B.Tech. in Industrial Chemistry, Department of Chemistry, IIT Hyderabad

Course No	Sem-I	Credits	Type
CYxxxx	Industrial Organic Chemistry-I	3	BS
CYxxxx	Environmental Chemistry	2	BS
MA1110	Calculus-I	1	BS
MA1220	Calculus-II	1	BS
MA1230	Series of Functions	1	BS
ID1063	Introduction to Programming	3	BE
ID1041	Engineering Drawing	2	BE
ID1054	Digital Fabrication Lab	2	BE
LA1760	English Communication	2	SS
	Total	**17**	

Course No	Sem-II	Credits	Type
CY1031	Chemistry Lab	2	BS
CYxxxx	Introduction to Systematic Inorganic Chemistry & Applications	3	DC
CYxxxx	Thermodynamics-I	3	DC
CYxxxx	Introduction to Biochemistry	2	DC
MA1140	Elementary Linear Algebra	1	BS
MA1150	Differential Equations	1	BS
MA1130	Vector Calculus	1	BS
ID1050	Introduction to AI	1	BE
EMxxxx	Introduction to Entrepreneurship	1	SS
LA1770	Personality Development	1	SS
	Total	**16**	

Course No	Sem-III	Credits	Type
CYxxxx	Industrial Organic Chemistry-II	3	DC
CYxxxx	Introduction to Quantum Chemistry	2	DC
CYxxxx	Organic Chemistry Lab	2	DC
CYxxxx	Material Science-I	3	DC
MA2110	Introduction to Probability	1	BS
CH2130	Transport Phenomena	3	BE
ID1100	Fluid Mechanics-I	2	BE
LAxxxx	LA/CA	2	SS
	Total	**18**	

Course No	Sem-IV	Credits	Type
CYxxxx	Food Technology	2	DC
CYxxxx	Physical Chemistry Lab	2	DC
CYxxxx	Coordination Chemistry and Study of Transition Metal Complexes	2	DC
CYxxxx	Petroleum and Petrochemicals	2	DC
CH2180	Heat Transfer	3	FE*
CYxxxx	Polymer Science-I	3	DC
MA2130	Complex Variables	1	BS
CH2170	Chemical Reaction Engineering-I	3	FE*
	Total	**18**	

Course No	Sem-V	Credits	Type
CYxxxx	Thermodynamics-II	3	DC
CYxxxx	Numerical and Computational Chemistry (Theory+Lab)	3	DC
CYxxxx	Electrochemical Energy Conversion	3	DC
CYxxxx	Colloids, Surface chemistry and Adsorption	3	DC
CYxxxx	Spectroscopy and Applications	2	DC
CYxxxx	Dept Elective-I**	2	DE
CYxxxx	Industry Lecture Series	1	DC
	Total	**17**	

Course No	Sem-VI	Credits	Type
CYxxxx	Internship/BTech Project[#]	6	DC
CYxxxx	Dept Electives-II**	3	DE
	Free electives-III**	3	FE
	LA/CA	2	SS
	Total	**14**	

Course No	Sem-VII	Credits	Type
CYxxxx	Introduction to Drug Design	2	DC
CYxxxx	Advanced Analytical Techniques (Lab course)	2	DC
CYxxxx	Materials Science-II	3	DC
CYxxxx	Polymer Science-II	3	DC
CYxxxx	Dept elective-III**	2	DE
	Free elective-IV**	2	FE
	Total	**14**	

Course No	Sem-VIII	Credits	Type
CYxxxx	Industrial Pollution and Chemical Industrial safety	3	DC
CYxxxx	Chemical Industrial separation techniques	2	DC
CYxxxx	Dept elective-IV**	2	DE
	Free elective-V**	2	FE
	Free elective-VI**	2	FE
	Total	**13**	

Total Number of Credits: 127

*Pre-approved free electives/advanced engineering

Students are encouraged for industry internship (6 credit). The BTech Project (6 credit) is mandatory for those not undergoing internship.

**The department electives and free elective credits indicated in each semester are only suggestions, the students are free to do these courses in other semesters.

Course No	Department Core	Credits	Sem
CYxxxx	Introduction to Systematic Inorganic Chemistry & Applications	3	II
CYxxxx	Thermodynamics - I	3	II
CYxxxx	Introduction to Biochemistry	2	II
CYxxxx	Industrial Organic Chemistry-II	3	III
CYxxxx	Introduction to Quantum Chemistry	2	III
CYxxxx	Org Chemistry Lab	2	III
CYxxxx	Material Science-I	3	III
CYxxxx	Food Technology	2	IV
CYxxxx	Physical Chemistry Lab	2	IV
CYxxxx	Coordination Chemistry and Study of Transition Metal Complexes	2	IV
CYxxxx	Petroleum and Petrochemicals	2	IV
CYxxxx	Polymer Science-I	3	IV

Course No	Department Core	Credits	Sem
CYxxxx	Electrochemical Energy Conversion	3	V
CYxxxx	Numerical and Computational Chemistry (Theory+Lab)	3	V
CYxxxx	Colloids, Surface chemistry and Adsorption	3	V
CYxxxx	Spectroscopy and Applications	2	V
CYxxxx	Internship/BTech Project[#]	6	VI
CYxxxx	Introduction to Drug Design	2	VII
CYxxxx	Advanced Analytical Techniques (Lab course)	2	VII
CYxxxx	Materials Science-II	3	VII
CYxxxx	Polymer Science-II	3	VII
CYxxxx	Industrial Pollution and Chemical Industrial safety	3	VIII
CYxxxx	Chemical Industrial separation techniques	2	VIII

CYxxxx	Thermodynamics-II	3	V
CYxxxx	Industry Lecture Series	1	V

Course No	Department Electives:	Credits	Sem
CYxxxx	Machine Learning in Chemistry	2	V
CYxxxx	Unit operations- Mechanical Processes	2	V
CYxxxx	Advanced Inorganic Chemistry	3	VI
CYxxxx	Heterogeneous Catalysis	3	VI
CYxxxx	Molecular Spectroscopy	2	VII
CYxxxx	Metals in Biological Systems/Biochemical Processes	2	VII
CYxxxx	Synthetic Methodology in Organic Chemistry	2	VII
CYxxxx	Chemical Process Economics and Entrepreneurship	2	VIII
CYxxxx	Statistical Methods in Chemical Industry	2	VIII
CYxxxx	Introduction to Toxicology	2	VIII
CYxxxx	MATLAB and Mathematical Computation	2	VIII
CYxxxx	Batteries and Fuel cells	2	
CYxxxx	Nuclear Chemistry	2	

	Total	**62**	

Course No	Free Electives (pre-approved??)	Credits	Sem
BT2040	Microbiology	2	VI
CH3140	Chemical Reaction Engineering-II	3	VII
CH3110	Mass Transfer – I	3	VII
CH3150	Mass Transfer - II	2	VIII

BS	Basic Science
BE	Basic Engineering
DC	Department Core
DE	Department Elective
FE	Free elective
SS	Social Science

Domain wise baskets

Course No	Basic Science	Credits	Sem
CYXXXX	Industrial Organic Chemistry-I	3	1
CY XXXX	Environmental Chemistry	2	1
CY1031	Chemistry Lab	2	2
MA1110	Calculus-I	1	1
MA1220	Calculus-II	1	1
MA1230	Series of Functions	1	1
MA1140	Elementary Linear Algebra	1	2
MA1150	Differential Equations	1	2
MA1130	Vector Calculus	1	2
MA2110	Introduction to Probability	1	3
MA2130	Complex Variables	1	4
	Total	**15**	
Course No	Social Science	Credits	Sem
LA1760	English Communication	2	1
EMXXXX	Introduction to Entrepreneurship	1	2
LA1770	Personality Development	1	2
	Free Electives (LA/CA)	2	3

Course No	Basic Engineering	Credits	Sem
ID1063	Introduction to programming	3	1
ID1041	Engineering Drawing	2	1
ID1054	Digital fabrication lab	2	1
AIxxxx	Introduction to AI	1	2
ID1100	Fluid Mechanics - I	2	3
CH2130	Transport Phenomena	3	2
	Total	13	
Course No	Advanced Engineering (pre-approved electives)	Credits	Sem
CH2180	Heat transfer	3	4
CH2170	Chemical Reaction Engineering-I	3	4
	Total	**6**	

	Free Electives (LA/CA)	2	6
ID4006	Ethics and values	2	8
	Total	**10**	

Course Description: B.Tech. in Industrial Chemistry, Department of Chemistry, IIT Hyderabad

Course No	Sem-I	Credit	Description
CYxxxx	Industrial Organic Chemistry-I	3	Chemical process industry: Introduction, Overview and current status, Raw materials, manufacturing and engineering, Introduction to different industries by taking relevant examples. Basic products of industrial syntheses (Suitable examples: Methanol, Formaldehyde and Formic acid etc.), Pharmaceuticals (Classifications, Aspirin, Paracetamol, Ibuprofen, morphine etc.), Food chemicals (Vitamins, Food additives and preservatives), Agrochemicals (Suitable examples: Fertilizers, Pesticides, Herbicides etc.), Plastic (Suitable examples: bioplastics, thermoplastics etc.). References 1. Industrial Organic Chemistry by Klaus Weissermel and Hans-Jurgen Arpe. 2. Handbook of Industrial Chemistry: Organic Chemicals by Mohammad Farhat AIi, Bassam M. El AIi, James G. Speight. 3. Industrial Organic Chemistry by Mark A. Banvenuto
CYxxxx	Environmental Chemistry	2	• Know our environment (chemistry of lithosphere, energy balance, sustainability and recycle), • Know about global warming (infrared absorption, molecular vibration, atmospheric window, residence time of greenhouse gases, evidences and effects of global warming), • Deeper analysis of atmospheric pollution (Chemistry of CO, NOx, VOCs, SO2, Industrial smog, photochemical smog), • Ozone depletion (production, catalytic destruction), • Organic Chemicals in the Environment, Insecticides, Pesticides, Herbicides and Insect Control, Soaps, Synthetic Surfactants, Polymers, and Haloorganics. • Fate of organic/inorganic chemicals in natural and engineered systems (fate of polymers after use, detergents, synthetic surfactants insecticides, pesticides etc. after use), • Aspects of transformations in atmosphere (microbial degradation of organics-environmental degradation of polymers, atmospheric lifetime, toxicity). Green Chemistry and Industrial Ecology. Future challenges (CO2 sequestering, Nuclear energy). A project on an environment related topic.
Course No	**Sem-II**	**Credit**	**Description**
CY1031	Chemistry Lab	2	Synthesis and characterisation of Paracetamol and Aspirin; Analysis of Organic Compound; Estimation of Phenol by Winkler's method; Estimation of Copper in Brass; Determination of Hardness of Water; Synthesis of Potash Alum from scrap Aluminium a Recycling of Aluminium Waste; Reaction Kinetics: determination of First order Rate Constant; Conductometric/pH metric determination of Acid Strength in Citrus Fruit; Determination of the distribution coefficient and Formation Constant of KI_3
CYxxxx	Introduction to Systematic Inorganic Chemistry & Applications	3	• Acids and bases: classification, Lewis acid and base concept, hard acid, hard base classification, Pearson's HSAB concept and application; Oxidation and reduction: redox reactions, redox potential, • Electrochemical series, use of electrochemical series; • Metallic chains, sheets and clusters; Metal silicates, zeolites and polyoxo-metallates; Metals and alloys, ceramic materials, intermetallic compounds and zintl phases; • Chemistry of phosphorus, phosphorus oxides and phosphorus hydrides; Chemistry of oxyacids and oxyanion of nitrogen and phosphorus; Differences between the chemistry of nitrogen and phosphorus; Chemistry of the halogens: pseudo-halogen, inter-halogen; Oxides and oxyacids; Polyhalides; • Chemistry of the rare gases: Chemistry of xenon, structure and bonding of xenon compounds; • Non-aqueous solvents: types of solvents, general characteristics, reactions in non-aqueous solvents with reference to liquid NH3 and liquid SO2.

			• Book: N. N. Greenwood and A. Earnshaw, Chemistry of the Elements, 2nd Ed., London: Butterworth Heinmann ,1997.
CYxxxx	Thermodynamics-I	3	Thermodynamic properties and equilibrium, concepts of heat and work, zeroth law of thermodynamics; concept of temperature, energy and various forms of energy; internal energy, enthalpy; specific heats; first law applied to elementary processes, closed systems and control volumes, steady and unsteady flow analysis. Second Law of Thermodynamics, Carnot cycle and Carnot principles/theorems, Clausius inequality and concept of entropy; microscopic interpretation of entropy, the principle of increase of entropy, T-S diagrams; second law analysis of control volume; availability and irreversibility; third law of thermodynamics; Properties of Pure Substances, ; P-V-T behaviour of simple compressible substances, phase rule, thermodynamic property tables and charts, ideal and real gases, ideal gas equation of state and van der Waals equation of state; law of corresponding states, compressibility factor and generalized compressibility chart.
Course No	**Sem-III**	**Credit**	**Description**
CYxxxx	Industrial Organic Chemistry-II	3	Industrially relevant compounds : Olefins (Manufacturing and uses of ethylene, propene, branched and unbranched higher olefins), Olefin metathesis; 1,3-Diolefins (1,3-butadiene, Isoprene, Chloroprene, Cyclopentadiene); Acetylene (Manufacturing and uses), Oxidation Products of Ethylene, Synthesis of industrially relevant compound using carbon monoxide (Hydroformylation and carbonylation of Olefins, Koch Carboxylic Acid Synthesis), Synthesis of industrially relevant Alcohols (Ethanol, Isopropanol, Butanols, Amyl Alcohols, Polyhydric alcohols). Industrially relevant Vinyl-Halogen and Vinyl-Oxygen Compounds (Vinyl chloride, Vinylidene Chloride, Vinyl Fluoride, Trichloro- and Tetrachloroethylene, Vinyl Esters and Ethers etc.). References: 1. Industrial Organic Chemistry by Klaus Weissermel and Hans-Jurgen Arpe.
CYxxxx	Introduction to Quantum Chemistry	2	The motivation for Quantum mechanics: Historical background, postulates and general principles of quantum mechanics; Operators and their properties; Schrodinger equation, its application on some model systems : free-particle and particle in a box (1D and 3D), the harmonic oscillator, the rigid rotator, and the hydrogen atom; Approximate methods; Angular momentum: Eigenfunctions and eigenvalues of angular momentum operator, Spin- Pauli Principle; Born-Oppenheimer approximation; VB and MO theory, Application to H2+, H2 molecule References: Quantum Chemistry by Levine; Quantum Chemistry by McQuarrie; Physical Chemistry by Atkins
CYxxxx	Organic Chemistry Lab	2	1) Separation of mixtures by Chromatography: Measure the Rf value in each case; a) Identify and separate the components of a given mixture of 2 amino acids (glycine, aspartic acid, glutamic acid, tyrosine or any other amino acid) by paper chromatography b) Identify and separate the sugars present in the given mixture by paper chromatography; 2) Synthesis of common industrial compounds involving two step reactions, (e.g. 4- bromo aniline, or 3-nitroaniline, or 4-amino benzoic acid, or 4-nitro benzoic acid) 3) Preparation of paracetamol and its analysis; 4) Preparation of sulphacetamide of sulphonamide and its analysis; 5) Preparation of oils of winter green and its analysis; 6) Determination of ascorbic acid in vitamin C tablets by iodometric or coulometric titrations. 7) Separation of a mixture of dyes by column chromatography; 8) Determination of alcohol contents in liquid drugs/galenical.
CYxxxx	Material Science-I	3	The course is designed to introduce fundamentals on solid-state materials that are suitable for applications to engineering systems. Course content: 1.Translational symmetry, Bravais lattices, point & space group, Miller indices (planes and directions), basic concepts of powder & single-crystal X-ray and neutron diffraction; 2. Crystal chemistry of important solid-state structure types; 3. Bonding in solids, Pauling's Rules, Bond Valence concept; 4. Point, line, planar, and bulk imperfections in crystalline solids 5. Introduction to Nano (nanocrystalline solids); 6. Synthetic methodologies to prepare bulk and nanocrystalline solids BOOKS: (a) Solid-state chemistry and its applications by Anthony R. West (b) Solid-state chemistry: an introduction by Lesley Smart and Elaine Moore (c) Elements of X-ray diffraction by B. D. Cullity.
Course No	**Sem-IV**	**Credit**	**Description**
CYxxxx	Food Technology	2	Carbohydrates: structure and functional properties of mono-, oligo-, & poly- saccharides including starch, cellulose, pectic substances and dietary fibre. Proteins: classification and structure of proteins in food. Lipids: classification and structure of lipids, rancidity,

			polymerization and polymorphism. Food flavours: terpenes, esters, aldehydes, ketones and quinines. Nutrition: balanced diet, essential amino acids and essential fatty acids, protein efficiency ratio, water soluble and fat-soluble vitamins, role of minerals in nutrition, co-factors, anti-nutrients, nutraceuticals, nutrient deficiency diseases. (Ref: Food Chemistry. 4th edition, Belitz, H.-D., Grosch, Werner, Schieberle, Peter. Springer-Verlag Berlin Heidelberg, 2019 Principles of Food Chemistry. by deMan, J.M., Finley, J., Hurst, W.J., Lee, C. Springer International Publishing, 2018))
CYxxxx	Physical Chemistry Lab	2	Experiments in Physical Chemistry covering First order and second order kinetics, activation energy, Freundlich adsorption, conductometric and pH metric titrations, distribution coefficient and equilibrium constant determination, phase diagram of a three component system, viscosity determination, study of systems with lower and upper CSTs, and mini-projects based on electro- and chemical- polymerization of aniline, study of the redox reactions and the different forms of PANI by cyclic voltammetry and UV-vis spectroscopy or preparation of silver nanoparticle colloids, and understanding the dependence of band ga on particle size using UV- vis spectroscopy, electrodeposition of Ni / NiOx films and study of their electrochemical and optical properties.
CYxxxx	Coordination Chemistry and Study of Transition Metal Complexes	2	• Crystal field theory, Splitting of d orbitals in linear, triangular, tetrahedral, square planar, trigonal bipyramidal, square pyramidal, octahedral and pentagonal bipyramidal fields of similar and dissimilar ligands. • Crystal field stabilization energies in weak field and strong field environments, octahedral site preference energy, tetragonal distortion and Jahn Teller effect. Shapes of complexes. Effect of crystal field stabilization on ionic radii, lattice energy, hydration enthalpy and stability of complexes (Irving Williams order). Kinetic aspects of crystal field stabilization, crystal field activation energy, labile and inert complexes. Electronic spectra of transition metal complexes – determination of free ion terms of d1 to d9, microstates, determination of ground and all excited state terms of dn terms in octahedral and tetrahedral fields, • Orgel diagrams (qualitative approach), hole formalism, inversion and equivalence relations, selection rules for spectral transitions, d-d spectra and crystal field parameters, Nephelauxetic series, qualitative idea of Tanabe–Sugano diagrams, charge transfer spectra. Magnetic properties – elementary idea. Book: Concepts and Models in Inorganic Chemistry – Douglass, McDanniel & Alexander Coordination Chemistry – S. F. A. Kettle, Inorganic Chemistry –A. G. Sharpe
CYxxxx	Petroleum and Petrochemicals	2	• Origin, formation and composition of petroleum, • petroleum processing: fractionation, blending of gasoline, gasoline treatment, kerosene treatment, treatment of lubes, petroleum wax and purification; • Thermal and catalytic processes: thermal cracking, catalytic cracking, catalytic reforming, naphtha cracking, coking, hydrogen processes, alkylation, isomerization processes; polymer gasoline, asphalt, upgradation of heavy crudes; • Specialty products: industrial gases, liquid paraffin, petroleum jelly; Sources of petrochemicals; Synthesis of methanol, formaldehyde, acetylene, synthetic gas, ethanol, ethylene, ethylene glycol, vinyl acetate, acrylic acid and acrylates, acrylonitrile, acetone, acetic acid, chloroprene, vinyl chloride, vinyl acetate, acrylonitrile, propylene, butadiene, butanes, isobutene, adipic acid, adiponitrile, benzene, toluene, xylene, phenol, styrene, phthalic acid, phthalic anhydride and their applications in chemical industry. • Book: B. K. B. Rao, Modern Petroleum Refining Processes, 4th Ed., Oxford & IBH Publishing Co. Pvt Ltd., New Delhi, 2002. • P. Wiseman, Petrochemicals, John Wiley & Sons, 1986.
CYxxxx	Introduction to Biochemistry	2	Structure, properties and reactions of mono- and di-saccharides; physicochemical properties of amino acids and peptides; structural features of proteins, nucleic acids, lipids, steroids, terpenoids, carotenoids, and alkaloids. Protein folding / misfolding and function; Enzyme kinetics, regulation and inhibition; Bioenergetics and metabolism; (Ref: Biochemistry by Raymond S. Ochs & Lehninger Principles of Biochemistry, 8th Edition)
CYxxxx	Polymer Science-I	3	• Classification of polymers, Kinetics of polymerization, • Molecular weight of polymer and its determination, Some specific methods for molecular weight determination of biopolymers- gel filtration, SDS-PAGE for proteins, Agarose gel method for nucleic acids. • Thermodynamics of polymer solution: Polymer conformation. Molecular weights and molecular weight distributions and their determinations (viscometry, osmometry, light scattering, size-exclusion chromatography; • Principles of macromolecular synthesis: step-growth vs. chain-growth polymerizations. • Advanced synthetic techniques for controlling molecular weight dispersity in synthetic polymers- Living polymerization (living ionic, living radical and living ring-opening polymerizations); block copolymers-synthesis,

			microstructure, and applications; Conjugated polymers and their electrical and opto-electronic properties. Book: Principles of Polymer Chemistry, P.J. Flory
Course No	**Sem-V**	**Credit**	**Description**
CYxxxx	Thermodynamics-II	3	Thermodynamic Relations, T-dS relations, Helmholtz and Gibbs functions, Gibbs relations, Maxwell relations, Joule-Thomson coefficient, coefficient of volume expansion, adiabatic and isothermal compressibilities, Clapeyron and Clapeyron-Clausius equations. Thermodynamic Cycles Carnot vapor cycle, ideal Rankine cycle, Rankine reheat cycle, air-standard Otto cycle, air-standard Diesel cycle, air-standard Brayton cycle, vapor-compression refrigeration cycle, Ideal Gas Mixtures Dalton's and Amagat's laws, properties of ideal gas mixtures, air-water vapor mixtures and simple thermodynamic processes involving them; specific and relative humidities, dew point and wet bulb temperature, adiabatic saturation temperature, psychrometric chart. Ref: Thermodynamics and its Applications" by J W Tester and M Modell Thermodynamics : An Engineering Approach" by Michael A Boles Fundamentals of Engineering Thermodynamics" by M J Moran and H N Shapiro
CYxxxx	Numerical and Computational Chemistry (Theory+Lab)	3	Programming principles using loops, arrays and functions; use of libraries; Numerical methods: truncation and round off errors; roots; interpolation; differentiation and integration; linear equations, matrix operations; curve fitting; ODEs; optimization; Application of numerical methods to chemical problems. Computational chemistry: A brief outline of molecular mechanics, semi-empirical approximations, ab initio methods, Density Functional Methods, basis sets, and Z-matrix; Application of these computational methods for prediction of structural and electronic properties of molecules, solid-state materials by using standard programs; computation of potential energy surfaces. Conformational analysis by molecular mechanics; Dynamical and structural studies of molecules using molecular dynamics simulations; Monte Carlo simulations of molecules; Molecular Docking Techniques. References: Fortran 90/95 for Science and Engineering, edition 2, S.J. Chapman, McGraw Hill Introduction to Numerical Computation, L. Eldén, L. Wittmeyer-Koch, H.B. Nielsen, J. Cramer, Essentials of Computational Chemistry: Theories and Models J. B. Foresman, A. Frisch, Exploring Chemistry with Electronic Structure Methods. R. Dronskowoski, R. Hoffmann, Computational Chemistry of Solid-state materials: A Guide for Material Scientists, Chemists, Physicists, and others.
CYxxxx	Electrochemical Energy Conversion	3	This course gives an insight to fundamental of electrochemistry; corrosion and electrodeposition of metals from the aspect of electrochemistry and the course will provide comprehensive exploration of all types of batteries and fuel cells and their applications. Contents: Electrochemical cell - redox reaction, origin of electrode potential, Standard Hydrogen Electrode, EMF series, Reference electrodes, Concentration cells, Liquid Junction Potential, Applications of EMF, Conductivity of electrolyte solutions, Activity, Activity coefficient, Debye - Huckel - Onsager Equation, Kinetics- Over-potential, Butler Volmer equation, Tafel equation. Corrosion: Basics, chemical and electrochemical corrosion, corrosion control, Electrodeposition. Principles of Operation of Cells and Batteries; Electrochemical Principles and Reactions; Factors Affecting Battery Performance; Battery Design; Primary cells and Batteries; Fundamentals of Secondary Batteries: Advanced Lead-acid, Ni-based and lithium-ion batteries, next generation batteries, Materials for batteries, Electrode preparation, cell Assembly, electrochemical performance analysis, understanding of degradation mechanism and Safety. Fuel cells: Introduction to Fuel Cells: working principle, direct methanol fuel cells, Proton Exchange Membrane Fuel Cells, alkaline fuel cells, phosphoric acid, solid oxide, molten carbonate Fuel cells. Advanced batteries and fuel cells for UPS, Solar, Telecom, Aerospace, Grid and Electric Vehicle applications. References: References:

			1. Peter Atkins, P., and J. De Paula. Atkins' physical chemistry. OUP Oxford, 2014. 2. Allen J., Bard and Larry R. Faulkner. " Electrochemical methods- Fundamentals and applications." Wiley, 2000. 3. John O'M. Bockris,, Amulya K.N. Reddy, Maria E. Gamboa-Aldeco, Modern Electrochemistry 2A, Fundamentals of Electrodics, 2nd Edn, 2006. 4. T. Ohtsuka, A. Nishikata, M. Sakairi, K. Fushimi, Electrochemistry for Corrosion Fundamentals, Springer, 2006. 5. Kirby W. Beard. Linden's Handbook of Batteries, Fifth Edition (McGraw-Hill Education: New York, Chicago, San Francisco, Athens, London, Madrid, Mexico City, Milan, New Delhi, Singapore, Sydney, Toronto, 2019). 6. Vladimir S. Bagotsky, Alexander M. Skundin and Yury M. Volfkovich (A.N. Frumkin Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Science, Russia) Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors" By, John Wiley & Sons Inc, New Jersey, USA, 2015, 372 pages, ISBN: 978-1-118-46023-6. 7. Ying-Pin Chen, Sajid Bashir, Jingbo Louise Liu, Nanostructured Materials for Next-Generation Energy Storage and Conversion: Advanced Battery and Supercapacitors, Springer Nature, 10-Oct-2019 - Technology & Engineering - 472 pages. 8. D. Pavlov, Lead-Acid Batteries: Science and Technology, Elsevier 31-May-2011 - Technology & Engineering - 656 pages. 9. C. Vincent, Bruno Scrosati, Modern batteries, Elsevier, 26-Sep-1997 - Technology & Engineering - 368 pages. 10. Paul Breeze, Fuel cells, 2017, Elsevier Science, 100 pages.
CYxxxx	Colloids, Surface chemistry and Adsorption	3	Introduction to Chemical Kinetics: Order, molecularity,1st-2nd- 3rd –nth order derivations, half-life, determining the order of reaction, the effect of Temperature, Concentration, Pressure, Catalyst on Reaction Rate, Arrhenius equation, Kinetics of nuclear reactions, reversible /opposing reactions, consecutive /successive reactions, side/parallel reactions, steady-state approximation, chain reactions, collision-transition state theory. Aggregation and self-assembly; Colloids: Classification and preparation; Structure and stability; The electrical double layer, Micelles, and biological membranes; Determination of size and shape; Mean molar masses; Laser light scattering The growth and structure of solid surfaces, The extent of adsorption; The extent of adsorption; The rates of surface processes Further readings. 1. Puri, Late BR, I. R. Sharma, and Madam S. Pathania. Principles of physical chemistry. Vishal, 2013. 2. Rajaram, J., and J. C. Kuriacose. "Kinetics and mechanism of chemical transformation." (1993). 3. Peter Atkins, P., and J. De Paula. Atkins' physical chemistry. OUP Oxford, 2014.
CYxxxx	Spectroscopy and Applications	2	General aspects of spectroscopy, Fundamentals and applications of the following methods: Nuclear Magnetic Resonance Spectroscopy: NMR phenomenon, spin 1/2 nuclei, 1H, 13C, 19F and 31P, Zeeman splitting, Boltzmann distribution, effect of magnetic field strength on sensitivity and resolution. 1H-NMR, chemical shift, anisotropic effects, chemical and magnetic equivalence, coupling constants. Karplus relationship of J on dihedral angle, first order splitting patterns and structure correlation. 13C NMR - natural abundance, sensitivity. NOE effects, 13C chemical shifts and structure correlations. IR spectroscopy: Basic principles of IR spectroscopy, functional group frequencies of various class of organic compound. Factors affecting the group frequencies. UV-Vis spectroscopy : basic principles, Electronic levels and types of electronic transitions in organic, effect of extended conjugation and Woodward-Fieser rules for calculation of absorption maximum. Mass spectrometry: Introduction, Basic principle, Instrumentation, isotope abundance, molecular ions, fragmentation processes of organic molecules and deduction of structural information. Problem on structure elucidation of organic compounds based in spectral data. Recommended Books 1. Silverstein, Bassler and Morill: Spectrometric identification of organic compounds 2. Willim Kemp: Organic spectroscopy 3. Pavia, Lampman, Kriz, Vyvyan: Introduction to Spectroscopy
CYxxxx	Dept Elective-I**	2	See list of electives

CYxxxx	Industry Lecture Series	1	A series of lectures will be conducted at the department inviting prominent industry persons. It is mandatory for the BTech students to attend and interact with the speaker.
Course No	**Sem-VI**	**Credit**	Description
CYxxxx	Internship/BTech Project[#]	6	
CYxxxx	Dept Electives-II**	3	See list of electives
Course No	**Sem-VII**	**Credit**	**Description**
CYxxxx	Introduction to Drug Design	2	Principles of Drug Discovery, Targets for drug discovery, and Identification of Lead Compounds; Physiochemical Properties of Drugs (Absorption, Distribution, Metabolism); Drug Receptor interactions; enzymes as drug targets, Drug design strategies, Structure-Based Drug Design; Use of chemoinformatics in drug design, Strategies for Organic Drug Synthesis; Combinatorial Chemistry; Prodrugs and drug delivery systems, Illustration of drug development through specific examples, Drug resistance, Drug synergism and combination therapy. Books: 1) Chemical Engineering in the Pharmaceutical Industry: Drug Product Design, Development, and Modeling by Mary T. am Ende (Editor), David J. am Ende (Editor). Wiley 2) Burger's Medicinal Chemistry, Drug Discovery and Development, 8 Volume Set. Volumes 1 – 8 Donald J. Abraham School of Pharmacy, Virginia Commonwealth University, Richmond, Virginia. 3) Silverman, R. B., The Organic Chemistry of Drug Design and Drug Action, 2nd Edition, 2004, ISBN: 0-12-643732-7, Academic Press 4) Organic Medicinal and Pharmaceutical chemistry. By Wilson and Gisvold's (English, Paperback, Beale John M) 5) Williams, D. A.; Lemke, T. L., Foye's Principles of Medicinal Chemistry. 5th ed.; Wolters Kluwer Health (India) Pvt. Ltd.: 2006.
CYxxxx	Advanced Analytical Techniques (Lab course)	2	• Synthesis and characterization of inorganic compounds in the diverse areas of Inorganic Chemistry such as Coordination Chemistry, • Organometallic Chemistry and Bioinorganic Chemistry etc. Characterization: • quantitative and qualitative determination of ligand and metal, use of spectral techniques (UV-visible, FT-IR, NMR, ESR, magnetic moment, analytical methods (conductance, TGA, DSC, cyclic voltametry). • Book: Synthesis and Technique in Inorganic Chemistry: A Laboratory Manual, Gregory S. Girolami, Thomas B. Rauchfuss and Robert J. Angelici. University Science Books. 2. Synthetic methods of organometallic and inorganic chemistry ed. by Wolfgang A. Herrmann, Georg Thieme Verlag, New York, 1997, Vol 7 and 8 3. • Vogel’s qualitative inorganic analysis, by Svehla, G. Publisher: Harlow: Longman, 1996. 4. Vogel’s textbook of quantitative inorganic analysis: including elementary instrumental analysis. By: Arthur Israel Vogel; John Bassett Publisher: London; New York: Longman, 1978.
CYxxxx	Materials Science-II	3	The course is designed to gain in depth knowledge on the physical properties of solid-state materials and their applications to engineering systems, characterization techniques and application. Course content: 1. Electrical properties of solids. 2. Band theory: metals, insulators, and semiconductors. 3. Bandgaps, doping, and devices. 4. Magnetism & magnetic materials 5. Thermal and optical properties of solids 6. Superconductors, thermoelectric, photoconductors, solar cell, and battery materials 7. Properties of important metals oxides and chalcogenides for catalytic applications. Taken from MS3 Contents: 1. Introduction to nanoscience, nanotechnology; 2. Concepts of nanochemistry (gold and silver) 3. Carbon nanostructures ; 4. Synthesis of Nanomaterials by Physico-chemical approaches.

			5. Advanced Characterization Methods: X-ray diffraction, Scanning Electron Microscopy, Transmission Electron Microscopy, Atomic Force Microscopy, Optical Absorption and Emission Spectroscopy, Thermogravimetric Analysis, X-ray photoelectron spectroscopies, Raman spectroscopies. 6. Application of nanomaterials and safety. Further reading: a) G. A. Ozin and A. C. Arsenault, Nanochemistry-A Chemical Approach to Nanomaterials -, RSC Publishing, Cambridge, 2006. b) G. Cao and Y. Wang, Nanostructures and Nanomaterials-Synthesis, Properties, and Applications, 2nd Edition, https://doi.org/10.1142/7885 , Pages: 596, 2011, BOOKS: (a) Solid-state chemistry and its applications by Anthony R. West; (b) Solid-state chemistry: an introduction by Lesley Smart and Elaine Moore
CYxxxx	Polymer Science-II	3	• Commodity and general-purpose thermoplastics: PE, PP, PS, PVC, Polyesters, Acrylic, PU polymers. Engineering Plastics: Nylon, PC, PBT, PSU, PPO, ABS, Fluoropolymers Thermosetting polymers: PF, MF, UF, Epoxy, Unsaturated polyester, Alkyds. Natural and synthetic rubbers: Recovery of NR hydrocarbon from latex, SBR, Nitrile, CR, CSM, EPDM, IIR, BR, Silicone, TPE. • Difference between blends and composites, their significance, choice of polymers for blending, blend miscibility-miscible and immiscible blends, • thermodynamics, phase morphology, • polymer alloys, polymer eutectics, plastic-plastic, rubber-plastic and rubber-rubber blends, FRP, particulate, • long and short fibre reinforced composites., Polymer compounding-need and significance, different compounding ingredients for rubber and plastics, • Cross-linking and vulcanization, vulcanization kinetics. • Flow of Newtonian and non-Newtonian fluids, different flow equations, dependence of shear modulus on temperature, molecular/segmental deformations at different zones and transitions. • Measurements of rheological parameters by capillary rotating, parallel plate, cone-plate rheometer. • Visco-elasticity-creep and stress relaxations, mechanical models, control of rheological characteristics through compounding, rubber curing in parallel plate viscometer, ODR and MDR., • Compression molding, transfer molding, injection molding, blow molding, reaction injection molding, extrusion, pultrusion, calendaring, rotational molding, thermoforming, rubber processing in two-roll mill, internal mixer. • Mechanical-static and dynamic tensile, flexural, compressive, abrasion, endurance, fatigue, hardness, tear, resilience, impact, toughness. • Conductivity-thermal and electrical, dielectric constant, dissipation factor, power factor, electric resistance, surface resistivity, volume resistivity, swelling, ageing resistance, environmental stress cracking resistance.
CYxxxx	Dept elective-III**	2	See list of electives
Course No	**Sem-VIII**	**Credit**	**Description**
CYxxxx	Industrial Pollution and Chemical Industrial safety	3	CPCB Guidelines, Air and Noise Pollution, Water pollution- ASP, ETP, etc Solid Waste Emission and control methods in the Production of Sulfuric Acid, Production of Nitrates-Containing Fertilizers, Lime Production, Soda Production, NaOH/Cl2 by electrolysis, Cement, Pharmaceutical Industry, Bulk Organic Chemical Industry Water Pollution: Identification, quantification and analysis of wastewater, Classification of different treatment methods into physico-chemical and biochemical techniques, Physico-chemical methods, General concept of primary treatment, Liquid-solid separation, Design of a settling tank, Neutralization and flocculation, Disinfection, Biological methods, Concept of aerobic digestion, Design of activated sludge process, Concept of anaerobic digestion, Air Pollution: Classification of air pollutants, Nature and characteristics of gaseous and particulate pollutants, Analysis of different air pollutants, Description of stack monitoring kit and high volume sampler, Atmospheric dispersion of air pollutants, Gaussian model for prediction of concentration of pollutant down wind direction, Plume and its behavior, Operating principles and simple design calculations of particulate control devices, Brief concepts of control of gaseous emissions by absorption, adsorption, chemical

			transformation and combustion. Solid Wastes: Analysis and quantification of hazardous and non-hazardous wastes, Treatment and disposal of solid wastes, Land filling, Leachate treatment, Incineration. Environmental Management System: Environment impact assessment, Its concept and constituents, Environmental audit, ISO-14000 system
CYxxxx	Chemical Industrial separation techniques	2	Raoult's law, distillation curves, Liquid-Liquid separation, Azeotropic distillation, Basics of Chromatography, LC, LC-MS-MS, HPLC, Detectors for HPLC, GC, detectors for GC, GC-MS-MS, GPC, IC.
CYxxxx	Dept elective-IV**	2	See list of electives

List of Electives: B.Tech. in Industrial Chemistry, Department of Chemistry, IIT Hyderabad

Course No	Sem-VIII	Credit	Description
CYxxxx	Machine Learning in Chemistry	2	Artificial intelligence (AI) rapidly changes many aspects of chemical sciences, from drug discovery, material design, and the discovery of new reactions and molecules till the acceleration of computer sciences and robotics for chemical applications. This course will cover the key aspects of AI and modern chemoinformatics and how they are applied on chemical sciences. Chemoinformatics: Basic Concepts and Methods Edited by Engel and Gasteiger, (Wiley-VCH Verlag GmbH & Co., 2018).
CYxxxx	Unit operations-Mechanical Processes	2	Particulate Sizes and Shapes, Screening Size Reduction, Storage and Conveying of Bulk Solids, Size Enlargement, Flow past Bluff Bodies, Flow Through Packed and Fluidized Beds, Filtration, Cross Flow Filtration and Membrane Separations, Gravity Sedimentation, Centrifugal Separations, Floatation (Ref: NPTEL)
CYxxxx	Advanced Inorganic Chemistry	3	• Basic Bonding Theory, Crystal Field Theory and Molecular orbital Theory, • Molecular Symmetry and Character Tables and their Application to Vibrational and Electronic spectroscopy, Selection Rules, • Reaction Mechanism (Redox, Photochemistry, Ligand substitution reactions), • Acid-Base and Donor-Acceptor Chemistry, Magneto-Chemistry, Organometallic Chemistry and Bioinorganic chemistry. • Applications to current research problems in inorganic and solid-state chemistry. • Book: Inorganic Chemistry by Catherine E. Housecroft and Alan G. Sharpe; Physical Inorganic Chemistry by S F A KETTLE; Advanced Inorganic Chemistry, 6th Edition by F. Albert Cotton, Geoffrey Wilkinson, Carlos A. Murillo, Manfred Bochmann.
CYxxxx	Industrial Heterogeneous catalysis	3	Introduction to Heterogeneous catalysis-Theory, Kinetic modelling, L-H and E-R mechanism. Electronic and Geometric factors, Industrial catalytic applications of Zeolites, Aluminophosphates, Mesoporous materials, Aminophosphates, Hydrotalcite, clays, Nanocomposites and Metal organic Frameworks.Nanoparticles for heterogeneous catalysis Catalysts Preparation Methods: Solid-Solid (Ceramic Method) Solid from Liquid- Sol-gel Method; Co-Precipitation Method; Hydrothermal Method, Chemical Vapor deposition Method. Characterization methods: Isotherm models, BET, BJH. TPD, TPD,TRP, Metal dispersion. Solid acids/bases/redox and multifunctional catalysts: Applications of Solid acids: Alkylation, Cracking, Isomerization, Aromatization, Methanol to olefin reaction. Solid basic catalysis. Solid redox catalysts: Phenol & Benzene hydroxylation, Ammoxidation, Alkane oxidation, Alcohol oxidation, Alkene epoxidation. Oxidative dehydrogenation,Electrocatalysis. Other Industrially important catalysts and processes: Wilkinson catalyst, Zeigler Natta catalyst, Fisher trope synthesis, Heck reaction, Suzuki coupling reaction, Haber process, Bio-diesel production, Photocatalysis. Enzymatic catalysis: Enzymatic catalysis, Kinetics, General Mechanism, Mechanisms for the Inhibition of Enzyme Catalysis, Advantages, LImitations, and Applications. Ref: 1. Catalysis: Principles and Applications, B. Viswanathan, S. Sivasanker, A.V. Ramaswamy, Narosa Publishing House, New Delhi 2007. 2. Industrial Catalysis A Practical Approach, Jens Hagen, Wiley-VCH, Verlag GmbH & Co. KGaA, 2006.
CYxxxx	Molecular Spectroscopy	2	Region of spectrum, spectral lines intensity and broadening, Microwave spectrum of rigid and non-rigid rotator, Principle of microwave oven; Vibrational spectra of harmonic and anharmonic oscillator, Vibrations of polyatomic molecules, group frequencies and its applications, instrumental methods. Raman spectroscopy and instrumentation, structure determination; Principles of UV-VIS

			spectroscopy and instrumentations; Principles and methodology of spin resonance spectroscopy: NMR and ESR; Magnetic resonance imaging (MRI). References: Physical Chemistry by Peter Atkins and Julio de Paula Fundamentals of molecular spectroscopy by Banwell High resolution spectroscopy by J. M. Hollas
CYxxxx	Metals in Biological Systems/Biochemical Processes	2	Metal ions in biology: metallo-proteins and enzymes containing Mg, Ca, V, Cr, Mn, Fe, Co, Ni, Cu, Zn, Mo and W ions. heme and non-heme systems, Peptide and nucleotide hydrolytic enzymes, Metal environment, electronic, magnetic and redox properties; fixation of N2, water-oxidation reactions, Synthetic models for the structure and function of the above enzymes, syntheses of ligand-metal complexes, reactivity of O2, CO, NO, N2; mechanistic aspects, high-valent metal-oxo (Fe-, Mn- and Cu) systems, Interaction of metal ions with nucleotides and peptides, hydrolysis of phosphate and amide groups, Metal based drugs, environmental applications and toxic effects.
CYxxxx	Synthetic Methodology in Organic Chemistry	2	Basic retrosynthetic analysis: terminology associated with, prostereoisomerism, homo, enantio, diastereo ligands and faces, stereoselective synthesis. Nucleophilic C-C bond forming reactions: organometallic reagents of lithium, magnesium, copper, chromium and iron, ylides of sulfur and nitrogen, Tebbe's reagent. Enolates, kinetic and thermodynamic enolates, enolate condensation reactions like Claisen, Dieckmann, Knoevenegal, Stobbe, Darzen glycidic ester. Umpolung reagents, definition of umpolung, acyl anion equivalent, equivalents of ketene, RCOCH2+, RCOCH2CH2CH2+, RCOCH2CH2CH2- etc. C-C bond formation via free radicals and carbenes: methods of generation of free radicals and carbenes, reactions of free radicals, coupling, addition, substitution, fragmentation and rearrangements. C-C bond formation using tin reagents: Protecting groups, protection of hydroxyl, carboxyl, carbonyl, amino groups. Protection of carbon-carbon multiple bonds. Illustration of protection and deprotection in synthesis. References 1. F. A. Carey and R. I. Sundberg, Advanced Organic Chemistry, Part A and B, 5th edition, Plenum Press, 2007. 2. S. Warren, Designing Organic Synthesis, John Wiley, 2009. 3. S. G. Davies, Organotransition Metal Chemistry, Application to Organic Synthesis, Pergamon Press, 1984. 4. R. K. Mackie and D. M. Smith, Guidebook to Organic Synthesis, ELBS, 1991. 5. Michael B. Smith, Organic Synthesis, McGraw Hill, 1994.
CYxxxx	Chemical Process Economics and Entrepreneurship	2	Terminology used in developing the costs of production, capital costs, cash flow analysis and profitability metrics Apply basic principles of process economics to improve design decisions Analyze and compare alternative technologies and scenarios Evaluate early-stage projects for technical and business assumptions critical to project success Formulate value propositions based on sound process design Communicate findings in an effective and illustrative way that encompasses the breadth of evaluation Use structured methods to identify customer needs, establish target performance specifications, generate and select product ideas and establish final product specifications
CYxxxx	Applied Statistical Methods and the Chemical Industry	2	Quality of Analytical Measurements-Propagation of error, Sampling strategy, Quality control methods-property control charts, precision control charts, collaborative tests and uncertainty of measurements, Significance tests: Comparison tests, outliers, ANOVA calculations. Analytical methods Metrological Quality: Various types of analytical methods, regression analysis, Limit of detection, Limit of quantification, Random error, Calibration of equipment and instruments. Curvilinear and outlier analysis. Standard Method Development and Validation: Optimization of experimental procedures in analytical chemistry, Standard addition, External standard, internal standard and dilution methods, response surfaces, specific examples, experimental design-fractional factorial

			designs. Validation testing parameters and their calculation with numerical examples Ref: 1. Quality Assurance and Quality Control in the Analytical Chemical Laboratory, Piotr Konieczka and Jacek Namiesnik, CRC Press, 2009 and 2nd Edition. 2. Quality Assurance in the Analytical Chemistry Laboratory, D. BrynnHibbert, Oxford University Press, New York, 2007 and 1st Edition.
CYxxxx	Introduction to Toxicology	2	Students examine basic concepts of toxicology as they apply to the effects of environmental agents, e.g. chemicals, metals, on public health. We discuss the distribution, cellular penetration, metabolic conversion, and elimination of toxic agents, as well as the fundamental laws governing the interaction of foreign chemicals with biological systems. A survey of general principles underlying the effects of toxic substances on biological systems, including consideration of the history, scope and applications of toxicology, toxicant exposure, the mechanisms of toxic action, and some major types of toxicants
CYxxxx	MATLAB and Mathematical Computation	2	This course site is the result of several iterations of an introductory course I have given at MIT, the last of which was called DR. MATLAB. In that course I strived to change the usual pattern of teaching/learning MATLAB from a programming view point to a mathematical one. The idea is that by thinking about mathematical problems, students are prodded into learning MATLAB for the purpose of solving the problem at hand. The down-side to this approach is that it is somewhat based on the idea that people are already excited about mathematics, or can be excited about it. That said, as I taught the course at MIT, it was not a big problem. Variables, arrays, conditional statements, loops, functions, and plots are covered in a project-based style where much of the learning happens away from the classroom. Students are expected to spend about 4 hours per week on homework. At the end of the course, students should be able to use MATLAB in their own work, and be prepared to deepen their MATLAB programming skills and tackle other languages for computing, such as Java, C++, or Python.
CYxxxx	Analytical and Advanced Techniques in Chemistry	2	• Synthesis and characterization of inorganic compounds in the diverse areas of Inorganic Chemistry such as Coordination Chemistry, • Organometallic Chemistry and Bioinorganic Chemistry etc. Characterization: • quantitative and qualitative determination of ligand and metal, use of spectral techniques (UV-visible, FT-IR, NMR, ESR, magnetic moment, analytical methods (conductance, TGA, DSC, cyclic voltametry). • Book: Synthesis and Technique in Inorganic Chemistry: A Laboratory Manual, Gregory S. Girolami, Thomas B. Rauchfuss and Robert J. Angelici. University Science Books. 2. Synthetic methods of organometallic and inorganic chemistry ed. by Wolfgang A. Herrmann, Georg Thieme Verlag, New York, 1997, Vol 7 and 8 3. • Vogel's qualitative inorganic analysis, by Svehla, G. Publisher: Harlow: Longman, 1996. 4. Vogel's textbook of quantitative inorganic analysis: including elementary instrumental analysis. By: Arthur Israel Vogel; John Bassett Publisher: London; New York: Longman, 1978.
CYxxxx	Batteries and Fuel cells	3	This course is a guide to the evolution of the use of electrochemistry to generate energy and power. The course will provide comprehensive exploration of all types of batteries and fuel cells and their applications. Principles of Operation of Cells and Batteries; Electrochemical Principles and Reactions; Factors Affecting Battery Performance; Battery Design; Primary cells and Batteries; Fundamentals of Secondary Batteries: Advanced Lead-acid, Ni-based and lithium-ion batteries, next generation batteries, Materials for batteries, Electrode preparation, cell Assembly, electrochemical performance analysis, understanding of degradation mechanism and Safety. Fuel cells: Introduction to Fuel Cells: working principle, direct methanol fuel cells, Proton Exchange Membrane Fuel Cells, alkaline fuel cells, phosphoric acid, solid oxide, molten carbonate Fuel cells. Advanced batteries and fuel cells for UPS, Solar, Telecom, Aerospace, Grid and Electric Vehicle applications. References: 1. Kirby W. Beard. Linden's Handbook of Batteries, Fifth Edition (McGraw-Hill Education: New York, Chicago, San Francisco, Athens, London, Madrid, Mexico City, Milan, New Delhi, Singapore, Sydney, Toronto, 2019).

			2. Vladimir S. Bagotsky, Alexander M. Skundin and Yury M. Volfkovich (A.N. Frumkin Institute of Physical Chemistry and Electrochemistry of the Russian Academy of Science, Russia) Electrochemical Power Sources: Batteries, Fuel Cells, and Supercapacitors" By, John Wiley & Sons Inc, New Jersey, USA, 2015, 372 pages, ISBN: 978-1-118-46023-6. 3. Ying-Pin Chen, Sajid Bashir, Jingbo Louise Liu, Nanostructured Materials for Next-Generation Energy Storage and Conversion: Advanced Battery and Supercapacitors, Springer Nature, 10-Oct-2019 - Technology & Engineering - 472 pages. 4. D. Pavlov, Lead-Acid Batteries: Science and Technology, Elsevier 31-May-2011 - Technology & Engineering - 656 pages. 5. C. Vincent, Bruno Scrosati, Modern batteries, Elsevier, 26-Sep-1997 - Technology & Engineering - 368 pages. 6. Paul Breeze, Fuel cells, 2017, Elsevier Science, 100 pages.
CYxxxx	Nuclear Chemistry	3	• Nuclear Chemistry Introduction: Basic Concepts, • Elementary Particles, and Decay Types, • Nuclear Properties: Nuclear masses and binding energies, • Chemistry of Actinide and Trans-actinide elements, Radioactive decay Kinetics (α- and β-decay and γ-ray decay), Nuclear Reactions, Nuclear Fuel Cycle, and Nuclear Reactor, • Separation Techniques for the Nuclear Wastes. • Book: Modern Nuclear Chemistry by Walter D. Loveland, David J. Morrisey, Glenn T. Seaborg