Equation; Particle Diffraction; Time-Independent Schrodinger Equation and Its Application to Particle in a 3-D Box, Simple Harmonic Oscillator, Rigid Rotor and H-Like Atoms

Chemical Bonding and Intermolecular Interactions: Molecular Orbital Theory; Schrodinger Equation to H₂⁺ and H₂ Molecule. Spin-Orbit Coupling; Supramolecular Interactions; *Quantum Mechanical Interpretation of Nanoparticle Properties:* Size-Dependent Properties; Quantum Well and Quantum Tunneling; Quantum Dots; Tunneling Microscopy

Text Books:

1. *Physical Chemistry*, P. Atkins and Julia de Paula, (9thEdn), Oxford, 2011
2. *Physical Chemistry*, R. J.. Silbey, R.A. Alberty and M. G. Bawendi, Wiley (4thEdn), 2006
3. *Chemical Kinetics*, K.J. Laidler, (3rdedn), Pearson Education, 2003
4. *Quantum Chemistry*, I. N. Levine, Phi, 2006

Reference Books:						
1. <i>Quantum Mechanics of Molecular Rate Processes</i> , R. D. Levine, Dower Publications, 2011						
2. <i>Concepts of Modern Catalysis and Kinetics</i> , I. Chorkendorff, VCH, 2013						
Code	Analytical Chemistry Laboratory	L	T	P	C	42 hrs
CY5155		-	-	3	2	
1. Estimation of Phosphoric acid in soft drinks by molybdenum blue method. Simultaneous Estimation of Phosphoric acid in cold drinks by molybdenum blue method. 2. Simultaneous determination of two metal ions by spectrophotometric method. 3. Determination of Fe ²⁺ by Potentiometric method. 4. Determination of Cu ²⁺ by conductometric titration method. 5. Determination of Cu ²⁺ in brass by electrogravimetric method. 6. Determination of the concentration of a salt by ion exchange method. 7. Determination of concentration of alkali metals by Flame photometry. 8. Separation of Zinc and Magnesium by an ion exchange resin and estimation of Zn(II) and Mg (II). Determination of the concentration of mixture of acids by pH metric method						
Code	Organic Chemistry Laboratory-II	L	T	P	C	42 hrs
CY5156		-	-	3	2	
Separation of Binary mixture, Detection of elements N, Cl, Br, I, S and functional groups alcoholic/phenolic OH, carboxylic, aldehyde, ketone, ester, nitro, amino, amido, N-substituted amino, imido groups, unsaturation (C=C), aromatic hydrocarbons, and halogenated derivatives present in the organic molecules. Synthesis of organic compounds based on Oxidation: Benzyl chloride to Benzoic acid, Reduction: Nitro benzene to aniline, Electrophilic aromatic substitution: Nitro benzene, sulphanilic acid, <i>p</i> -bromo acetanilide Synthesis of optically active compounds: benzopinacol, O-acylation: Aspirin & N-acylation, O-benzoylation: phenyl benzoate, Diazotization reaction						
Code	Physical Chemistry Laboratory-II	L	T	P	C	42 hrs
CY5157		-	-	3	2	
Evaluation of Independent and Overall Order of Oxidation Reaction; Rate Constant and Order of Base Catalysed Hydrolysis of Ester; Rate Constant and Order of Decolouration Alkaline Phenolphthalein; Determination of Molar Rotation of Chiral Compounds and Effect of Temperature; Kinetics of Inversion of Sucrose; Evaluation of pK _a of Indicator Dye and Isosbestic points Evaluation of ΔG ^o , ΔS ^o and ΔH ^o values of Redox Reactions; Bond Length and Bond Strength of Hetero-Diatomic Molecules by FTIR; Evaluation of Stability Constants and ΔG ^o of Metal-Ligation (Metal Complexation) Emission Spectra of metal ions; Fluorescence vs Absorbance of Dyes; Band Gap of Semiconductors Kinetics of Fast Homogeneous Reactions by Stopped-Flow Technique; Hammett-Taft Linear Free Energy Relationships Evaluation of Activation Energy by Arrhenius Method Kinetic Methods of Analysis: Enzymatic Determination of Glucose; Effect of Dielectric Constant on the Rate of Reaction; Primary Salt Effect Determination of Surface area of a powder by BET Method Determination of Isoelectric Point of Amino Acids An open ended experiment done on project mode						

SEMESTER-III						
(Analytical Chemistry Streams)						
Code	X-ray and Microscopic Methods of Analysis	L	T	P	C	56 hrs
CY6201	(Core)	4	-	-	4	
<p>X-ray absorption, fluorescence and photoelectron spectroscopy: Principles, Duane-Hunt law, Continuum and Line Spectra, Chemical analysis, Wavelength dispersive and energy dispersive instruments, qualitative and quantitative analysis, Applications. Photoelectron spectroscopy: principle, chemical shift, depth profile study, analytical applications.</p> <p>Particle diffraction methods: Introduction, reflection high energy electron diffraction (RHEED), Neutron diffraction, instrumentation, small angle neutron diffraction (SANS) analysis, applications.</p> <p>Electron microscopy: Scanning electron microscopy, instrumentation, electron sources and lenses, resolution and contrast, environmental SEM, FE-SEM, Energy dispersive X-ray spectrometry (EDX), Applications. Transmission electron microscopy (TEM): Principle, instrumentation, imaging, electron diffraction, reflection electron microscopy, applications.</p> <p>Probe microscopy methods: Scanning tunneling microscopy, principles, basic parameters, atomic resolution, surface imaging, lithography. Atomic force microscopy: Principles, Chemical force microscopy, AFM Lithography, applications.</p>						
<p>Text Books :</p> <ol style="list-style-type: none"> 1. <i>Principles of Instrumental Analysis</i>, Skoog, Holler, Crouch, Cengage Learning, 6th India reprint edition, 2010. 2. <i>Physical principles of electron microscopy: an introduction to TEM, SEM and AEM</i>, R F Egerton, Springer, 2010. 3. <i>Transmission electron microscopy: A Textbook for materials science</i>, David B Williams, C Barry Carter, Springer, 2nd ed., 2009. 4. <i>Instrumental Methods of Chemical Analysis</i>, Chatwal&Anand, Himalaya, 5th ed., 2014. 						
<p>Reference Books :</p> <ol style="list-style-type: none"> 1. <i>Surface Analysis: The Principal Techniques</i>, John C Vikerma, Ian Gilmore (Eds.), Wiley 2ndEdn, 2009. 2. <i>Scanning electron microscopy and X-ray microanalysis</i>, J Goldstein, D Newbury, D Joy, C Lyman, P Echlin, E Lifshin, L Sawyer, J R Michael, Springer, 3rd ed., 2003. 3. <i>Chemical Analysis – Modern Instrumentation Methods and Techniques</i>, Rouessac and Rouessac, John Wiley, 6th edition, 2010. 						
Code	Physical Methods of Chemical Analysis	L	T	P	C	56 hrs
CY6202	(Core)	4	-	-	4	
<p>Atomic Absorption Spectroscopy: Atomic Absorption; Instrumentation; Graphite Furnace; Hydride Generation; Applications</p> <p>Inductively Coupled Plasma Optical Emission (ICP-OES) Spectroscopy: Atomic Emission; Flame Emission Spectroscopy vs ICP-OES; Instrumentation; Ultra-Trace Analysis</p> <p>Molecular Fluorescence, Phosphorescence and Chemi- and Bioluminescence: Jablonsky Diagram; Life Time of Excimers; Comparison and Contrast between Fluorescence and Phosphorescence; Instrumentation; Applications; Chemi- and Bioluminescence; Photoemissive Reactions; Luminescence Microscopy</p>						

<p>Polarimetry, Optical Rotatory Dispersion and Circular Dichroism: Plane Polarised Light; Chirality; Polarimetry of Chiral Compounds; Optical Rotatory Dispersion Spectroscopy; Circular Dichroism and Ellipsometry; Cotton Effect; Octant Rule; Instrumentation; Applications</p> <p>Radiometric and Tracer Methods:</p> <p>Mossbauer Spectroscopy: Recoilless Gamma Ray Absorption; Mossbauer Effect; Instrumentation; Chemical Shift (Isomer Shift); Quadrupole Shift; Zeeman Effect; Applications</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> 1. <i>Introduction to Instrumental Analysis</i>, Robert D Braun, McGraw Hill, 2009 2. <i>Instrumental Analysis</i>, Skoog, Holler, Crouch 3. Chemical and Electrochemical Energy Systems, R. Narayan and B. Viswanathan, (6th Edn) Cengage Learning, 2007 3. <i>Instrumental Methods of Analysis</i>, Willard, Merritt, Dean and Settle, (7th Edn.), CBS- Wadsworth Publ. Co., 2004 						
Code	Instrumental Methods of Chemical Analysis	L	T	P	C	84 hrs
CY6203	Laboratory-I	-	-	6	4	
<p>Determination of Alkalinity of water; DO and BOD and COD of waste water. Determination of Total Solids from waste water and coagulants required for the treatment of waste water; Determination of Fluoride and Chloride from water by ion analyzer potentiometry. Determination of phosphate, sulphate and nitrate by spectrophotometric method. Determination of particulates by Turbidimetry. Determination of phenol from waste water by spectrophotometric method. Determination of Pb²⁺, Cr³⁺ and Cu²⁺ by ICPOES method; Photocatalytic degradations of dye. Total solids-Determination of requirement of coagulants Determination of anions and silicates using spectrophotometric and ion analyzer potentiometric methods.</p>						
<p>Manuals/Text Books:</p> <ol style="list-style-type: none"> 1. <i>A Text-book of quantitative chemical analysis of pure salts, alloys, minerals and technical products</i>, John Charles Oslen, Nabu, 2011. 2. <i>Chemical analysis in the laboratory</i>, I M Harvey and R M Baker, RSC, 2002 3. <i>Elements Of Chemical Analysis: Inorganic and Organic</i>, E.A. Pamel, Kessinger Pub. Co, 2007 						
<p>Reference Books:</p> <ol style="list-style-type: none"> 1. <i>Practical instrumental analysis - Methods, quality assurance and laboratory management</i>, Sergio Petrozzi, Wiley, 1st Edn., 2012. 						
Code	Quantitative Analysis Laboratory	L	T	P	C	84 hrs
CY6204		-	-	6	4	
<p>Titrimetric analysis: Estimation of phenol and aniline by iodometric method, keto group of acetone by iodoform, formaldehyde in formalin, Estimation of cinnamic acid by addition of iodine, Estimation of urea and acetamide, Determination of Acid value, saponification value and iodine value of oils and fats, Determination of Equilibrium constant of keto-enol tautomerism.</p> <p>Instrumental analysis: Conductometric and pH metric determinations of citric acid and benzoic acid, Potentiometric determinations of phenol and acetone, Gravimetric determination of benzophenone, Synthesis and characterization of Nano-silver and colloidal cadmium sulfide particles, Chromatographic analysis of mixtures by GC and HPLC, Monolayer deposition and quantitative analysis, Thin film polymers by electrodeposition, Adlayer of metals and quantitative analysis.</p>						
<p>Manuals/Text Books:</p>						

1. *A Text-book of quantitative chemical analysis of pure salts, alloys, minerals and technical products*, John Charles Oslen, Nabu, 2011.
2. *Chemical analysis in the laboratory*, I M Harvey and R M Baker, RSC, 2002
3. *Elements Of Chemical Analysis: Inorganic and Organic*, E.A. Pamel, Kessinger Pub. Co, 2007

Reference Books:

1. *Practical instrumental analysis - Methods, quality assurance and laboratory management*, Sergio Petrozzi, Wiley, 1st Edn., 2012.

Semester-III						
(Elective for Analytical Chemistry Stream)						
Elective-I						
Code	Environmental Chemistry	L	T	P	C	42 hrs
CY6211		3	-	-	3	
<p>Chemistry of Atmosphere: Origin, composition and structure of atmosphere-particles, ions and radicals in the atmosphere-Greenhouse effect-Causes, consequences and abatement of Green house effect-Ozone depletion- Causes, consequences and abatement of ozone depletion-Photochemical smog-Effects and control.</p> <p>Air Pollution-Monitoring and Control: Airsampling techniques-Sources and effects, of oxides of sulphur, oxides of nitrogen, oxides of carbon- Monitoring of air pollutants by Instrumental methods-Monitoring and Control of particulate pollution- Monitoring of air pollutants by Instrumental methods-Control of air pollution by raw material change, process modification, adsorption, absorption and combustion methods.</p> <p>Classification of Water Pollutants: Unique characteristics of water; Water and the Living Environment; Water and the Non-living Environment; The Different Types of Pollutants; Chemical Pollutants; Physical Pollutants; Physiological Pollutants; Thermal Pollution.</p> <p>Monitoring of Water Pollutants: Pollution indicators, Dissolved Oxygen; Biological Oxygen Demand; Chemical Oxygen Demand; Waste water: Constituents – Microorganisms; Solids; Inorganic constituents, Organic matter, Water Quality requirements, pH values of Wastes and Receiving water, Suspended solids.</p> <p>Environmental Impact Assessment: Environmental Impact Assessment process in India-Environmental acts and rules.</p> <p>Control of Pollution through Green Chemistry: Basic principles of Green Chemistry-Green catalysts-Green synthesis-Green solvents.</p>						
Text Books:						
<ol style="list-style-type: none"> 1. <i>Fundamental Concepts of Environmental Chemistry</i>, G.S. Sodhi, Narosa publishing House, 2ndEdn.,2005. 2. <i>Environmental Impact Assessment Process in India and the draw backs</i>, Aruna Murthy, HimanshuSekharPatra, Environmental Conservation Team, 2005. 3. <i>Waste water treatment</i>, M.N. Rao and A.K. Datta, Oxford Publications, 2ndEdn.,2007. 4. <i>Environmental Science and Engineering</i>, J. Glynn Henry and Garry W. Heinke, Prentice-Hall, Inc., New Jersey, USA, 2ndEdn., 						
Code	Nanomaterials: Synthesis and Characterization	L	T	P	C	42 hrs
CY6212		3	-	-	3	
Scope of nanoscience and nanotechnology, nanoscience in nature, Synthetic Methods: Chemical Routes: Sol-gel synthesis, microemulsions or reverse micelles, co-precipitation method, solvothermal synthesis, hydrothermal synthesis, and Physical methods:chemical vapour						

deposition method, electrodeposition method, high energy ball milling etc. Techniques for characterization: Diffraction technique, spectroscopy techniques, electron microscopy techniques for the characterization of nanomaterials, Studies of Nano-structured Materials: fullerenes, carbon nanotubes, core-shell nanoparticles, nanoshells, self-assembled monolayers, and magnetic nanoparticles.

Text Books:

1. *NANO: The Essentials*, T Pradeep, McGraw-Hill, **2007**.
2. *Textbook of Nanoscience and nanotechnology*, B S Murty, P Shankar, Baldev Rai, BB Rath and James Murday, Univ. Press, **2012**.
3. *Nanomaterials: An Introduction to Synthesis, Properties and Applications*, Dieter Vollath, G., Wiley-VCH Verlag GmbH & Co. KGaA, Germany, 2ndEdn., **2013**.
4. *Nanoparticles: From Theory to Application*, Schmid, G., Wiley-VCH Verlag GmbH & Co. KGaA, Germany, 2ndEdn., **2010**.
5. *Concepts of Nanochemistry*, Cademartiri L., Ozin G. A., Wiley-VCH Verlag GmbH & Co. KGaA, Germany, **2009**.

Reference Books:

1. *Nanostructures & Nanomaterials; Synthesis, Properties & Applications*, Guozhong Cao, Imperial College Press, **2007**.
2. *Nanotechnology, Fundamentals and Applications*: Manasi Karkare, IK International, **2008**.
3. *Nanomaterials Chemistry*, C. N. R. Rao, Achim Muller, K. Cheetham, Wiley-VCH, **2007**.

Code	Chemical, Electrochemical and Biosensors	L	T	P	C	42 hrs
CY6213		3	-	-	3	

Principle of chemical and electrochemical biosensors, Industrial applications, medical diagnosis, implant analysis, remote sensing and control, On-site, portable analysis.

Transduction methodologies: absorbance and fluorescence methods, microcantilever and microbalance methods, electrochemical, optochemical and surface plasmon resonance techniques. Molecular recognition materials: Biomolecular materials, artificial molecular-recognition materials, biomimic-enzymes and -receptors.

Electrochemical and biosensors: Microelectrodes, interdigitated array electrodes, self-assemblies, microarray methods, miniaturization, multiplex analysis for electrochemical sensors. Surface plasmon resonance, microcantilever and microbalance sensors.

Applications: Environmental monitoring, Food and beverage industry - preservatives and mycotoxins, Biomedical diagnosis – cholesterol, cancer marker, genome analysis, defense applications.

Text Books:

1. *Chemical Sensors and Biosensors*, Brian R. Eggins, John Wiley, 2004.
2. *Sensors in Biomedical Applications – Fundamentals, Technology and applications*, Gabor Harsanyi, CRC Press, 2000.
3. *Electrochemical Sensors in Bioanalysis*, Raluca-Ioana Stefan, CRC Press, 2001.
4. *Analytical Electrochemistry*, Joseph Wang, John Wiley, 2006.

Reference Books:

1. *Optical Sensors*, Jorg Haus, Wiley VCH, 2010.
2. *Biosensors: Electrochemical and mechanical biosensors*, Paul Ed Millner, Scion Publishing, 2008.
3. *Optical sensors: Industrial, Environmental and Diagnostic Application (Springer Series)*, R Narayanaswamy, O.S. Wolfbeis (Eds.), Springer, 2010.
4. *Biosensors in Food Processing, Safety and Quality Control – Mehmet Mutlu (Ed.)*, CRC Press, 2010.

Code	Bioinorganic Chemistry	L	T	P	C	42 hrs
CY6214		3	-	-	3	

Essential and trace metal ions in biology and their distribution, special ligands - porphyrins, chlorin and corrin. Enzymes- factors contributing to the catalytic efficiency of enzymes. O₂ binding and activation by heme, non-heme and copper proteins: Iron transport and storage proteins in bacterial and mammalian systems: Electron transport-FAD, NAD, FMN, ubiquinone; blue copper proteins, cytochromes, iron- sulfur proteins – rubredoxin, ferridoxins, Nitrogen-cycle enzymes: Mn in photosynthesis and O₂ evolution: Photosystem I and II – chlorophyll, Non-redox enzymes with Mg, Zn, Ni: urease, Applied bioinorganic chem–metals in medicine, anti-cancer agents–cisplatin, radiopharmaceuticals (Tc), diagnostic (Gd in MRI) and therapeutic agents. Toxicity of Hg, Cd, Pb and As and chelation therapy.

Text Books:

1. *Principle of Bioinorganic chemistry*, Lippard and Berg, Univ. Science Books, **1994**.
2. *Biocoordination chemistry*, Fenton, Oxford chemistry primer, **1995**.
3. *Bioinorganic chemistry: Inorganic perspective in the chemistry of Life*, Kaim and Schwederski, **1994**.
4. *Inorganic chemistry*, Shriver, Atkins, and Langford, **1994**.
5. *Bioinorganic Chemistry*, Bertini, Gray, Lippard and Valentine Viva books Pvt. Ltd. **1998**.

Code	Statistics and Quality Control in Chemical Analysis	L	T	P	C	42 Hours
CY6215		3	-	-	3	

Quality of Analytical Measurements: Sampling strategy, Quality control methods-property control charts, precision control charts, collaborative tests and uncertainty of measurements, Numerical calculations.

Significance tests: Comparison tests, outliers, ANOVA calculations.

Analytical methods Metrological Quality: Various types of analytical methods, Calibration of equipment and instruments.

Standard Method Development and Validation: Optimization of experimental procedures in analytical chemistry, response surfaces, specific examples, experimental design-fractional factorial designs. Validation testing parameters and their calculation with numerical examples.

Text Books:

1. *Statistics and chemometrics for Analytical chemistry*, James N Miller and Jane C Miller, Pearson, 5th Edn., 2005.
2. *Statistical methods in Analytical chemistry*, Peter C Meier, Richard E Zund, John Wiley & Sons, 2000.
3. *Quality Assurance and Quality Control in the Analytical Chemical Laboratory*, PiotrKonieczka and JacekNamiesnik, CRC Press, 2009.
4. *Quality in the Analytical Chemistry Laboratory*, Elizabeth Pricard, Vicki Barwick, John Wiley & Sons, 2008.
5. *Quality Assurance in the Analytical Chemistry Laboratory*, D.BrynnHibbert, Oxford University Press, New York, 2007.

Semester-III
(Common Electives for Both Organic and Analytical Chemistry Streams)
Elective-II

Code	Bioanalytical Chemistry	L	T	P	C	42 hrs
CY6121		3	-	-	3	
<p>General principle of Analytical biochemistry- sampling in biosystems, Introduction to Biomolecules (lipids, proteins, amino acids, Nucleic acids, enzymes, carbohydrates) specific Examples</p> <p>Principle and application of electrophoresis: principle of electro separation ,types of electrophoreses, Instrumental electrophoresis applications of both charged and uncharged species. Protein purification and sequencing methods. Mass spectrometric methods for quantification of biomolecules of high molecular weights.</p> <p>Centrifugation and separation: Isolation of biomolecules, basic principles of centrifugation, types of centrifugation methods for biomolecules, Flow cytometry, principles and applications.</p> <p>Immunological methods: immunoassays types, enzyme assay methods ,and Radioimmuno methods(RIA) and biological tracers.</p> <p>Sensors for identification and determinations:Biosensors for glucose, DNA and other biologically important molecules.</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> 1. <i>UnderastandingBioanalytical chemistry-principle and applications</i>, Victor A Gault, Neville H McClenaghan,Wiley Blackwell, 2009. 2. <i>Bioanalytical Chemistry</i>, David J Holme, Hazel Peck, Prentice hall, 3rd Edn., 2000. 3. <i>Analytical Biochemistry</i>, Andreas Manz, PetrasDittrich, NocollePamme, DimitrivIossifiedis, Imperial College Press, 2nd Edn., 2015. 4. <i>Bioanalytical chemistry</i>, Susan R Mikkelson and Eduard Corton, Wiley, 2004. 						
Code	Chemical Education and Research	L	T	P	C	42 hrs
CY6122		3	-	-	3	
<p>Chemistry as the Central Science: Uniqueness of Chemical Stoichiometry; Chemistry of Inanimate and Living Materials, Chemistry and Civilization; Chemistry in Product Industry; UN Slogan, ‘<i>Chemistry- Our Life and Our Future</i>’; <i>Amazements in Chemistry</i>: Amusement in Chemistry Classroom; Chemistry and Magic</p> <p>Chemical Hazards and Disasters: Chemistry of Explosives, Poisons and Polluttants; GLPs;</p> <p>Models and Tools of Chemical Education: Models and Virtual Experiments</p> <p>Thrust Areas of Chemical Research: Topic by Relevance to Health, Nutrition, Energy, Environment, Sanitation, Technology, Rural Employment, Harnessing Natural Resources;</p> <p><i>IPR and Patents in Chemical Research and Innovations</i>:Intellectual Property Rights in Chemical Innovations and Products; Patent Paradigms</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> 1. <i>Chemical Education</i>, S. Ladage and S.D. Samant, Narosa Publishing House, 2012 2. <i>Affective Dimensions in Chemistry Education</i>, M. Kahveci and M. Orgill, Springer (e-Book), 2015 3. <i>Essentials of Chemical Education</i>, <u>H. D Barke</u>, <u>G. Harsch</u>, <u>S. Schmid</u> and <u>H. Gerdau</u>, Springer, 2015 <p>Reference Books:</p> <ol style="list-style-type: none"> 1.<i>Chemical Education: Towards Research-Based Practice - Contemporary Trends and Issues in Science Education</i>, <u>J. K. Gilbert</u>, <u>O. de Jong</u>, <u>R. Justi</u>, <u>D. F. Treagust</u> and <u>J. H. van Driel</u>, Springer, 2002 2. <i>Multiple Representations in Chemical Education: Models and Modeling in Science Education</i>, <u>J. K. Gilbert</u>, and <u>D. Treagust</u>, Springer, 2009 3. <i>All About Chemistry; Big Questions</i>, <u>Robert Winston</u>, D.K. Children, 2015 						

Code	Applications of Chemical Spectroscopy	L	T	P	C	42 hrs
CY6123		3	-	-	3	
<p>Infrared Spectroscopy: Characteristic group frequencies. Fourier Transform infrared spectroscopy; Applications</p> <p>Ultraviolet and visible spectroscopy: Principles and applications</p> <p>Nuclear Magnetic Resonance Spectroscopy: AB, AX, ABC, AMX Systems; Simplification of complex proton NMR spectra, double resonance, Lanthanide shift reagents; Carbon-13 NMR spectroscopy; COSY, NOE, FT NMR, 2D NMR and CIDNP</p> <p>Mass Spectrometry: Principles, Quadruple mass spectrometer. Metastable ions. Nitrogen rule, rings and double bond equivalent. Fragmentation McLafferty rearrangement. Particle bombardment methods, PD, SIMS, FAB, Gas chromatography - mass spectrometry, MS data system, Combined applications of UV, IR, NMR and Mass in the elucidation of molecular structure</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> 1. <i>Organic Spectroscopy</i>, William Kemp, ELBS, 4thEdn., 2000. 2. <i>Applications of Spectroscopy to Organic Compounds</i>, Silvestin & Bacceler, Pergaman Press, 2003. 						
Code	Polymers and Their Applications	L	T	P	C	42 hrs
CY6124		3	-	-	3	
<p><i>History of macromolecular science, Concept of macromolecules:</i> Degree of polymerization, molecular mass, polydispersity, number, weight average, viscosity average. Molecular weight distribution in linear polymers, polymerizability. <i>Concept of functionality:</i> Writing the structure of the polymer formed for a given monomer and its classification. <i>Nomenclature of polymers:</i> a) origin, b) structure, c) type of atom in the main chain, d) formation, e) Homopolymers, copolymers, f) behavior, g) form and application. Chemical bonding in polymers, Stereochemistry of polymers, Types of polymerization reactions, Raw materials, Methods of polymerization, Test procedures for properties of polymers, <i>Specialty polymers:</i> Liquid crystalline polymers, conducting polymers, Electroluminescent polymers, inorganic polymer, nanocomposites of polymers, biomedical polymers, Inorganic polymers, Polymeric Materials for controlled Drug Delivery Systems, Polymer recycling.</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> 1. <i>Principles of Polymerization</i>, Bahadur, P., and Sastry, N. V., Narosa Publishing House, New Delhi 2002. 2. <i>Polymer Science and Technology: Plastics, Rubbers, Blends and Composites</i>, Premamoy Ghosh, Tata McGraw-Hill Education, 2001. 3. <i>The Chemistry of Polymers</i>, John W. Nicholson, Royal Society of Chemistry, 2012 						
<p>Reference Books:</p> <ol style="list-style-type: none"> 1. <i>Polymers: Chemistry and Physics of Modern Materials</i>, 3rd Edition, John W. Nicholson, Royal Society of Chemistry, 2012. 2. <i>Handbook of Sustainable Polymers: Structure and Chemistry</i>, Ed. by Vijay Kumar Thakur, Manju Kumari Thakur, CRC Press, 2016 						

(Analytical Chemistry Streams)						
Code	Advance Electrochemical Methods	L	T	P	C	56 hrs
CY6251	(Core)	4	-	-	4	
<p>Steady state and potential step techniques: linear sweep voltammetry, differential pulse voltammetry, Stripping voltammetry: anodic stripping and cathodic stripping voltammetry, adsorptive stripping voltammetry, principles and applications. Cyclic Voltammetry: principles and applications. Hydrodynamic measurements, Rotating disk and ring disk electrodes, flow-cell analysis. Chronomethods, principles, chrono-potentiometric, -amperometric and -coulometric measurements, instrumentation and applications. Electrocatalysis of hydrogen and oxygen evolution reactions. Electrochemical sensors: Potentiometric and amperometric sensors, principles, instrumentation, and applications.</p> <p>Electrochemical impedance spectroscopic measurements, principles and applications, Potentiodynamic polarization studies, Tafel methods. Electrochemical quartz crystal microbalance, principle, thin layer coatings, electropolymerization and electrodeposition of metals, applications.</p> <p>Electrochemical supercapacitors: comparison with batteries for energy storage, density and charge-discharge behaviour, energy and power densities of storage devices, Pseudocapacitance, ruthenium and porous materials, applications.</p> <p>Electrochemical scanning tunneling microscopy and Electrochemical atomic force microscopy, principles, instrumentation, Potential-UV-VIS measurements, Potential-Infrared measurements, applications.</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> <i>Electrochemical methods: Fundamentals and applications</i>, Allen J Bard and Larry R Faulkner, John Wiley, 2nd Edn., 2010. <i>Electroanalytical methods: Guide to experiments and applications</i>, Fritz Scholz, Springer, 2nd Edn., 2010. <i>Fundamentals of Electroanalytical Chemistry</i>, P M S Monk, John Wiley, 2003. <i>Electrochemical supercapacitors - Scientific fundamentals and technological applications</i>, B E Conway, Springer, 2014. 						
<p>Reference Books:</p> <ol style="list-style-type: none"> <i>Analytical Electrochemistry</i>, Joseph Wang, John Wiley, 3rd Edn., 2006. <i>Electrochemistry of Functional Supramolecular Systems</i>, Paola Ceroni, Alberto Credi and Margherita Venturi (Ed.), John Wiley, 2010. 						
Code	Advance Chromatographic Methods	L	T	P	C	56 hrs
CY6252	(Core)	4	-	-	4	
<p>High Performance Liquid Chromatography: Modern stationary phases, new detectors, chiral mobile phases, specific applications. UPLC: Ultra performance liquid chromatography, stationary phases for UPLC, specific applications. Supercritical Fluid chromatography: Principle - super critical fluids, properties of supercritical fluids Instrumentation, detectors, injection techniques, pressure restrictors, specific applications. Ion Chromatography: Principle, - Applications in qualitative and quantitative analysis. Hyphenated techniques: Introduction to interfaces, Principle, instrumentation and applications of GC-MS, LC-MS, LC-MSn and GCFTIR. Multidimensional Chromatography: The importance of multidimensional chromatography, principle and specific applications. Capillary Electrophoresis: Principle, instrumentation, detectors, Applications.</p>						
<p>Text Books:</p> <ol style="list-style-type: none"> A. Braithwaite and F.J. Smith, <i>Chromatographic Methods</i>, 5th Edition, Blackie Academic & Professional (Chapman & Hall), 2009. 						

2. Hans-Joachim Hubschmann, Hand Book of GC-MS, Fundamentals and Applications, Wiley-VCH, 2009.						
3. Robert E. Ardrey, Liquid Chromatography-Mass Spectrometry-An Introduction, Wiley, 2003.						
Code	Instrumental Methods of Chemical Analysis	L	T	P	C	84 hrs
CY6253	Laboratory-II	-	-	6	4	
<p>Titrimetric analysis: Estimation of paracetamol and phenyl butazonein drug formulations, Potentiometric determinations of paracetamol and isoniazid, Conductometric and pH metric determinations of citric acid and ascorbic acid.</p> <p>Modern instrumental methods: Cyclic and differential pulse voltammetric determinations of neurotransmitters and ascorbic acid. Electrochemical determinations under static and flow-through conditions. Fluorescence quenching - excitation and emission spectral analysis, Diffuse reflectance spectroscopic analysis; Linear Sweep Voltammetric Estimation of Ascorbic Acid Cyclic Voltammetric Study of Ferricyanide/ferrocyanide couple; Faraday Paradox (Corrosion of Steel by Conc. and Dil HNO₃); DSC of Calcium Oxalate Fluorimetric Estimation of Zinc and Its Life Time; Gel Electrophoresis of Egg and Plant Proteins; Spectroelectrochemical study of Ascorbic Acid; Circular Dichroism of Camphor Infrared Spectrum of CCl₄ and CHCl₃ Vapours; Photo-Diode Array for Kinetics of Decolouration of Murexide; Anodic Stripping Voltammetry of Mixture of Cu²⁺, Zn²⁺, Pb²⁺ LC-MS of phenols in benzene ; Multivariate Linear Regression Analysis of Co²⁺, Ni²⁺, Cu²⁺ Spectra; Integrated Sphere Diffuse Reflection Absorption of Dye Stuffs; Band Gap Estimation of Thin Films by NIR Spectroscopy</p>						
<p>Manuals/Text Books:</p> <p>1. <i>Quantitative chemical analysis adapted for use in laboratories</i>, Frank Clowes and J B Coleman, Nabu, 2010.</p> <p>2. <i>Laboratory experiments to accompany general, organic and biological chemistry - An Integrated Approach</i>, D B Macaulay, J M Bauer, M M Bloomfield, Wiley, 2nd Edn., 2009..</p> <p>Reference Books:</p> <p>1. <i>Food analysis laboratory manual</i>, Suzanne Nielsen, Springer, 2015.</p> <p>2. <i>Practical instrumental analysis - Methods, quality assurance and laboratory management</i>, Sergio Petrozzi, Wiley, 1st Edn., 2012.</p>						

Semester-IV (Elective for Analytical Chemistry Stream)						
Elective-III						
Code	Chemical and Electrochemical Systems of Energy	L	T	P	C	42 hrs
CY6261		3	-	-	3	
<p>Thermochemistry and Chemical Kinetics of Energy Sources: Heats of Combustion of Fuels; Differential Scanning Calorimetry; Ignition Point, Flash Point; Chemical Energy Sources; <i>Chemistry of Conventional and Non-Conventional Energy Materials</i>; Petroleum Products, Petroleum Refinery; Biomass and Gobar Gas; Hydrogen as a Fuel; Coal Carbonization and Gasification;</p> <p>Electrochemical Energy Systems: Primary and Secondary batteries, Solid state and molten solvent batteries, Lithium ion batteries; Fuel cells; Current-Voltage and Current Interrupt measurements; Porosity, Solid Oxide Fuel Cells.</p> <p>Solar Energy Harnessing: Photovoltaic and Photogalvanic energy storage, Regenerative Photoelectrochemical Cells; Photocorrosion; Electrodes with chemically modified surfaces;</p>						

Photochemical and Photoelectrochemical Cleavage of Water: Chemically Modified Electrodes for Water Cleavage; Coordination Chemistry of Water Cleavage

Environmental Concerns and Green Methods of Energy Sources: Quality of Chemical Energy Sources; Monitoring of Energy Extraction from Materials; Nanochemical Methods in Energy Extraction; Modeling of Combustion and Other Energy Tapping from Materials

Text Books:

1. *Energy Systems Engineering – Evaluation and Implementation*, Francis Vanek, Louis Albright, LARGUS Argonnet, McGraw-Hill, **2012**.
2. *Energy Systems and Sustainability: Power for a Sustainable Future*, Bob Everett, Godfrey Boyle, Stephen Peake and Janet Ramage, Oxford Uni Press, 2012.
3. *Chemical and Electrochemical Energy Systems*, R. Narayan and B. Viswanathan, Universities Press, 1998
4. *Lithium Ion Batteries – Advances And Applications*, Gianfranco Pistoria, Elsevier, **2014**

Reference Books:

1. *Dynamic Modeling of Electrochemical Energy Systems*, Lucia Gauchia and Javier Sanz; LAP Lambert Academic Publishing, **2010**
2. *Electrochemical Energy: Advanced Materials and Technologies (Electrochemical Energy Storage and Conversion)*, Pei Kang Shen Chao-Yang Wang, San Ping Jiang (Ed), CRC, **2016**
3. *Tomorrow's Energy: Hydrogen, Fuel Cells, and the Prospects for A Cleaner Planet*, Peter Hoffmann, Byron Dorgan, MIT Press, **2012**
4. *Solar Energy Conversion*, Yuri V Pleskov, Springer-Verlag, **1990**
5. *Solar Energy Conversion – Dynamics of Interfacial Electron and Excitation Transfer*, Piotrowiak, Laurie Peter, Heinz Frei and Tim Zhao, RSC, **2013**

Code	Surface Analytical Techniques	L	T	P	C	42 hrs
CY6262		3	-	-	3	

Principles, Instrumentation of Electron Spectroscopy for Chemical Analysis (ESCA): Quantification methods and standards, Analytical Applications. Auger electron spectroscopy: Depth Profile Analysis, Secondary ion mass spectrometry (SIMS): Surface enhanced Raman Spectroscopy (SERS): Principles, Electromagnetic theory of SERS, Sensitivity factor, Quantitative analysis, SERRS of Ag and Au metal colloids, Electron Energy Loss Spectroscopy (EELS): Electron Microprobe analysis: Low Energy Ion Scattering Spectroscopy: Surface structural analysis.

Text Books :

1. *Surface analysis methods in materials science*, D J O'Connor, Brett A Sexton, Roger S C Smart (Eds), Springer Series in surface sciences, 2ndEdn., **2010**.
2. *Surface Analysis: The Principal Techniques*, John C Vikerma, Ian Gilmore (Eds.), 2ndEdn., Wiley, **2009**.
3. *An introduction to surface analysis by XPS and AES*, John F Watts, John Wolstenholme, Wiley, 2ndEdn., **2003**.
4. *Surface enhanced Raman spectroscopy*, Sebastian schlucker, Wolfgang Kiefer (Eds), Wiley VCH, **2011**.

Reference Books:

1. *Principles of Instrumental Analysis*, Skoog, Holler, Crouch, Cengage Learning, 6thEdn., **2010**.
2. *Instrumental Methods of Analysis*, Willard, Merritt, Dean, Settle, CBS / Wadsworth Publ. Co., 7thEdn., **1988**.
3. *Practical Surface Analysis by Auger and X-ray Photoelectron Spectroscopy*, D. Briggs, M.P. Seah, John Wiley, **1983**.

<p>4. <i>Surface and thin film analysis</i>, GernotFriedbacher, Henning Bubert (Eds), Wiley-VCH, 2ndEdn.,2011.</p> <p>5. <i>Surface enhanced Raman scattering: Physics and applications</i>, KatrinKneipp, Martin Moskovits, HaraldKneipp (Eds), Springer, 2010.</p>						
Code	Supramolecular Chemistry	L	T	P	C	42 hrs
CY6263		3	-	-	3	
<p>Definition of supramolecular chemistry. Nature of binding interactions in supramolecular structures: ion-ion, ion-dipole, dipole-dipole, H-bonding, cation-p, anion-p, p-p, and van der Waals interactions.</p> <p>Synthesis and structure of crown ethers, lariat ethers, podands, cryptands, spherands, calixarenes, cyclodextrins, cyclophanes, cryptophanes, carcerands and hemicarcerands., Host-Guest interactions, pre-organization and complimentarity, lock and key analogy. Binding of cationic, anionic, ion pair and neutral guest molecules.</p> <p>Crystal engineering: role of H-bonding and other weak interactions.</p> <p>Self-assembly molecules: design, synthesis and properties of the molecules, self assembling by H-bonding, metal-ligand interactions and other weak interactions, metallomacrocycles, catenanes, rotaxanes, helicates and knots.</p> <p>Molecular devices: molecular electronic devices, molecular wires, molecular rectifiers, molecular switches, molecular logic.</p> <p>Relevance of supramolecular chemistry to mimic biological systems: cyclodextrins as enzyme mimics, ion channel mimics, supramolecular catalysis etc.</p> <p>Examples of recent developments in supramolecular chemistry from current literature</p>						
Text Books:						
<ol style="list-style-type: none"> 1. <i>Supramolecular Chemistry-Concepts and Perspectives</i>, J.-M. Lehn; Wiley-VCH, 1995. 2. <i>Supramolecular Chemistry</i>, P. D. Beer, P. A. Gale, D. K. Smith, Oxford University Press, 1999. 3. <i>Supramolecular Chemistry</i>, J. W. Steed and J. L. Atwood, Wiley, 2000. 						
Reference Books:						
<ol style="list-style-type: none"> 1. Title, Author(s), Publisher, Edn, Year 2. 3. 						
Code	Tandem and Hyphenated Analytical Methods	L	T	P	C	42 hrs
CY6264		3	-	-	3	
<p>Autosamplers, Triggering, Stopped Flow Techniques</p> <p>Tandem Mass Spectrometry</p> <p>GC-IR, LC-IR, LC-NMR, LC-DAS, CE-UV, Preparatory LC-UV</p> <p>ICP-MS and MS-IR</p> <p>TGA-IR</p> <p>Peltier Thermometry-Molecular Spectroscopy</p> <p>Spectroelectrochemistry</p> <p>Electrochemical Microscopy</p>						
Text Books:						
<ol style="list-style-type: none"> 1. <i>Introduction to GC-MS Coupling</i>, Stéphane Bouchonnet, CRC Press, 2013 2. <i>LC-MS in Drug Bioanalysis</i>, Q. Alan Xu and Timothy L. Madden, Springer, 2012 						
Reference Books:						

1. <i>Identification and Quantification of Drugs, Metabolites and Metabolizing Enzymes by LC-MS</i> , SwapanChowdhury, Elsevier, 2005						
Semester-IV						
(Common Electives for Both Organic and Analytical Chemistry Streams)						
Elective-IV						
Code	Organometallic Chemistry	L	T	P	C	42 hrs
CY6171		3	-	-	3	
<p>Review of formalisms such as oxidation state, 18-electron rule, classes of ligands, structure and bonding. Review of reaction mechanisms, ligand substitution, oxidative addition, reductive elimination, migratory insertion, hydride elimination, transmetallation, nucleophilic and electrophilic attack on the ligands coordinated to metals.</p> <p>Metal alkenes and alkynes compounds: synthesis, reactions and bonding- Organo tin reagents, hydrostannation reaction and synthetic utility of vinylstannanes and allylstannanes in addition and substitution reactions. Organoboron and aluminium reagents, alkyl and aryl derivatives, synthesis and examples of applications in C-C bond forming reactions.</p> <p>Metal carbene compounds: Synthesis of Fischer carbene complexes-synthesis of Schrock carbene complexes. Ligand substitution reactions and Fluxionality in Organometallic compounds.</p> <p>Metal Clusters: Synthesis and reactions.</p> <p>Homogeneous Catalysis using Organometallic Compounds: Asymmetric synthesis Catalytic Hydrogenation of Alkenes and related compounds-Hydroformylation reactions-Methanol Carbonylation and Olefin Oxidation- Olefin Metathesis-Palladium catalysed C-C and C-N cross coupling reactions-Olefin polymerization and Oligomerisation reactions Metal (Cr, Fe, Ru) arene complexes, synthesis and structure. Activation of arene nucleus and side chain. Nucleophilic substitution and addition of arene-Metal (Rh, Ir) catalyzed C-H activation reactions and their synthetic utility.</p>						
Text Books:						
1. <i>Organometallics in Synthesis</i> , Schlosser, M., A manual, John Wiley, New York, 1996.						
2. <i>Transition metals in the synthesis of complex organic molecules</i> , Hegedus, L.S., University Science, Book, CA, 2 nd Edn., 1999.						
3. <i>Organometallic Chemistry and Catalysis</i> , Astruc, D., Springer Verlag, 2007.						
4. <i>Organotransition metal chemistry: Applications to organic synthesis</i> , Davies, S. G., Pergamon Press, New York, 1986.						
5. <i>Basic Organometallic Chemistry- Concepts, Synthesis and Applications</i> , BD Gupta and AJ Elias, Universities Press Private Limited, India, 2011.						
Reference Books:						
1. Title, Author(s), Publisher, Edn, Year						
2.						
Code	Emerging Topics in Organic Synthesis	L	T	P	C	42 hrs
CY6172		3	-	-	3	
<p>Recent Developments in the multicomponent reactions (MCRs): General Approaches of MCRs, Synthesis of different heterocyclic compounds using 3, 4 and 5 component reactions, MCRs using homogeneous and heterogeneous catalysts. Click chemistry: Importance of in Click chemistry, Applications of click chemistry in drug discovery, biology and materials chemistry. Alternative Solvent Systems in Organic Synthesis, Recent Developments in Ionic liquids, Deep Eutectic Solvents, Organic reactions in aqueous medium, Tandem reactions in Organic Synthesis, Cascade reactions in Organic Synthesis, Domino reactions in Organic Synthesis, Metal Carbenes in Organic Synthesis, Hyper valent</p>						

iodine reagents in organic synthesis, Recent advances in Flow chemistry and Micro reactors. **Soft metals in Organic Synthesis:** Silver in Organic Synthesis, Indium in Organic Synthesis, Gold in Organic Synthesis. Nanomaterials in catalysis and Organic Synthesis, Separation techniques, process chemistry, Trouble shooting in organic synthesis

Text Books:

1. *Multicomponent Reactions: Concepts and Applications for Design and Synthesis*, Raquel P. Herrera, Eugenia Marqués-López, John Wiley & Sons., 1 Edn, 2015
2. *Click Reactions in Organic Synthesis*, Srinivasan Chandrasekaran, John Wiley & Sons., 1 Edn, 2016.
3. *Modern Gold Catalyzed Synthesis*, Stephen K. Hashmi, Dean F. Toste, John Wiley & Sons, 2012
4. *Modern Solvents in Organic Synthesis*, Paul Knochel, Springer, 2003.
5. *Catalytic Cascade Reactions*, Ed. by Peng-Fei Xu, Wei Wang, John Wiley & Sons, 2013.
6. *Domino Reactions in Organic Synthesis*, Lutz F. Tietze, Gordon Brasche, Kersten Gericke, John Wiley & Sons, 2006.
7. *Enantioselective Multicatalysed Tandem Reactions*, Hélène Pellissier, Royal Society of Chemistry, 2014.

Reference Books:

1. *Microreactors in Organic Synthesis and Catalysis*, Ed. by Thomas Wirth Title, John Wiley & Sons, 2008.
2. *Metal Carbenes in Organic Synthesis*, K H Dtz, Springer Science & Business Media, 2004.
3. *Nanomaterials in Catalysis*, Ed. by Philippe Serp, Karine Philippot, John Wiley & Sons, 2012.
4. *Chiral Separation Techniques: A Practical Approach*, Ganapathy Subramanian, John Wiley & Sons, 2008

Code	Advance Optical and Magnetic Resonance Spectral	L	T	P	C	42 hrs
CY6173	Methods	3	-	-	3	

Atomic and Molecular Spectra: Atomic Absorption and Molecular Absorption; Stark and Zeeman Effects; ICP-MS and Isotopic Abundance; Gamma-Ray Absorption Spectra; Symmetry and Selection Rules of Transition Moment Integrals; Specular and Grazing Angle Reflection Spectra; NIR and Vacuum UV Absorptions; Electronic Spectra; Huckels Molecular Orbitals; Frontier Molecular Orbitals; *in-situ* Spectral Techniques; Surface Enhanced Raman Spectroscopy; Fluorescence Life Time and Quantum Yields; Non-Linear Optical Phenomena; Applications

Nuclear Magnetic Resonance Spectra: *Relaxation Processes:* Measurement of T_1 and T_2 by Inversion Recovery and Spin Echoes Method; Quadrupolar Relaxation; *Multiple Spin Resonance Methods:* Homo and Heteronuclear Double Resonance; Off-Resonance and Gated Decoupling; Spin Tickling; Nuclear Overhauser Effect; *COSY LR, NOESY and J-Resolved Spectra:* Instrumentation and Applications; *Nuclear Quadrupole Resonance:* Nuclear Quadrupole Moment and NQR Transitions in Axially Symmetric and Non-Symmetric Molecules; Instrumentation and Applications

EPR Spectra: *ESR Spectra of Triplet Spin Systems:* Spin Exchange, Hyperfine and Zero-Field Splitting in Triplet Spin Molecules; *EPR Spectra of Transition Metal Complexes:* Russell-Saunders and Spin-Orbit Coupling, Hund's Rules; EPR Manifestations of Jahn-Teller and Kramers Distortions; *EPR Double Resonance Techniques:* ENDOR and EEDOR

Text Books:

1. *Modern Molecular Spectroscopy*, K. S. Randhawa, McMillan, 2003
2. *Electronic Absorption Spectroscopy*, D.N. Satyanarayana, University Press, 2001

3. *Magnetic Resonance Spectroscopy: ESR.NMR NQR*, D.N. Satyanarayana, University Press, IK International Publishing House, 2014

Reference Books:

1. *Fluorescence Spectroscopy and Microscopy: Methods and Protocols*, Y. Engelborghs and A. J.W.G. Visser, Humana Press, 2014

2. *Molecular Vibrations: The Theory of Infrared and Raman Vibrational Spectra*, E.B. Wilson, Dower Publications, Inc, 2001

3. *Molecular Spectroscopy Workbench: Advances, Applications, and Practical Advice on Modern Spectroscopic Analysis*, Emil W. Ciurczak, Wiley, 1998

Code	Quality Assurance in Chemical Industry	L	T	P	C	42 hrs
CY6174		3	-	-	3	

Statistical Quality Control Techniques: Statistical treatment of data. Control charts, Performance Evaluation- uncertainties in measurement.

Analytical Methods: Standard, official and literature methods. Validation of methods - Ruggedness test. Good Laboratory Practices – Accreditation of QC laboratories.

Instruments and Equipment calibration and maintenance: Calibration and detection limits – Calibration and maintenance of common laboratory instruments and equipment. Documentation for Quality Assurance

Quality management System (QMS): Quality management concepts and principles – ISO 9001:2000 Quality Management system Requirements, Documentation, Implementation, Process approach. Quality Audits, Assessment and Certification. Case studies on ISO 9001 : 2000 in chemical industries. Total Quality Management.

Six Sigma approach to quality: Six Sigma metrics. Managing Six Sigma. Applying Six Sigma to chemical industries.

Text Books:

1. *Handbook of Quality Assurance for the Analytical Chemistry Laboratory*, James O.Dux, Van Nostrand Reinhold, New York, 1986

2. *Training Manual on ISO 9000 :2000 and TOM – Girdhar J. Grani.*
Raj publishing House Trust, 1996.

3. *Managing Six-Sigma – Forrest W. Breyfogle III.* James M. Cupello
Beckimeadows, John Wiley & Sons, 2001

Code	Polymorphism: Chemistry and Industrial Applications	L	T	P	C	42 hrs
CY6175		3	-	-	3	

Polymorphism- Definition, Differences between polymorphism and pseudopolymorphism, significance of polymorphism in drug product performance, packing / conformational polymorphism, thermodynamics of polymorphs, enantiotropy / monotropy, concept of transition temperature, Burger and Ramberger rule (Heat of transition rule, Heat of fusion rule, Entropy of fusion rule and Heat capacity rule), Density rule, Infrared rule.

Synthesis of polymorphs-Crystallization process: Molecular aggregation events in crystallization, energetic of crystallization, enthalpy entropy balance, types of nucleation, Ostwald's step rule. Solvent-mediated (Fast Evaporation&Slow Evaporation), Capillary Crystallization, Mechanical (Grinding & Slurry Sonication), Hi-throughput crystallization.

Analytical techniques for studying and characterization polymorphs-Optical/hot stage microscopy, Thermal methods (DSC, TGA), X-ray crystallography (Powder X-ray Diffraction& Single crystal X-ray Diffraction), Infrared spectroscopy, Raman spectroscopy,

solid state NMR, Scanning electron microscopy, Atomic force microscopy and scanning tunnelling microscopy and Density measurements, Hi-throughput screening of polymorphs. Polymorphism of pharmaceuticals- Occurrence of polymorphism in Drug substances, Excipients, Dissolution rate, solubility and bioavailability. Thermal analysis of pharmaceuticals, The importance of metastable forms and amorphous forms. Polymorphism in pharmaceutical salts and pharmaceutical co-crystals. Polymorphism of dyes and pigments- Occurrence of polymorphism among pigments (Quinacridones, Perylenes, Phthalocyanines and Some other pigments). Polymorphism and Patents-Ranitidine hydrochloride, Cefedroxil, Terazosin hydrochloride and Aspartame. Implications of polymorphism in pharmaceutical development- Regulatory concerns related to polymorphism, introduction to latest regulatory position on polymorphism.

Text Books:

1. Polymorphism in Molecular Crystals by Joel Bernstein, Oxford University Press, 1st Edition, 2002.
2. Polymorphism in Pharmaceutical Solids Edited by Harry Brittain
3. Solid State Characterization of Pharmaceuticals Edited by Angeline and Mark arkrzewski
4. Crystal Engineering: A textbook, Edited by G. R. Desiraju, J. J. Vittal and A. Ramanan
5. Polymorphism - In the Pharmaceutical Industry Hardcover – by R Hilfiker

Reference Books:

Code	Food and Beverages Chemistry	L	T	P	C	42 hrs
CY6176		3	-	-	3	

The role of Water, Lipids, Amino acids, Proteins, Carbohydrates, enzymes, nutrients and natural toxicants in foods, *Food additives*: Artificial sweeteners – saccharin, cyclamate, aspartame – food flavors. Emulsifying agents, *Modern food*: Snack foods. Production of bread, bun and biscuits. Raw materials, methods and machinery required. Candy manufacturing. Caramelization. Fast foods, Instant foods, Dehydrated foods, *Beverages*: Processing and technologies of alcoholic and non-alcoholic beverages, basic concepts of quality assurance and quality control applicable to the beverage industry, Soft drinks, soda, fruit juices, Introduction to refrigeration, slow freezing, quick freezing, introduction to thawing, changes during thawing and its effect on food, Food Irradiation- Introduction, kinds of ionizing radiations used in food irradiation, emulsions, properties of emulsions, formation of emulsion, emulsifying agent, food foams. *Food Adulteration*: Contamination of wheat, rice, dhal, milk, butter, etc., Food poisons: natural poisons (alkaloids, nephrotoxins), pesticides (DDT, BHC, Follidol), Chemical poisons (KCN), Objectives of packaging, flexible packaging, properties of the following packaging materials

Text Books:

1. *Food Science*, Srilakshmi B., New age International Pvt. Ltd. Publishers, III ed. 2003.
2. *Food Processing and Preservation*. Siva Sankar B., Prentice – Hall of India Pvt. Ltd., New Delhi. 2002.
3. *Principles. Text book of medical biochemistry*, Ramakrishnan S., Prasannam K.G and Rajan R – Orient Longman Ltd. III ed. 2001.
4. *FOODS: Facts and Principles*. Shakuntala Manay N. and Shadaksharaswamy M. New Age International Pvt. Ltd. Publishers, II ed. 2002.

Reference Books:

1. *Food Chemistry*, By H.-D. Belitz, Werner Grosch, Peter Schieberle, 4th Edition, Springer Science & Business Media, 2009
Principles of Food Chemistry, John M. deMan, Springer, 2013