Learning Outcomes based Curriculum Framework (LOCF)
for
(B.Sc. with Chemistry)
Undergraduate Programme
2021

MANIPUR UNIVERSITY

CANCHIPUR 795003

Course Structure	
Course	***Credit**
I. Core Course (18 Papers)	
(13 Theory papers of 4 credit each ***4 Theory papers of 5 credit each)**	**13×4 = 52** **4 × 5 = 20**
Core Course Practical/Tutorial*	
(13 Practical Papers of 2 credit each ***4 Tutorials of 1 credit each** ****1 Project/dissertation of 6 credit)**	**13×2= 26** **4 × 1 = 4** **1 × 6 = 6**
II. Elective Course (10 papers)	
(a) Discipline Specific Elective (4 papers)	
(4 Papers of 5 credit each) ***4 Tutorials of 1 credit each)**	**4 × 5 = 20** **4 × 1 = 4**
(b) Generic Elective/Interdisciplinary Course (6 papers)	
(6 Papers of 6 credit each *** Credit pattern depends on the course opted by the student)**	**6 ×6 = 36**
III. Ability Enhancement Course (4 papers)	
(a) Ability Enhancement Course	
(2 Papers of 3 credit each **2 Tutorials of 1 credit each)**	**2 × 3 = 6** **2 × 1 = 2**
(b) Skill Enhancement Course	
(2 Papers of 3 credit each **2 Tutorials of 1 credit each)**	**2 × 3 = 6** **2 × 1 = 2**
IV. Value Addition Course	
(8 papers of 2 credit each)	**2 × 8 = 16**
Total	**200**

Core and DSE courses without practicals will have tutorial and have credit distribution of 5 credits for theory and 1 credit for tutorial, total 6 credits, same as the papers with practical.

****Project/dissertation course is treated as practical with 6 credits.***

Course Structure at a Glance

Core Courses (CC)

Sr. No.	Name of the course	Type of course	L	T	P	Credits
CC 1	Inorganic Chemistry-I	Core course	3	1	0	**4**
	Inorganic Chemistry Laboratory-I	Core course	0	0	2	**2**
CC 2	Organic Chemistry-I	Core course	3	1	0	**4**
	Organic Chemistry Laboratory-I	Core course	0	0	2	**2**
CC 3	Analytical Chemistry	Core course	3	1	0	**4**
	Analytical Chemistry Laboratory	Core course	0	0	2	**2**
CC 4	Physical Chemistry-I	Core course	3	1	0	**4**
	Physical Chemistry Laboratory-I	Core course	0	0	2	**2**
CC 5	Green Chemistry	Core course	3	1	0	**4**
	Green Chemistry Laboratory	Core course	0	0	2	**2**
CC 6	Inorganic Chemistry-II	Core course	3	1	0	**4**
	Inorganic ChemistryLaboratory-II	Core course	0	0	2	**2**
CC 7	Physical Chemistry-II	Core course	3	1	0	**4**
	Physical Chemistry Laboratory-II	Core course	0	0	2	**2**
CC 8	Molecular Spectroscopy & Photochemistry	Core course	5	1	0	**6**
CC 9	Inorganic Chemistry-III	Core course	3	1	0	**4**
	Inorganic Chemistry Laboratory-III	Core course	0	0	2	**2**
CC 10	Organic Chemistry-II	Core course	3	1	0	**4**
	Organic Chemistry Laboratory-II	Core course	0	0	2	**2**
CC 11	Introduction to Quantum Chemistry	Core course	5	1	0	**6**
CC 12	Organic Chemistry-III	Core course	3	1	0	**4**
	Organic Chemistry Laboratory	Core course	0	0	2	**2**
CC 13	Physical Chemistry-III	Core course	3	1	0	**4**
	Physical Chemistry Laboratory-III	Core course	0	0	2	**2**
CC 14	Materials Chemistry	Core course	5	1	0	**6**
CC 15	Advanced Chemistry-I	Core course	3	1	0	**4**
	Advanced Chemistry Laboratory I	Core course	0	0	2	**2**
CC 16	Advanced Chemistry-II	Core course	3	1	0	**4**
	Advanced Chemistry Laboratory II	Core course	0	0	2	**2**
CC 17	Research Methodology	Core course	5	1	0	**6**
CC 18	Project/Dissertation	Core course	0	0	6	**6**

CORE COURSES (PASS/HONOURS IN CHEMISTRY) .....Page no

Semester VII

Semester VIII

ELECTIVES COURSES (06 Papers) (Credit: 06 Each)

(a) Discipline Specific Electives (DSE) Courses

Semester V

Any One from the following:

Semester VI

Any One from the following:

Semester VII

Any one of the following:

Semester VIII

Any one of the following:

(b) Generic Elective Courses (GEC)

Semester III

Semester IV

Semester V

Semester VI

Semester VII

Semester VIII

ABILITY ENHANCEMENT COURSES (04 papers)(Credit:04 each)

(a) Ability Enhancement Compulsory Courses (AECC)

(b) Skill Enhancement Courses (SEC)

Semester I

Any One from the following:

Semester II

Any One from the following:

VALUE ADDITION COURSES (VAC) (08 papers) (Credit:02 each)

Semester I : CH-VAC-111; CH-VAC-112

Semester II: CH-VAC-123; CH-VAC-124

Semester III: CH-VAC-235

Semester IV: CH-VAC-246

Semester V: CH-VAC-357

Semester VI: CH-VAC-368

To be choosen from the following:

1. Yoga
2. Sports
3. Health Care
4. NCC
5. NSS
6. Ethics
7. Culture.

Structure of B. Sc. Pass/Honours (Chemistry) Programme

Semester	Type	Core	DSE	GEC*	AECC	SEC	VAC
	Credits	18×6=108	4×6=24	6×6=36	2×4=8	2×4=8	8×2=16
I		CH-111			CH-AECC-111	CH-SEC-111/112/113	CH-VAC-111
		CH-112					CH-VAC-112
II		CH-120			CH-AECC-112	CH-SEC-121/122/123	CH-VAC-123
		CH-123					CH-VAC-124
III		CH-230		CH-GEC-230			CH-VAC-235
		CH-231					
		CH-233					
IV		CH-240		CH-GEC-240			CH-VAC-246
		CH-241					
		CH-242					
V		CH-350	CH-DSE-351/352/353/354	CH-GEC-350			CH-VAC-357
		CH-352					
VI		CH-360	CH-DSE-361/362/363/364	CH-GEC-360			CH-VAC-368
		CH-363					
VII		CH-471	CH-DSE-471/472	CH-GEC-470			
		CH-472					
VIII		CH-481	CH-DSE-481/482	CH-GEC-480			
		CH-482					

*GE Courses are to be chosen from the GE courses offered by other disciplines (Physics, Mathematics, Biochemistry, Botany and Zoology).

SCHEME FOR CHOICE BASED CREDIT SYSTEM in B.Sc. Pass/Honours (Chemistry)

SEMESTER	COURSE CODE	COURSE NAME	Credits
I	CH-AECC-111	English for Communications	4
	CH-111	Inorganic Chemistry-I	4+2=6
		Inorganic Chemistry-Lab-I	
	CH-112	Organic Chemistry-I	4+2=6
		Organic Chemistry-Lab-I	
	CH-SEC-111/112/113	Skill Enhancement Course	4
	CH-VAC-111	Value Addition Course 1	2
	CH-VAC-112	Value Addition Course 2	2
		Total credits in Semester I	24
II	CH-AECC-112	Environmental Studies	4
	CH-120	Analytical Chemistry	4+2=6
		Analytical Chemistry Laboratory	
	CH-123	Physical Chemistry-I	4+2=6
		Physical Chemistry Laboratory-I	
	CH-SEC-121/122/123	Skill Enhancement Course	4
	CH-VAC-123	Value Addition Course 3	2
	CH-VAC-124	Value Addition Course 4	2
		Total credits in Semester II	24
III	CH-230	Green Chemistry	4+2=6
		Green Chemistry Laboratory	
	CH-231	Inorganic Chemistry-II	4+2=6
		Inorganic Chemistry Laboratory-II	
	CH-233	Physical Chemistry-II	4+2=6
		Physical Chemistry Laboratory-II	
	CH-GEC-230	Generic Elective Course	4+2/5+1=6
		Lab/tutorial	
	CH-VAC-235	Value Addition Course 5	2
		Total credits in Semester III	26
IV	CH-240	Molecular Spectroscopy & Photochemistry	5+1=6
	CH-241	Inorganic Chemistry-III	4+2=6
		Inorganic Chemistry Laboratory-III	
	CH-242	Organic Chemistry-II	4+2=6
		Organic Chemistry Laboratory-II	
	CH-GEC-240	Generic Elective Course	4+2/5+1=6
		Lab/tutorial	
	CH-VAC-246	Value Addition Course 6	2
		Total credits in Semester IV	26
V	CH-350	Introduction to Quantum Chemistry	5+1=6
	CH-352	Organic Chemistry-III	4+2=6
		Organic Chemistry Laboratory	
	CH-DSE-351/352/353/354	Discipline Specific Elective	4+2/5+1=6
		Lab/tutorial	
	CH-GEC-350	Generic Elective Course	4+2/5+1=6
		Lab/tutorial	

CORE COURSES

These are 18 courses of 6 credits each. All courses are compulsory. These courses have the following credit pattern.

For Theory and practical based papers:

L	T	P	Cr
3	1	2	6

For Theory papers without Practical:

L	T	P	Cr
5	1	0	6

SEMESTER -I

Core Course-1: CH-111:Inorganic Chemistry-I

L	T	P	Cr
3	1	0	4

On completion of this course, the students will be able to understand:

Learning objective:

1. Atomic theory and its evolution.
2. Learning scientific theory of atoms, concept of wavefunction.
3. Elements in periodic table; physical and chemical characteristics, periodicity.
4. To predict the atomic structure, chemical bonding, and molecular geometry based on accepted models.
5. To understand atomic theory of matter, composition of atom.
6. Identity of given element, relative size, charges of proton, neutron and electrons, and their assembly to form different atoms.
7. Defining isotopes, isobar and isotone.
8. Physical and chemical characteristics of elements in various groups and periods according to ionic size, charge, etc. and position in periodic table.
9. Characterize bonding between atoms, molecules, interaction and energetic (ii) hybridization and shapes of atomic, molecular orbitals, bond parameters, bond-distances and energies.

10. Valence bond theory incorporating concepts of hybridization predicting geometry of molecules.
11. Importance of hydrogen bonding, metallic bonding.

Self-study:

1. Electronic configuration of various elements in periodic table
2. Predicting structure of molecules
3. How hydrogen bonding, metallic bonding is important in common materials' scientific applications to material fabrication

UNIT-1 Atomic Structure: (10 classes of 60 minutes each)

Classical approach to understanding the matter and atoms, Rutherford model and its failure, Bhor's model and atomic spectra of atom and quantization of angular momentum, dual nature of electrons, limitations of Bohr's model and atomic spectra of hydrogen atom, de'Broglie equation, Heisenberg's Uncertainty Principle and its significance Schrödinger's wave equation, significance of wave functions, Quantum numbers and their significance, concept of orbit and orbitals. Shapes of *s*, *p*, *d* and *f* orbitals. Probability diagrams. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity Aufbau's principle and its limitations, Electronic configuration, Variation of orbital energy with atomic number.

UNIT-2: Periodicity of Elements: (10 classes of 60 minutes each)

s, *p*, *d*, *f* block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to *s* and *p*-block.
(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.
(b) Atomic radii (van'der Waals)

(c) Ionic and crystal radii.

(d) Covalent radii (octahedral and tetrahedral)

(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.
(f)Electron gain enthalpy, trends of electron gain enthalpy.

(g) Electronegativity, Pauling, Mullikan, Allred Rachow scales, electronegativity and bond order, partial charge, hybridization, group electronegativity.

UNIT-3: Chemical Bonding: (14 classes of 60 minutes each)

(i)*Ionic bond:* General characteristics, types of ions, size effects, radius ratio rule and itslimitations. Packing of ions in crystals. Madelung constant, Born-Haber cycle and its application, Solvation energy.

(ii) *Covalent bond:* Lewis structure, Valence Shell Electron Pair Repulsion Theory (VSEPR), Shapes of simple molecules and ions containing lone – and bond-pairs of electrons multiple bonding, sigma and pi-bond approach, Valence Bond theory, (Heitler-London approach). Hybridization containing *s*, *p* and *s*, *p*, *d* atomic orbitals, shapes of hybrid orbitals, Bents rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of simple homonuclear and heteronuclear diatomic molecules, MO diagrams of simple tri and tetra-atomic molecules, e.g., N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, HCHO, (idea of s-pmixing and orbital interaction to be given) NH_3, H_3O^+, SF_4, CIF_3, ICl_2. Covalent character in ionic compounds, polarizing power and polarizability. Fajan rules, polarization. Ionic character in covalent compounds: Bond moment and dipole moment. Ionic character from dipole moment and electronegativities difference.

UNIT-4: Metallic bonding and Weak chemical forces: (6classes of 60 minutes each)

(i) *Metallic Bond:* Qualitative idea of valence bond and band theories, Semiconductors, Insulators, defects in solids.

(ii) Weak Chemical Forces: van der Waals, ion-dipole, dipole-dipole, induced dipole dipole-induced dipole interactions, Lenard-Jones 6-12 formula, hydrogen bond, effects of hydrogen bonding on melting and boiling points, solubility, dissolution.

UNIT-5: Oxidation-Reduction reactions:(4 classes of 60 minutes each)

Electronic concept of oxidation number, concept of oxidation-reduction, redox equations, standard electrode potential and its applications to inorganic reactions, principles involved in volumetric analysis to be carried out in the class

Recommended Books/References:

1. Lee,J.D. *Concise Inorganic Chemistry,* Wiley, 5thEd^{n}.
2. Douglas, B.E., McDaniel, D.H., AlexanderJ.J., *Concepts & Models of Inorganic Chemistry, (Third Edition)* John Wiley & Sons, 1999.
3. Atkins, P.W. and DePaula, J. *Physical Chemistry*, Tenth Edition, Oxford University Press,2014.
4. Rodger,G.E. *Inorganic and Solid State Chemistry*, Cengage Learning, 2002.

CH-111P : Inorganic Chemistry Laboratory-1

L	T	P	Cr
0	0	2	2

(A) Titrimetric Analysis

(i) Calibration and use of apparatus.

(ii) Preparation of solutions of different Molarity/Normality of titrants.

(iii) Use of primary and secondary standard solutions.

(B) Acid-Base Titrations

(i) Estimation of carbonate and hydroxide present together in mixture.

(ii) Estimation of carbonate and bicarbonate present together in a mixture.

(iii) Estimation of free alkali present in different soaps/detergents

(C) Oxidation-Reduction Titrimetry

(i) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution.

(ii) Estimation of oxalic acid and sodium oxalate in a given mixture.

(iii) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books/References:

1. Mendham, J., *A.I.Vogel's QuantitativeChemicalAnalysis,* Sixth Edition, Pearson, 2009.
2. Svehala G. and Sivasankar I.B, *Vogel's Qualitative Inorganic Analysis*, Pearson,I ndia, 2012.

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

Core Course-2: CH-112: Organic Chemistry-I

L	T	P	Cr
3	1	0	4

On completion of this course, the students will be able to understand:

Learning objectives:

1. Basic of organic molecules, structure, bonding, reactivity and reaction mechanisms.
2. Stereochemistry of organic molecules–conformation and configuration, asymmetric molecules and nomenclature.
3. Aromatic compounds and aromaticity, mechanism of aromatic reactions.
4. Understanding hybridization and geometry of atoms, 3-D structure of organic molecules, identifying chiral centers.
5. Reactivity, stability of organic molecules, structure, stereochemistry.
6. Electrophile, nucleophiles, free radicals, electronegativity, resonance, and intermediates along the reaction pathways.
7. Mechanism of organic reactions (effect of nucleophile / leaving group, solvent), substitution *vs*. elimination.

Self-study:

1. Design and syntheses of organic molecules.
2. Structure identification through IR, NMR and Mass spectroscopic data.
3. Lab/Instrumentation techniques used for analyzing reaction mechanisms.
4. Advanced soft-wares / Models used for predicting stereochemistry / study of energy minimization of organic molecules.

UNIT-1: Basics of Organic Chemistry: (10 classes of 60 minutes each)

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties. Electronic Displacements: Inductive, electromeric,

Resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength. Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophlicity and basicity; Types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals and Carbenes).
Organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

UNIT-2: Stereochemistry: (6 classes of 60 minutes each)

Concept of asymmetry, Fischer Projection, Newmann and Sawhorse projection formulae and their interconversions; Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with C.I.P rules. Optical Isomerism: Optical Activity, Specific Rotation, Chirality / Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers,

mesostructures, Racemic mixtures, Relative and absolute configuration: D/L and R/S designations.

UNIT-3: Chemistry of Aliphatic Hydrocarbons: (18 classes of 60 minutes each)

A. Carbon-Carbon sigma bonds

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz- Fittig Reactions, Free radical substitutions: Halogenation -relative reactivity and selectivity.

B. Carbon-Carbon pi-bonds

Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations. Reactions of alkenes: Electrophilic additions their mechanisms (Markownikoff / Anti-Markownikoff addition), mechanism of oxymercuration-demercuration, hydroboration- oxidation, ozonolysis, reduction (catalytic and chemical), syn- and anti-hydroxylation (oxidation). 1, 2- and 1, 4- addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethylbenzene; Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions.

C. Cycloalkanes and Conformational Analysis

Cycloalkanes and stability, Baeyer strain theory, Conformation analysis, Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms.

UNIT-4: Aromatic Hydrocarbons (6 classes of 60 minutes each)

Aromaticity: Huckel's rule, aromatic character of arenes, cyclic carbocations / carbanions and heterocyclic compounds with suitable examples; Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft'salkylation / acylation with their mechanism; Directing effects of substituent groups.

Recommended Books / References:

1. Morrison, R.N. and Boyd, R.N. *Organic Chemistry*, 6thEdn., Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Pine S.H. *Organic Chemistry*, Fifth Edition, McGraw Hill, (2007)
3. F.A.Carey,*Organic Chemistry*, Seventh Edition,Tata McGraw Hill (2008).
4. J. Clayden, N. Greeves, S.Warren, *Organic Chemistry*, 2ndEd., (2012), Oxford University Press.
5. F.A. Carey, R.J. Sundberg, *Advanced Organic Chemistry*, *Part A: Structure and mechanism*, Kluwer Academic Publisher, (2000).

CH-112P :Organic Chemistry Laboratory -I

L	T	P	Cr
0	0	2	2

1. Checking the calibration of the thermometer.

2. Purification of organic compounds by crystallization using the following solvents:

   a. Water b. Alcohol c. Alcohol-Water

3. Determination of the melting points of given organic compounds and unknown organic compounds (using Kjeldahl method and electrically heated melting point apparatus).
4. Effect of impurities on the melting point–mixed melting point of two unknown organic compounds.
5. Determination of boiling point of liquid compounds. (boiling point lower than and more than100°C by distillation and capillary method)
6. Chromatography

   a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography

   b. Separation of a mixture of two sugars by ascending paper chromatography

   c. Separation of a mixture of *o*- and *p*-nitrophenol or *o*- and *p*-amino phenol by thin layer chromatography (TLC).

Recommended Books/Reference:

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5thEd.,* Pearson (2012)

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

SEMESTER - II

Core Course-3 : CH-120: Analytical Chemistry

L	T	P	Cr
3	**1**	**0**	**4**

Learning objective:

1. Familiarization with fundamentals of analytical chemistry.
2. Basics of spectroscopic, thermal, electrochemical techniques
3. Learning basics of separation techniques and its applications.
4. Understanding analytical tools, statistical methods applied to analytical chemistry.
5. Understanding principle of UV-Vis spectroscopy and its applications.
6. Understanding principles of thermo-gravimetric analysis and study of thermal decomposition of materials/characterization of materials.
7. Understanding basics of electro-analytical techniques and its applications.
8. Understanding principles of separation technology and its use in advanced instrumentations.

Self-study:

1. Thermo-gravimetric Analysis of different compounds and application of mathematical models.
2. Study of different kinds of chromatograms; calculation of R_f.

UNIT-1: Qualitative and quantitative aspects of analysis (4 classes of 60 minutes each)

Tools in analytical chemistry and their applications, Sampling, evaluation of analytical data, errors, accuracy and precision, statistical test of data; F, Q and t-test, rejection of data, and confidence intervals.

UNIT-2: Spectroscopy (8 classes of 60 minutes each)

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

a) **Vibration spectroscopy:** Basic principles of instrumentation, sampling techniques. Application of IR spectroscopy for characterization through interpretation of data, Effect and importance of isotope substitution. Introduction to Raman spectra
b) **UV-Visible Spectrometry:** Basic principles of instrumentation, principles of quantitative analysis using estimation of metal ions from aqueous solution, Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method.

UNIT-2: Thermal analysis (6 classes of 60 minutes each)

Theory of thermogravimetry (TG and DTG), instrumentation, estimation of Ca and Mg from their mixture.

UNIT-3: Electroanalytical methods (6 classes of 60 minutes each)

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Determination of pKa values.

UNIT-4: Separation techniques (16 classes of 60 minutes each)

Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and non-aqueous media.
Chromatography techniques: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange. Development of chromatograms: frontal, elution and displacement methods. Qualitative and quantitative aspects of chromatographic methods of analysis using LC, GLC, TLC and HPLC.

Recommended Books/Reference Books:

1. Mendham,J., *A.I.Vogel's Quantitative Chemical Analysis 6thEd.,* Pearson, 2009.
2. Willard,H.H. *etal.*: *Instrumental Methods of Analysis*, 7thEd. Wardsworth Publishing California, USA,1988.
3. Christian,G.D, *Analytical Chemistry*, 6thEd. John Wiley & Sons, NewYork, 2004.
4. Harris,D.C.: *Exploring Chemical Analysis*, 9th Ed. NewYork, W.H.Freeman, 2016.
5. Skoog,D.A., Holler F.J.& Nieman,T.A. *Principles of Instrumental Analysis,* Saunder College Publications, (1998).
6. Mikes,O. *Laboratory HandBook of Chromatographic & Allied Methods*, Elles Harwood John Wiley 1979.
7. Ditts, R.V. *Analytical Chemistry; Methods of separation*, VanNostrand, 1974.
8. Khopkar, S. M., *Basic Concepts of Analytical Chemistry*, New Age (Second edition) 1998

CH-120P: Analytical Chemistry Laboratory

L	T	P	Cr
0	0	2	2

(Recommended to carry out at least two experiments from each section)

I. Chromatography:

(i) Paper chromatographic separation of Fe^{3+}, Al^{3+}, and Cr^{3+}.

(ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the Rf values.

(iii) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their Rf values.

(iv) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC.

II. Solvent Extractions:

(i) To separate a mixture of Ni^{2+} & Fe^{2+} by complexation with DMG and extracting the Ni^{2+}-DMG complex in chloroform, and determine its concentration by spectrophotometry.

(ii) Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.

(iii) Determination of Na, Ca, Li in coladrinks and fruit juices using flame photometric techniques.

III. Analysis of soil:

(i) Determination of pH of soil.

(ii) Total soluble salt

(iii) Estimation of calcium, magnesium, phosphate, nitrate

IV. Ion exchange:

(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.

(ii) Separation of metal ions from their binary mixture.

(iii) Separation of amino acids from organic acids by ion exchange chromatography.

V. Spectrophotometry

(i) Determination of pKa values of indicator using spectrophotometry.

(ii) Structural characterization of compounds by infrared spectroscopy.

(iii) Determination of dissolved oxygen in water.
(iv) Determination of chemical oxygen demand (COD) and Biological oxygen demand (BOD).
(v) Determine the composition of the Ferric-salicylate/ferric-thiocyanate complex by Job's method.

Recommended textbooks/references:

1. Mendham,J., *A.I.Vogel'sQuantitativeChemicalAnalysis 6thEd.,*Pearson,2009.
2. Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed, Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian,G.D. *Analytical Chemistry*, 6thEd. John Wiley & Sons, NewYork, 2004.
4. Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. NewAge International Publisher, 2009.
5. Skoog, D.A. Holler F.J. and Nieman, T.A. *Principles of Instrumental Analysis*, Cengage Learning India Edition.
6. Mikes, O. & Chalmes, R.A. *Laboratory Handbook of Chromatographic & Allied Methods*, Elles HarwoodLtd. London.
7. Ditts, R.V. *Analytical Chemistry: Methods of separation.* Van Nostrand, NewYork, 1974.

Core Course 4: CH-123: Physical Chemistry – I

L	T	P	Cr
3	1	0	4

Learning Objectives:

1. Familiarization with various states of matter.
2. Physical properties of each state of matter and laws related to describe the states.
3. Calculation of lattice parameters.
4. Electrolytes and electrolytic dissociation, salt hydrolysis and acid-base equilibria.
5. Understanding Kinetic model of gas and its properties.
6. Maxwell distribution, mean-free path, kinetic energies.
7. Behavior of real gases, its deviation from ideal behavior, equation of state, isotherm, and law of corresponding states.

8. Liquid state and its physical properties related to temperature and pressure variation.
9. Properties of liquid as solvent for various household and commercial use.
10. Solids, lattice parameters–its calculation, application of symmetry, solid characteristics of simple salts.
11. Ionic equilibria–electrolyte, ionization, dissociation.
12. Salt hydrolysis (acid-base hydrolysis) and its application in chemistry.

Self-study:

1. Determination of lattice parameters of given salt.
2. Study of X-Ray diffraction pattern and finding out reference from JCPDI file.
3. Numerical related to salt hydrolysis, ionic equilibria.

UNIT-1: Gaseous State (14 classes of 60 minutes each)

Deviations from ideal gas behavior, compressibility factor and its variation with pressure for different gases. Causes of deviation from ideal behavior. Van der Waals equation of state, its derivation and application in explaining real gas behaviour; Berthelot and Dieterici equation; virial equation of state; van der Waals equation expressed in virial form, Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, critical and van der Waals constants, law of corresponding states.
Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure.
Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

UNIT-2: Liquid State (4 classes of 60 minutes each)

Structure and physical properties of liquids; vapour pressure, surface tension, viscosity, and their dependence on temperature, Effect of addition of various solutes on surface tension and viscosity; temperature variation of surface tension and viscosity of liquids; cleansing action of detergents; structure of water.

UNIT-3: Solid State (10 classes of 60 minutes each)

Nature of the solid state; law of constancy of interfacial angles; law of rational indices; Miller

indices; elementary ideas of symmetry, symmetry elements and symmetry operations; qualitative idea of point and space groups; seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law; a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Defects in crystals. Glasses and liquid crystals.

UNIT-4: Ionic Equilibria (12 classes of 60 minutes each)

Strong, moderate and weak electrolytes; degree of ionization; factors affecting degree of ionization; ionization constant and ionic product of water. Ionization of weak acids and bases; pH scale; common ion effect; dissociation constants of mono-, di- and tri-protic acids.
Salt hydrolysis; hydrolysis constants; degree of hydrolysis and pH for different salts.Buffer solutions; Henderson equation; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry. Solubility and solubility product.
Brönsted-Lowry concept of acid-base reactions; solvated proton; relative strength of acids; types of acid-base reactions; leveling solvents; Lewis acid-base concept; Classification of Lewis acids; Hard and Soft Acids and Bases (HSAB); application of HSAB principle.
Qualitative treatment of acid-base titration curves (calculation of pH at various stages). Theory of indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolyte systems.

Recommended Books:

1. Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 8th Ed., Oxford University Press (2006).
2. Ball, D. W. *Physical Chemistry* Thomson Press, India (2007).
3. Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).
4. Mortimer, R. G. *Physical Chemistry* 3rd Ed. Elsevier: NOIDA, UP (2009).
5. Barrow, G. M. *Physical Chemistry* 5th Ed. Tata McGraw Hill (2007).

CH-123P: Physical Chemistry Laboratory – I

L	T	P	Cr
0	0	2	2

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

1. Surface tension measurements

a) Determine the surface tension by (i) drop number, and (ii) drop weight method.
b) Study the variation of surface tension of detergent solutions with concentration.

2. Viscosity measurements using Ostwald's viscometer

a) Determination of viscosity of aqueous solutions of (i) polymer, (ii) ethanol, and (iii) sugar at room temperature.
b) Viscosity of sucrose solution with the concentration of solute.

3. pH metry

a) Effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures.
b) Preparation of buffer solutions of different pH (i) Sodium acetate-acetic acid, (ii) Ammonium chloride-ammonium hydroxide
c) pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.
d) Determination of dissociation constant of a weak acid.

Recommended Books:

1. Khosla, B. D.; Garg, V. C.; Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P. *Experiments in Physical Chemistry* 8th Ed.; McGraw-Hill: New York (2003).
3. Halpern, A. M.; McBane, G. C. *Experimental Physical Chemistry* 3rd Ed.; W.H. Freeman & Co.: New York (2003).
4. Athawale V. D.; Mathur P. *Experimental Physical Chemistry* New Age Intenational (2001)

SEMESTER – III

Core Course-5:CH-230: Green Chemistry

L	T	P	Cr
3	1	0	4

Learning objective:

After completion of the course, the learner shall be able to understand:

1. Green chemistry and its principles.
2. Green synthesis and reactions.
3. Green chemistry for sustainable solutions.

4. Understanding principles of green chemistry.
5. Understanding design of chemical reactions/chemical synthesis using green chemistry principles.
6. Atom economy and design of chemical reactions using the principle.
7. Understanding the use of green chemistry principle and processes in laboratory reactions.

Self-study:

1. Use of green chemistry in designing new laboratory experiments.
2. Use of principle of atom economy and design experiments using the principle.
3. Use of green chemistry in combinatorial chemistry and biomimetic catalyst.

UNIT-1: Introduction to Green Chemistry (4 classes of 60 minutes each)

Basic introduction and explaining goals of Green Chemistry. Limitations/Obstacles in the pursuit of the goals of Green Chemistry

UNIT-2: Principles of Green Chemistry and Designing a Chemical synthesis (12 classes of 60 minutes each)

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on Designing a Green Synthesis using these principles (Prevention of Waste/byproducts; maximum incorporation of the materials used in the process into the final products.

Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions).

UNIT-3: Green Synthesis /Reactions:(16 classes of 60 minutes each)

1. Green Synthesis of adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis).
2. Microwave assisted reactions in water: (Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols) and reactions in organic solvents (Diels-Alder reaction and Decarboxylation reaction).
3. Ultrasound assisted reactions: Sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)
4. Surfactants for carbondioxide–replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments.
5. Designing of Environmentally safe marine antifoulant.

6. An efficient, green synthesis of a compostable and widely applicable plastic (polyl actic acid) made from corn.
7. Healthier Fats and oil by Green Chemistry: Enzymatic Interesterification for production of no Trans-Fats and Oil

UNIT-4: Future Trends in Green Chemistry (6 classes of 60 minutes each)

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solvent less reactions; cocrystal controlled solid state synthesis (C_2S_3); Green chemistry in sustainable development.

Recommended Books/References:

1. Ahluwalia,V.K.,Kidwai,M.R.*New Trends in Green Chemistry*, Anamalaya Publishers (2005).
2. Anastas,P.T. & Warner,J.K,*Green Chemistry-Theory and Practical*, Oxford University Press (1998).
3. Matlack,A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
4. Cann,M.C. and Connely, M.E. *Real-World cases in Green Chemistry*, ACS (2000).
5. Ryan, M.A. and Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, (2002).
6. Lancaster, M. *Green Chemistry:An Introductory Text* RSC Publishing, Second Edition, 2010.

CH-230P: Green Chemistry Laboratory

L	T	P	Cr
0	0	2	2

(Following is the list of suggestive experiments. Six experiments may be conducted)

1. Preparation of biodiesel from vegetable/waste cooking oil.

2. Use of molecular model kit to stimulate the reaction to investigate how the atom economy illustrates Green Chemistry.
3. Reactions like addition, elimination, substitution and rearrangement may also be studied for the calculation of atom economy.
4. Benzoin condensation using Thiamine Hydrochloride as a catalyst (instead of cyanide).

5. Extraction of D-limonene from orange peel using liquid CO_2 prepared form dry ice.

6. Mechanochemical solvent free synthesis of azomethines

7. Solvent free, microwave assisted one pot synthesis of phthalocyanine Cu(II) complex.

8. Photo reduction of benzophenone to benzopinacol in presence of sunlight.

RecommendedBooks/References:

1. Anastas, P.T & Warner,J.C. *Green Chemistry: Theory and Practice,* Oxford University Press (1998).
2. Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate chemistry experiment*. American Chemical Society, Washington DC (2002).
3. Ryan,M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).
4. Sharma,R.K.; Sidhwani, I.T. and Chaudhari, M.K.I.K. *Green Chemistry Experiment: Amonograph,* International Publishing ISBN 978-93-81141-55-7 (2013).
5. Cann, M.C. and Connelly, M.E. *Real world cases in Green Chemistry*, American Chemical Society (2008).
6. Lancaster, M. *Green Chemistry: An Introductory Text,* RSC Publishing, Second Edition, 2010.
7. Pavia, D.L., Lampman, G.M., Kriz, G.S. & Engel, R.G. *Introduction to Organic Laboratory Techniques: A Microscale and Macro Scale Approach,* W.B. Saunders,1995

Core Course-6:CH-231: Inorganic Chemistry-II

L	T	P	Cr
3	1	0	4

Learning objective:

After completion of the course, the learner shall be able to understand:

1. Oxidation-Reductions and their use in metallurgy.
2. Chemistry of sand p-block elements.
3. Chemistry of noble gases.
4. Inorganic polymers and their use.
5. Understanding redox reactions in hydrometallurgy processes.
6. Structure, bonding of sand p-block materials and their oxides/compounds.
7. Understanding chemistry of boron compounds and their structures.
8. Chemistry of noble gases and their compounds; application of VSEPR theory in explaining structure and bonding.

9. Understanding chemistry of inorganic polymers, their structures and uses.

Self-study:

1. Extraction of metals through metallurgical operations and their uses.
2. Bonding of various s- and p- block elements.
3. Use of boron compounds.
4. Chemistry of inorganic polymers and their uses.

UNIT-1: Acids and Bases (6 lectures of 60 minutes each)

Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB), Application of HSAB principle.

UNIT-2: General principle of metallurgy (8 classes of 60 minutes each)

Occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon or carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel- de Boer process and Mond's process, Zone refining.

UNIT-3: Chemistry of *s*- and *p*-Block Elements (14 classes of 60 minutes each)

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behavior of first member of each group. Allotropy and catenation. Complex formation tendency of *s*- and *p*- block elements. Hydrides and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate.

Studies on structure, bonding, preparation, properties and uses: Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Per-oxo acids of Sulphur inter-halogen compounds, poly-halideions, pseudo-halogens, properties of halogens.

UNIT-4: Noble Gases (6 classes of 60 minutes each)

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Bonding in noble gas compounds (Valence bond and MO treatment for XeF_2), Shapes of noble gas compounds (VSEPR theory).

UNIT-5: Inorganic Polymers (6 classes of 60 minutes each)

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Silicates-Clays and Zeolites, molecular sieves,

polyphosphagens, Borazines, and polyphosphazenes, and polysulphates.

Recommended books/references:

1. Lee, J.D. *Concise Inorganic Chemistry*, ELBS,1991.
2. Douglas,B.E; McDaniel, D.H. & Alexander,J.J. *Concepts & Models of Inorganic Chemistry, 3rd Ed.*, John Wiley Sons, N.Y. 1994.
3. Greenwood, N.N., Earnshaw. *Chemistry of the Elements*, Butterworth-Heinemann. 1997.
4. Cotton, F.A.& Wilkinson,G. *Advanced Inorganic Chemistry*, Wiley, VCH, 1999.
5. Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning India Edition, 2002.
6. Miessler,G.L. & Donald, A. Tarr. *Inorganic Chemistry* Fourth Ed., Pearson, 2010.
7. Atkins,P.W. and Shriver D.N. *Atkins' Inorganic Chemistry* 5th Ed. Oxford University Press (2010).

CH-231P: Inorganic Chemistry Laboratory-II

L	T	P	Cr
0	0	2	2

(A) Iodo/Iodimetric Titrations

(i) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodimetrically).

(ii) Estimation of available chlorine in bleaching powder iodometrically.

(B) Inorganic Preparations

(i) Cuprous Chloride, Cu_2Cl_2

(ii) Preparation of Aluminium potassium sulphate (Potash alum) or Chrome alum.

Recommended books/references:

1. Mendham,J., *A.I.Vogel's Quantitative Chemical Analysis* Sixth Edition, Pearson, 2009.

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

Core Course 7 :CH-233: Physical Chemistry – II

L	T	P	Cr
3	1	0	4

Learning Objectives:

1. Laws of thermodynamics and concepts.
2. Partial molar quantities and its attributes.
3. Dilute solution and its properties.
4. Understanding the concept of system, variables, heat, work, and laws of thermodynamics.
5. Understanding the concept of heat of reactions and use of equations in calculations of bond energy, enthalpy, etc.
6. Understanding the concept of entropy; reversible, irreversible processes. Calculation of entropy using 3rd law of thermodynamics.
7. Understanding the application of thermodynamics: Joule Thompson effects, partial molar quantities.
8. Understanding theories/thermodynamics of dilute solutions.

Self-study:

1. Use of thermochemical equations for calculation of energy and related terms.
2. Use of thermodynamics in explaining chemical behavior of solute/solvent and reactions.
3. Study of calorimeter principle and its use.

UNIT-1: Introduction to Thermodynamics (20 classes of 60 minutes each)

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics.Laws of thermodynamics.

First law: Concept of heat, q, work, w, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions.

Thermochemistry: Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equations), pressure on enthalpy of reactions.

Second Law: Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

Third Law: Third Law of thermodynamics, residual entropy, calculation of absolute entropy of molecules.

Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

UNIT-2: Partial Molar Quantities (6 classes of 60 minutes each)

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs-Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

UNIT-3: Chemical Equilibrium (8 classes of 60 minutes each)

Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases; concept of fugacity. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between various equilibrium constants K_p, K_c and K_x. Le Chatelier principle; equilibrium between ideal gases and pure condensed phase.

UNIT-4: Solutons and Colligative Properties (6 classes of 60 minutes each)

Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Excess thermodynamic functions. Thermodynamic derivation using chemical potential to derive relations between the four colligative properties: [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

Recommended Books:

1. Atkins, P. and De Paula, J. *Physical Chemistry* 10th Ed. (2014).
2. Castellan, G. W. *Physical Chemistry* 4th Ed., Narosa (2004).
3. Engel, T. and Reid, P. *Physical Chemistry* 3rd Ed., Prentice Hall (2012).

4. McQuarrie, D. A. and Simon, J. D. *Molecular Thermodynamics* Viva Books (2004).
5. Roy, B. N. *Fundamentals of Classical and Statistical Thermodynamics* Wiley (2001).
6. Assael, M.J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A.; Will, S. *Commonly Asked Questions in Thermodynamics*.CRC Press (2011).
7. Levine, I. N. *Physical Chemistry* 6th Ed., Tata Mc Graw Hill (2010).
8. Metz, C.R. *2000 Solved problems in chemistry*, Schaum Series (2006).

CH-233P: Physical Chemistry Laboratory– II

L	T	P	Cr
0	0	2	2

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

1. Thermochemistry

(a) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).
(b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
(c) Calculation of the enthalpy of ionization of ethanoic acid.
(d) Determination of basicity/proticity of a polyprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also calculation of the enthalpy of neutralization of the first step.
(e) Determination of enthalpy of hydration of salt such as copper sulphate.
(f) Study of the solubility of benzoic acid in water and determination of change in enthalpy.
(g) Study of the effect of concentration of solute on elevation of boiling point of water.

2. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.

3. Study the equilibrium of at least one of the following reactions by the distribution method:
(a) I_2 (aq) + I → I_3^-(aq)
(b)Cu^{2+} (aq) + $n$$NH_3$→$Cu(NH_3)_n$

4. Study the kinetics of the following reactions.
(a) Acid hydrolysis of methyl acetate with hydrochloric acid.

(b) Saponification of ethyl acetate.

5. Adsorption: Verification of Freundlich and Langmuir isotherms for adsorption of acetic acid and selected organic dye(s) on activated charcoal. (Use of calorimeter for calculation of heat of reactions may be demonstrated)

Recommended Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand, New Delhi (2011).
2. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P. *Experiments in Physical Chemistry*, 8th Ed., McGraw-Hill (2003).
3. Halpern, A. M.; McBane, G. C. *Experimental Physical Chemistry*, 3rd Ed., W, H. Freeman (2003).

SEMESTER -IV

Core Course-8: CH-240:Molecular Spectroscopy and Photochemistry

L	T	P	Cr
5	1	0	6

Learning objectives:

1. To understand the interaction of electromagnetic radiation with molecules.
2. To understand basic principles of spectroscopy.
3. Franck-Condon principles and electronic transitions.
4. Photochemical reactions.

UNIT-1: (15 classes of 60 minutes each)

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation. Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies. Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.

UNIT-2: (10 classes of 60 minutes each)

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin,Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.
Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and pre-dissociation.

UNIT-3: Photophysical and photochemical processes (15 classes of 60 minutes each)

Laws of photochemistry, quantum yield. Jablonski diagrams: Franck-Condon principle, Law of photochemical equivalence, quantum efficiency, low and high quantum efficiency. Kinetics of photochemical reactions (H_2+ Br_2=HBr, 2HI=H_2+I_2), energy transfer in photochemical reactions (photosensitization and quenching), fluorescence, phosphorescence, chemiluminescence, Discussion of Electronic spectra and photochemistry (Lambert-Beer law and its applications).

Recommended books/References:

1. Laideler, K.J. and Meiser, J.M. *Physical Chemistry* Third Edition (International) 1999
2. Levine, I.N., *Physical Chemistry,* Fourth Edition, McGraw-Hill (International),1995.
3. McQuarrie, D.A. and Simon, J.D. *Physical Chemistry-A Molecular Approach,* University Science Books, 1998.
4. Rohatgi-Mukherjee K. K. *Fundamentals of Photochemistry*, New age (revised second edition).
5. Banwell,C.N. & McCash, E.M. *Fundamentals of Molecular Spectroscopy* 4th Ed.Tata McGraw-Hill: NewDelhi (2006).

Course Course-9: CH-241:Inorganic Chemistry-III

L	T	P	Cr
3	1	0	4

Learning objectives:

After completion of the course, the learner shall be able to understand:

1. Coordination compounds– its nomenclature, theories, d-orbital splitting in complexes, chelate.

2. Transition metals, its stability, color, oxidation states and complexes.
3. Lanthanides, Actinides–separation, color, spectra and magnetic behavior
4. Bioinorganic chemistry–metal ions in biological system, its toxicity; hemoglobin.
5. Molecular orbital theory, d-orbital splitting in tetrahedral, octahedral, square planar complexes, chelate effects.
6. Hemoglobin and its importance in biological systems.

Self-study:

1. IUPAC nomenclature of coordination compounds/complexes.
2. Prediction of structure of complexes using various theories; color and magnetic properties of different complexes.
3. Use of lanthanide/actinide compounds in industries.
4. Toxicity of various metals and mechanism of metal-biological system interactions.

UNIT-1: Coordination Chemistry (10 classes of 60 minutes each)

Werner's theory, EAN rule, valence bond theory (inner and outer orbital complexes), Crystal field theory, d-orbital splitting, weak and strong fields, pairing energies, factors affecting the magnitude of (Δ). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry, Jahn-Teller theorem, square planar complexes, d-orbital splitting in trigonal bipyramidal, square pyramidal and cubic ligand field environments, CFSE, Variation of lattice energies, enthalpies of hydration and crystal radii variations in halides of first and second row transition metal series, Qualitative aspect of Ligand field theory, MO diagrams of metal complexes, IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with the coordination number 4 and 6, Chelate effect.

UNIT-2: Transition Elements (10 classes of 60 minutes each)

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, and ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Bsworth diagrams). Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding their metallurgy)

UNIT-3: Lanthanides and Actinides (10 classes of 60 minutes each)

Electronic configuration, oxidation states, color, spectra and magnetic behavior, lanthanide contraction, separation of lanthanides (ion-exchange method only).

UNIT-4: Bioinorganic Chemistry (10 classesof 60 minutes each)

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxy peptidase. Excess and deficiency of some trace metals. Toxicity of metalions (Hg, Pb, Cd and As), toxicity, chelating agents in medicine. Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

Recommended textbooks/References:

1. Purcell, K.F & Kotz, J.C. *Inorganic Chemistry* W.B. Saunders Co, 1977.
2. Huheey, J.E., *Inorganic Chemistry*, Prentice Hall,1993.
3. Lippard, S.J. & Berg, J.M. *Principles of Bioinorganic Chemistry* Panima Publishing Company 1994.
4. Cotton, F.A. & Wilkinson, G, *Advanced Inorganic Chemistry* Wiley-VCH,1999.
5. Greenwood, N.N. & Earnshaw, A. *Chemistry of the Elements*, Butterworth-Heinemann,1997.

CH-241P: InorganicChemistry Laboratory- III

L	T	P	Cr
0	0	2	2

((List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

1. Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given on understanding of the chemistry of different reactions. Following radicals may be analyzed:
Carbonate, nitrate, nitrite, sulphide, sulphate, sulphite, acetate, fluoride, chloride, bromide, iodide, borate, oxalate, phosphate, ammonium, potassium, lead, copper, cadmium, bismuth, tin, iron, aluminum, chromium, zinc, manganese, cobalt, nickel, barium strontium, calcium, magnesium. Mixtures containing one interfering anion, or insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) or combination of anions e.g. CO_3^{2-} and SO_3^{2-}, NO_2^- and NO_3^-, Cl^- and Br^-, Cl^- and I^-, Br^- and I^-, $NO_3^-$and Br^-, $NO_3^-$and I^-. Spot analysis/tests should be done whenever possible.
2. Controlled synthesis of two copper oxalate hydrate complexes: kinetic *vs* thermodynamic factors.
3. Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}. (Also find the λ_{max} of the prepared

complex using instrument).

4. Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g.bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

5. Preparation of any two of the following complexes and measurement of their conductivity measurement:

- Tetraammine carbonato cobalt(III) nitrate
- Tetraammine copper(II) sulphate
- Potassium trioxalato ferrate(III) trihydrate

Recommended books/reference books

1. S. Komiya, *Synthesis of organometallic compounds:A practical guide*, Wiley.
2. A.I.Vogel: *Qualitative Inorganic Analysis*, Prentice Hall,7th Edn.
3. Vogel's *Qualitative Inorganic Analysis,* Revised by G.Svehla, Pearson Education, 2002.

Core Course-10 :CH-242: Organic Chemistry-II

L	T	P	Cr
3	1	0	4

Learning objectives:

After completion of the course, the learner shall be able to understand:

1. Familiarization about classes of organic compounds and their methods of preparation.
2. Basic uses of reaction mechanisms.
3. Name reactions, uses of various reagents and the mechanism of their action.
4. Preparation and uses of various classes of organic compounds.
5. Organometallic compounds and their uses.
6. Organic chemistry reactions and reaction mechanisms.
7. Use of reagents in various organic transformation reactions.

Self-study:

1. Elucidating reaction mechanisms for organic reactions.

2. Organometallic compounds and their uses.
3. Use of active methylene groups in organic mechanism and preparation of new organic compounds.

UNIT-1: Chemistry of Halogenated Hydrocarbons (8 classes of 60 minutes each)

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_N^i mechanisms with stereochemical aspects and effect of solvent, etc.; nucleophilic substitution vs. elimination.
Aryl halides: Preparation, including preparation from diazonium salts. nucleophilic aromatic substitution; SNAr, Benzyne mechanism.
Relative reactivity of alkyl, allyl / benzyl, vinyl and aryl halides towards nucleophilic substitution reactions. Organometallic compounds of Mg and Li and their use in synthesis.

UNIT-2: Alcohols, Phenols, Ethers and Epoxides (6 classes of 60 minutes each)

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement.
Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism.
Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$

UNIT-3: Carbonyl Compounds (10 classes of 60 minutes each)

Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α-substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, PDC and PGC); Addition reactions of unsaturated carbonyl compounds: Michael addition; Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethylmalonate and ethylacetoacetate.

UNIT-4: Carboxylic Acids and their Derivatives (10 classes of 60 minutes each)

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxyl acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids; Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group-Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and

Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.

UNIT-5: Sulphur containing compounds (6 classes of 60 minutes each)

Preparation and reactions of thiols, thioethers and sulphonic acids.

Recommended Books/references:

1. Solomons,T.WG., Fryhle, B.Craig, *Organic Chemistry,* John Wiley & Sons, Inc (2009).
2. McMurry, J.E. *Fundamentals of Organic Chemistry*, Seventh edition Cengage Learning, 2013.
3. P. Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition (1997), Orient Longman, New Delhi.
4. Morrison R.T. and Boyd R.N.*Organic Chemistry*, Sixth Edition, Prentice Hall, India, 2003.

CH-242P: Organic Chemistry Laboratory-II

L	T	P	Cr
0	0	2	2

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).
(One experiment from each group to be demonstrated)

1. Identification of elements (N, S, and halogen) and Functional group tests for alcohols, phenols, carbonyl, carboxylic acid and amine group of compounds.
2. Organic preparations:

i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*-toluidines and *o*-, *m*-, *p*-anisidine)andphenols(β-naphthol, vanillin, salicylic acid) by any one method: (Using conventional method and Using green chemistry approach)
ii. Benzolyation of one of the amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and one of the phenols (*β*-naphthol, resorcinol, *p*-cresol) by Schotten-Baumann reaction.
iii. Oxidation of ethanol/isopropanol (Iodoform reaction).

iv. Bromination (anyone)

(a) Acetanilide by conventional methods

(b) Acetanilide using green approach (Bromate-bromide method)

v. Nitration: (anyone)

(a) Acetanilide / nitrobenzene by conventional method

(b) Salicylic acid by green approach (using ceric ammonium nitrate).

vi. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.

vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.

viii. Hydrolysis of amides and esters.

ix. Semicarbazone of any one of the following compounds: acetone, ethylmethyl ketone, cyclohexanone, benzaldehyde.

x. *S*-Benzyl isothiouronium salt of one each of water soluble/insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).

xi. Aldol condensation with either conventional or green method.

xii. Benzil-Benzilic acid rearrangement.

Recommended Books/References:

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

SEMESTER-V

Core Course-11: CH-350: Introduction to Quantum Chemistry

L	T	P	Cr
5	1	0	6

Learning objectives:

1. To provide the concept of important physical and experimental facts which dismiss Newton's classical mechanics that fail to explain a number of microphysical phenomena, consequently lead to the birth of quantum mechanics.

2. To help the student solve the eigen-value equation, particle in a one-dimensional box, Schrodinger equation.

3. To teach the significance of simple harmonic oscillator and rigid rotor

4. To provide the concepts of valence bond and molecular orbital theory

Self-Study:

1. Solve mathematical problems related to simple harmonic oscillator and rigid rotor
2. Transformation between cartesian and spherical coordinates

UNIT-1: Origin of Quantum Theory (15 classes of 60 minutes each)

Introduction to black-body radiation and distribution of energy, photo-electic effect, concept of quantization, wave particle duality (de-Broglie's hypothesis), The uncertainty principle, The wave function: wave function and its interpretation, conditions of normalization and Orthogonality and its significance. Basic idea about operators, eigen function and values, Schrodinger equation and application to free-particle and particle in a box, boundary conditions, wave functions and energies, degeneracy, hydrogenatom, Schrodinger equation in polar coordinates, radial and angular parts of the hydrogenic orbitals, degeneracies, spherical harmonics, representations of hydrogenic orbitals.

UNIT-2: Harmonic Oscillator and Rigid Rotor (15 classes of 60minutes each)

Quantitative treatment of simple harmonic osciallator model, setting up of Schodinger equation and discussion of solution of wave functions. Rigid rotator model and discussion of application of Schrodinger equation. Idea about transformation to spherical polar coordinate, discussion on solution.

UNIT-3: Hydrogenoids and Chemical Bonds in Diatomic Molecules (10 classes of 60 minutes each)

Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus. Valence bond and molecular orbital approaches, LCAO-MO treatment of H_2, H_2^+; bonding and anti-bonding orbitals, Comparison of LCAO-MO and VB treatments of H_2 (only wavefunctions, detailed solution not required) and their limitations.

Recommended books/References:

1. Laideler K.J.and Meiser J.M. *Physical Chemistry* Third Edition (International) 1999

2. Levine I. N., *Physical Chemistry,* Fourth Edition, McGraw-Hill (International), 1995.
3. McQuarrie D.A. and Simon J.D. *Physical Chemistry - A Molecular Approach,* University Science Books,1998.
4. Chandra, A.K. *Introductory Quantum Chemistry* Tata McGraw-Hill (2001).
5. House, J.E. *Fundamentals of Quantum Chemistry* 2nd Ed. Elsevier:USA (2004).

CoreCourse-12 : CH-352:Organic Chemistry-III

L	T	P	Cr
3	1	0	4

Learning objectives:

After completion of the course, the learner shall be able to understand:

1. Nitrogen containing functional groups and their reactions.
2. Familiarization with polynuclear hydrocarbons and thei rreactions.
3. Heterocyclic compounds and their reactions.
4. Alkaloids and Terpenes
5. Understanding reactions and reaction mechanism of nitrogen containing functional groups.
6. Understanding there actions and mechanisms of diazonium compounds.
7. Understanding the structure and their mechanism of reactions of selected polynuclear hydrocarbons.
8. Understanding the structure, mechanism of reactions of selected heterocyclic compounds.
9. Classification, structure, mechanism of reactions of few selected alkaloids and terpenes.

Self-study:

1. Use of benzene diazonium salt in organic synthesis.

2. Applications of heterocyclic compounds in pharmaceutics/drugs and the mechanism of actions.
3. Pharmaceutics / Biomedical applications of alkaloids and terpenes.
4. Nitrogen containing organic compounds / heterocyclic compounds in synthetic chemistry.

UNIT-1: Nitrogen Containing Functional Groups (8 classes of 60 minutes each).

Preparation and important reactions of nitro compounds, nitriles and isonitriles and amines; Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3° amines with Hinsberg reagent and nitrous acid. Diazonium salts: Preparation and synthetic applications.

UNIT-2: Polynuclear Hydrocarbons (8 classes of 60 minutes each)

Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons.

UNIT-3: Heterocyclic Compounds (12 classes of 60 minutes each)

Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom; Synthesis, reactions and mechanism of substitution reactions of Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine, Structure elucidation of indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander's synthesis, Knorrquinoline synthesis, Doebner-Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction, Derivatives of furan: Furfural and furoic acid.

UNIT-4: Alkaloids (6 classes of 60 minutes each)

Natural occurrence, General structural features, Isolation and their physiological action Hoffmann's exhaustive methylation, Emde's modification, Structure elucidation and synthesis of Hygrine and Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine.

UNIT-5: Terpenes (6 classes of 60 minutes each)

Occurrence, classification, isoprene rule; Elucidation of stucture and synthesis of Citral, Neral and α-terpineol.

Recommended Text Books/references:

1. Morrison,R.T., Boyd,R.N., Bhatterjee,S.K., *Organic Chemistry*, 7thEdn., Pearson.
2. Acheson,R.M. *Introduction to the Chemistry of Heterocyclic compounds,* John Welly & Sons (1976).
3. Solomons,T.W., Fryhle Craig, *Organic Chemistry,* John Wiley & Sons, Inc (2009).
4. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
5. Kalsi, P.S. *Organic reacations and their mechanisms*, New Age Science (2010).
6. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry,* Oxford University Press Inc., NewYork (2001).
7. Singh,J., Ali, S.M. & Singh,J. *Natural Product Chemistry*, Prajati Parakashan (2010).
8. Bansal R. K. *Heterocyclic Chemistry: Syntheses, Reactions and Mechanisms*, New Age, Third Edition (1999).
9. Clayden J., Greeves N., Warren S., *Organic Chemistry*, 2nd Ed., (2012), Oxford University Press.

CH-352P: Organic Chemistry Laboratory-III

L	T	P	Cr
0	0	2	2

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

1. Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, e.g. salicylic acid, cinnamic acid, nitrophenols, etc.

2. Identification of functional groups of simple organic compounds by IR spectroscopy and NMR spectroscopy (IR and NMR of simple organic compounds may be done wherever facilities are available, otherwise sample spectra may be provided for simple organic compounds like Ethanol, Aniline, Phenol, aceticacid, other simple aldehydes, carboxylic acid,etc., for identification of functional groups. References from standard spectroscopy books may also be taken for such purpose for enhancing students understanding and skill).

3. Preparation of methyl orange.

4. Extraction of caffeine fromtea leaves.

5. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars using simple laboratory procedures.

Recommended Books/References:

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

SEMESTER- VI

Core Course-13: CH-360: Materials Chemistry

L	T	P	Cr
5	1	0	6

Learning objectives:

After completion of the course, the learner shall be able to understand:

1. Crystalline solids–parameters, symmetry.
2. Silica based materials in applications.
3. Technological importance of ionic liquids, preparation of materials–using sol-gel technique.
4. Nano-structured materials, self-assembled structure.
5. Composites and its applications.
6. Understanding basic parameters of crystalline solids, symmetry and crystal structures.
7. Mesoporous/microporous silica based materials, functionalized hybrid materials and its applications.
8. Preparation of inorganic solids, host-guest chemistry, ionic liquids and its significance.
9. Understanding self-assembled structures, nano-structured materials, carbon nanotubes,

applications.

10. Understanding composites and their industrial applications.

Self-study:

1. Hybrid materials/functionalized hybrid materials and their applications in industry.
2. Applications of nano-structured materials in targeted drug delivery/pharmaceutical applications/industrial applications.
3. Use of composites in industry.

UNIT-1: Basics of crystalline solids (8 classes of 60 minutes each)

Crystalline solids, crystal systems, Bravais lattices, coordination number, packing factors – cubic, hexagonal, diamond structures, lattice planes, Miller indices, interplanar distances, directions, types of bonding, lattice energy, Madelung constants, Born Haber cycle, cohesive energy, Symmetry elements, operations , translational symmetries - point groups, space groups, equivalent positions, close packed structures, voids, crystal structures, Pauling rules, defects in crystals, polymorphism, twinning.

UNIT-2: Silica based materials (8 classes of 60 minutes each)

Introduction to Zeolites, metallosilicates, silicalites and related microporous materials, Mesoporous silica, metaloxides and related functionalized mesoporous materials: Covalent organic frameworks, Organic-Inorganic hybrid materials, periodic mesoporous organo silica, metalorganic frameworks: H_2/CO_2 gas storage and catalytic applications

UNIT-3: Inorganic solids/ionic liquids of technological importance (8 classes of 60 minutes each)

Preparation of inorganic solids: Conventional heat and beat methods, Co-precipitation method, Sol-gelmethods, Hydro-thermal method, Ion-exchange and Intercalation methods. Introduction to Solid electrolytes, inorganic liquid crystals. Ionic liquids, forces responsible for ionic liquids, synthesis and application of imidazolium and phosphonium based ionic liquids. Host-guest chemistry (elementary ideas).

UNIT-4: Nanomaterials (8 classes of 60 minutes each)

Overview of nanostructures and nano-materials: classification. Preparation of gold and silver metallic nanoparticles, self-assembled nanostructures - control of nano-architecture-one dimensional control. Carbon nanotubes and inorganic nanowires.

UNIT-5: Composite materials (8 classes of 60 minutes each)

Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix

composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

Recommend books/References:

1. Atkins P, Overton T., Rourke J. Weller M. and Armstrong F., *Shriver and Atkins' Inorganic Chemistry* Oxford University Press, Fifth Edition, 2012.
2. Adam,D.M. *Inorganic Solids: An introduction to concepts in solid-state structural chemistry*. John Wiley,1974.
3. Poole, C.P. & Owens,F.J. *Introduction to Nanotechnology.* John Wiley 2003.
4. Rodger,G.E. *Inorganic and Solid State Chemistry*, Cengage Learning, 2002.

Core Course 14: CH-363: Physical Chemistry – III

L	T	P	Cr
3	1	0	4

Learning Objectives:

1. Phases, components, Gibbs phase rule, Phase diagrams and applications.
2. Chemical kinetics: type of reactions, determination of rate, theories of reaction rate, steady state approximation.
3. Catalyst – mechanism, acid base catalysis, enzyme catalysis.
4. Adsorption isotherms.
5. Understanding phases, components, Gibb's phase rule and its applications, construction of phase diagram of different systems, the application of phase diagram.
6. Understanding the basics of chemical kinetics: determination of order, molecularity, and understanding theories of reaction rates, determination of rate of opposing/parallel/chain reactions with suitable examples, application of steady state kinetics, Steady-state approximation.
7. Catalyst – mechanism of catalytic action, enzyme catalysis.
8. Langmuir, Freundlich – adsorption isotherms, significance, multilayer adsorption – theory and significance.

Self-study:

1. Application of phase diagram.
2. Study of reaction kinetics, Fast reactions.
3. Heterogeneous catalysis used in industry and its mechanism of action.
4. Application of adsorption isotherms in metal adsorption, significance.

UNIT-1: Phase Equilibria (14 classes of 60 minutes each)

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications. Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions. Three component systems, water- chloroform-acetic acid system, triangular plots.
Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and nonideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation. Nernst distribution law: its derivation and applications.

UNIT-2: Chemical Kinetics (14 classes of 60 minutes each)

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated rate laws for first, second and fractional order reactions, pseudo-unimolecular reactions, determination of the order, kinetics of complex reactions (limited to first order): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions. Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates.

UNIT-3: Catalysis (6 classes of 60 minutes each)

Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; effect of particle size and efficiency of nanoparticles as catalysts. Enzyme catalysis, Michaelis-Menten mechanism, acid-base catalysis.

UNIT-4: Surface Chemistry (6 classes of 60 minutes each)

Physical adsorption, chemisorption, adsorption isotherms (Freundlich, Temkin, Derivation of Langmuir adsorption isotherms, surface area determination), BET theory of multilayer adsorption (no derivation), Adsorption in solution.

Recommended Books:

1. Atkins P. W. and De Paula J., *Physical Chemistry*, 10th Ed. Oxford University Press (2014).
2. Castellan, G. W. *Physical Chemistry*, 4th Ed., Narosa (2004).
3. McQuarrie, D. A. & Simon, J. D., *Molecular Thermodynamics*, Viva Books (2004).
4. Engel, T. & Reid, P. *Physical Chemistry* 3rd Ed., Prentice-Hall (2012).
5. Zundhal, S.S. *Chemistry Concepts and Applications* Cengage India (2011).
6. Ball, D. W. *Physical Chemistry* Cengage India (2012).
7. Mortimer, R. G. *Physical Chemistry* 3rd Ed., Elsevier (2009).
8. Levine, I. N. *Physical Chemistry* 6th Ed., Tata McGraw-Hill (2011).
9. Metz, C. R. *Physical Chemistry* 2nd Ed., Tata McGraw-Hill (2009).

CH-363P: Physical Chemistry Laboratory – III

L	T	P	Cr
0	0	2	2

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities)

Conductometry

1. Determination of cell constant
2. Equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
3. Conductometric titrations of: (i) strong acid *versus* strong base, (ii) weak acid *versus* strong base, (iii) mixture of strong acids, (iv) weak acid *versus* strong base, (v) strong acid *versus* weak base.

Potentiometry

Potentiometric titrations of: (i) Strong acid *versus* strong base (ii) Weak acid *versus* strong base (iii) Dibasic acid *versus* strong base (iv) Potassium dichromate *versus* Mohr's salt.

Recommended Books:

1. Khosla, B. D.; Garg, V. C. and Gulati, A. *Senior Practical Physical Chemistry*, R. Chand New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry* Eighth Edition; McGraw-Hill: New York (2003).
3. Halpern, A. M. and McBane, G. C. *Experimental Physical Chemistry* 3rd Ed.; W.H. Freeman & Co.: New York (2003).

SEMESTER VII

Core Course-15: CH-471: Advanced Chemistry-I

L	T	P	Cr
3	1	0	4

Course Outcome:

On completion of this course, the students will be able to

1. Develop their understanding on the application of computer in chemistry
2. Understand different theories developed to explain the coordination complexes and the magnetic behaviour of these compounds
3. Important organic reactions
4. Quantum chemistry and intrinsic chemical reactions

UNIT-1: Introduction to Computational Chemistry (10 classes of 60 minutes each)

Different generations, types and parts of computers. Number systems and interconversion between different number systems. Binary arithmetic. Logic gates and Truth table. Assembler and Compiler. Algorithm, Flow Charts. Introduction to Fortran language. Representation of various data types - Characters, Constants and Variables in Fortran. Arithmetic expressions. Input-Output statements. Control statements: GO TO, IF, END IF, DO, CONTINUE, END, and STOP statements. FORMAT Statement. Relational Operators. Development of FORTRAN programme with examples related to Chemistry.

UNIT-2: Coordination and magnetochemistry (10 classes of 60 minutes each)

Crystal field theory (CFT) and its limitations, Jahn-Teller effect in d^n ions in ground state, experimental evidences of metal ligand overlap: IR, NMR, EPR, intensities of d-d transition, Nephelauxetic effect, theoretical failure of ionic model, Adjusted crystal field theory, Molecular orbital theory of octahedral and tetrahedral complexes (qualitative principles involved in complexes with and without π-bonding).
Brief review of different types of magnetic behaviour, quenching of orbital angular momenta, temperature-independent paramagnetism, Term symbols for metal ions, application of CFT to explain

magnetic properties of coordination compounds.

UNIT-3: General Organic reaction mechanism (10 classes of 60 minutes each)

Aliphatic substitution reaction, SN1, SN2, and SNi reaction, Electrophilic substitution reaction, SE1, SE2, SEi mechanism, Aromatic substitution reaction, SNAr, SRN1 mechanism, Reactivity, effect of substrate, leaving group and attacking nucleophile. Nucleophilic substitution reactions, nucleophilic substitution at saturated carbon compounds.
Elimination reactions, E1 E2 and E1cB, Mechanism and stereochemistry of different types of elimination reactions, formation of other double bonds (C=N, C=O) and triple bonds; Addition to carbon-carbon multiple bonds, mechanistic and stereochemical aspects of addition reactions involving electrophiles, nucleophiles and free radicals, hydroboration, alkylation, epoxidation and hydroxylation.

UNIT-4: Quantum Chemistry (10 classes of 60 minutes each)

Postulates of quantum mechanics. Schrödinger equation and Eigen value equation. Hermitian operators.Average or expectation values. Schrödinger equation for a free particle in a one-dimensional box, emergence of quantum numbers and origin of quantization. Application of the one-dimensional problem to π-conjugated systems. Treatment of a free particle in a ring and in three-dimensional box, emergence of degeneracy in 3D cases. Potential energy barrier, tunnelling through a barrier and elementary idea on scanning tunnelling microscope and tunnelling in chemical reactions.
Reference books suggested:

1. E. Lewars; *Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics*, Springer.
2. J. B. Foresman, Æ. Frisch; *Exploring Chemistry with Electronic Structure Methods*, Gaussian, Inc. Pittsburg, PA.
3. C. J. Cramer; *Essentials of Computational Chemistry: Theories and Models*, Wiley.
4. F. A. Cotton, G. Wilkinson, A. Murillo, M. Bochmann; *Advanced Inorganic Chemistry*, Wiley International, 6th Ed.
5. J.E. Huheey, E. A. Keiter, R. L. Keiter; *Inorganic Chemistry- principles of structure and reactivity*, Harper Collins College Publishers, 1993.
6. R. L. Dutta, A. Shyamal; *Elements of Magnetochemistry*, S. Chand Co., New Delhi.
7. J. March; *Advanced Organic Chemistry,* John Wiley & Sons, 1992.
8. E. J. Eliel; *Stereochemistry of Carbon Compounds*, McGraw Hill.
9. F. A. Carey, R. L. J. Sundberg; *Advanced Organic Chemistry, Part A and B*, Plenum Press, New York.
10. S. H. Pine; *Organic Chemistry* McGraw Hill, 1987.
11. D. Nasipuri; *Stereochemistry of Organic Compounds*, Wiley, 1994.
12. P.S. Kalsi; *Organic Reaction and their Mechanism*, New Age, 1996.
13. I. N. Levine; *Quantum Chemistry*, Tata Mc Graw Hill.
14. A. K. Chandra; *Introductory Quantum Chemistry*, Tata Mc Graw Hill.

CH-471P: Advanced Chemistry Laboratory- I

L	T	P	Cr
0	0	2	2

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities)

(A) Synthesis and characterisation of inorganic compounds:

(i) $Cu(acac)_2$

(ii) Tetrammine copper sulphate

(iii) Prussian blue

(iv) $[Ni(Py)_4(SCN)_2]$

(v) Nickel(II) dimethylglyoxime complex.

(B) (i) Construction of a ternary phase diagram for a three-component system – water, acetic acid, and benzene/toluene/chlorobenzene/CCl_4/cyclohexane/ethylenediamine; and study the effect of at least two different concentrations of NaCl/KCl for the same composition.

(ii) Determination of the order of reaction for saponification of ethyl acetate by NaOH and hence its rate constant. Also study the effect of presence of NaCl/KCl at atleast two different concentrations.

(iii) Determination of the equivalent conductivity of a strong electrolyte (NaCl or KCl) in different composition of water-ethanol/dioxane mixture and hence verification of the applicability of Debye-Hückel-Onsager equation.

Books Suggested:

1. A. I. Vogel; *Quantitative Inorganic Analysis*, Longman Sc. & Tech.
2. G. Marr, B. W. Rockett; *Practical Inorganic Chemistry*, Van Nostrand.
3. W.L. Jolly; *Synthesis and characterisation of inorganic compounds*, McGraw Hill.
(Other books/reading materials may also be suggested).

Core Course-16: CH-472: Advanced Chemistry- II

L	T	P	Cr
3	1	0	4

Course Outcome:

On completion of this course, the students will be able to

1. understand that changes in matters upon interaction with electromagnetic radiation
2. understand various reaction mechanisms of inorganic compounds
3. learn about photochemistry and pericyclic reactions of important organic compounds
4. learn about the statistical thermodynamics

UNIT-1: Interaction of Electromagnetic Radiation with Matter (10 classes of 60 minutes each)

Time dependent Schrödinger equation, interaction of electromagnetic radiation with matter, solution of the total wave function, rate of change of a system from one stationary state to another stationary state, transition moment integral, Einstein's coefficients, correlation of Einstein's coefficient with experimental data, oscillator strength and its physical significances.

UNIT-2: Inorganic Reaction Mechanisms (10 classes of 60 minutes each)

Mechanism of ligand substitution reactions. Factors affecting the reactivity of the complexes. Effect of electronic structure of the metal atom on the reactivity of complexes (based on VBT and CFT). Kinetic application of CFT on the rate of reactions (with reference to acid hydrolysis of octahedral Co(III) complexes). Mechanism and evidences for base hydrolysis of Co(III) complexes. Substitution reactions of Inorganic complexes (with reference to octahedral Co(III) and square planar Pt(II) complexes). Electron transfer reactions: Types and factors affecting electron transfer reactions.

UNIT-3. Photochemistry and Pericyclic Reactions (10 classes of 60 minutes each)

General principles, orbital symmetry consideration related to photochemical reaction, photochemistry of carbonyl groups, Norish Type I and Type II cleavage, photochemistry of alkenes and dienes, aromatic compounds and cycloaddition, Paterno-Buchi reaction. Molecular orbital symmetry, Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene. Woodward-Hoffmann correlation diagrams. Frontier molecular orbital and Perturbational molecular orbital approach. Electrocyclic reactions: conrotatory and disrotatory motions. Cycloadditions: antarafacial and suprafacial additions. 4n and 4n+2 systems, 2+2 addition of ketenes. Sigmatropic rearrangements: suprafacial and antarafacial shifts of H, 3,3- and 5,5- sigmatropic rearrangements. Claisen, Cope and aza-Cope rearrangements.

UNIT-4: Statistical Thermodynamics (10 classes of 60 minutes each)

Partition functions and their physical significance. Translational partition function using particle in a box model for ideal gases. Rotational partition function using rigid-rotor model for ideal diatomic

molecules. Vibrational partition function for ideal diatomic gases using simple harmonic oscillator model. Electronic partition function for diatomic molecules. Nuclear partition function. Factorization of partition functions. Law of equipartition of energy, heat energy. Thermodynamic functions in terms of partition function.

Books Suggested:

1. R. S. Drago; *Physical Methods in Chemistry,* Saunders College Publishers.
2. R. Chang; *Basic Principles of Spectroscopy,* McGraw Hill.
3. G. M. Barrow; *Molecular Spectroscopy,* McGraw Hill.
4. C. N. Banwell, E. M. McKash; *Fundamentals of Molecular Spectroscopy,* Tata McGraw Hill.
5. F. A. Cotton, G. Wilkinson, A. Murillo, M. Bochmann; *Advanced Inorganic Chemistry,* Wiley International, 6th Ed.
6. F. Basolo, R. G. Pearson; *Mechanisms of Inorganic Reactions,* Wiley-Eastern Ltd.
7. R. B. Woodward, R. Hoffman; *Conversion of Orbital Symmetry*, Verlag-Chemie Academic Press, 1970.
8. L. Flemming; *Frontier Orbital Theory and Organic Chemical Reactions*, John-Wiley and Sons.
9. S. Glasstone; *Theoretical Chemistry,* Affiliated East-West Press.
10. L. K. Nast; *Elements of Classic: A Land Statistical Thermodynamics,* Addison-Wesley.
11. T. L. Hill; *Statistical Thermodynamics,* Addison-Wesley Publication Co.
12. M. C. Gupta; *Statistical Thermodynamics,* Wiley Easter.

(Other books/reading materials may also be suggested).

CH-472P: Advanced Chemistry Laboratory- II

L	T	P	Cr
0	0	2	2

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities)

(A) Organic Chemistry

1. a) Purification of binary mixtures by Thin Layer Chromatography
   b) Separation of tertiary mixtures of amino acids by paper chromatography

2. Preparation of organic compounds involving not more than two stages. (Representative reactions to be covered: Esterification and saponification, Oxidation, Reduction, Nucleophilic substitution, Condensation reactions, Preparation of dyes, Aromatic electrophilic substitution.

(B) Physical Chemistry

1. Determination of critical micelle concentration (CMC) and counter ion bindings of an anionic surfactant in presence of an ionic salt such as NaCl or KCl.

2. Determination of acid-base dissociation constant of a given weak acid in water and in presence of an organic solvent.

3. To find out the strength of HCl and acetic acid in a mixture of both by a titrating solution.

4. To study the formation of complex found between Fe^{2+} ion and *o*-phenanthrolene by Job's method using a UV-Visible spectrophotometer.

SEMESTER VIII

Core Course-17: CH-481: Research Methodology

L	T	P	Cr
5	1	0	6

Learning outcomes:

At the end of the course the students will be able to:

1. Understand the concept of research and different types of research in the context of biology
2. Develop laboratory experiment related skills.
3. Develop competence on data collection and process of scientific documentation
4. Analyze the ethical aspects of research
5. Evaluate the different methods of scientific writing and reporting

UNIT-1: Basic Concepts of Research (12 lectures of 60 minutes each)

Research-definition and types of research (Descriptive *vs* analytical; applied *vs* fundamental; quantitative *vs* qualitative; conceptual *vs* empirical). Research methods *vs* methodology. Literature-review and its consolidation; Library research; field research; laboratory research.

UNIT-2: Data Collection and Documentation of Observations (12 lectures of 60 minutes each)

Maintaining a laboratory record; Tabulation and generation of graphs. Imaging of tissue specimens and application of scale bars. The art of field photography.

UNIT-3: Overview of Application to Chemistry related problems (8 lectures of 60 minutes each)

Key chemistry research areas, chemoinfomatics.

Unit 4: Ethics and Good Practical's and Art of Scientific Writing (8 lectures of 60 minutes each)

Authors, acknowledgements, reproducibility, plagiarism, Numbers, units, abbreviations and nomenclature used in scientific writing. Writing references. Power-point presentation. Poster presentation. Scientific writing and ethics, Introduction to copyright-academic misconduct/plagiarism.

Core Course-18: CH-482: Project/Dissertation

L	T	P	Cr
0	0	6	6

Suggested Topics for Individual/ Team Projects (as given in the UGC Syllabus)

1. Synthesis of Aspirin.
2. Finding EMF of electrochemical cells.
3. Preparation of biodiesel.
4. Study of chemistry of photography.
5. Water analysis of nearby areas; finding out the toxic/heavy metals, anions and purification of water using simple available lab technology.
6. Study of air-pollution parameters of a given locality.
7. Forensic analysis of given species

DISCIPLINE SPECIFIC ELECTIVE COURSES

These courses with 6 credits each have the following credit pattern.

For Theory and practical based papers:

L	T	P	Cr
3	1	2	6

For Theory papers without Practical:

L	T	P	Cr
5	1	0	6

SEMESTER - V

CH-DSE -351: Medicinal Chemistry

(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

At the end of the course the students will be able to:

1. The basics of medicinal chemistry, biophysical properties
2. Biological activity parameters
3. Drug metabolism
4. Biophysical and chemical properties of enzymes, hormones, vitamins
5. Concept of rational drug design

UNIT-1:Bio-physicochemical properties

Acidity/Basicity, Solubility, Ionization, Hydrophobic properties, Hydrophilic properties, Lipinski Rule, Drug-like properties, Understanding of the biological activity parameters such as K_i, K_d, LD_{50}, EC_{50}, IC_{50}, CC_{50}, ADMET properties

UNIT-2: Structural properties

Isosterism, Bioisosterism, Nonclassical isosteres, Understanding of the 3D-structure along with bond length, bond angle and dihydral angle, Concept of Configuration and Conformation with examples, Concept of stereochemistry in terms of biological response with examples, Stereoselective receptors or enzymes such as muscarinic receptor, Stereochemically pure drug and recemates, Examples such as catecholamines, etc.

UNIT-3: Drug target understanding

Metabolism, Drug metabolism, Anti-metabolite, Enzyme inhibitor, Agonist, Antagonist, Examples.

UNIT-4: Medicinal Chemistry of Therapeutic Agent

Structure, Chemistry, Mode of action and adverse effect of the representative therapeutic agents such as Anti-infective agent, Antimalarials, Antibacterial, Antiviral, Anticancer, CNS acting drugs, Adrenergic Agents, Cholinergic Drugs, Diuretics, Cardivascular, local anesthetic agent, Analgesic Agents, Histamine and Antihistamine agents.

UNIT-5: Steroids, Prostaglandins, Enzyme, Hormone and Vitamins

Biophysico-chemical properties, Steroid Hormone Receptors, Chemical Contraceptive agents,

COX-2 inhibitors, Prostaglandins for Ophthalmicuse, pharmaceutically important enzyme products such as Pancreatin, Trypsin, Insulin. Classification of vitamins with examples.

UNIT-6: Concept of rational drug design

Structure-activity relationship, Drug-receptor understanding, Molecular modeling, Structure based drug design. QSAR.

Recommended books/References:

1. Charles Owens Wilson, John H. Block, OleGisvold, John Marlowe Beale, *Wilson and Gisvold's Textbook of Organic Medicinal and Pharmaceutical.*
2. David A.Williams, Thomas L.Lemke, William O. Foye *Foye's Principles of Medicinal Chemistry* (2008), Kluwer publication.
3. Joseph Price Remington, Alfonso R. Gennaro, *Remington: The Science and Practice of Pharmacy,* Vol.1 (1995), MACK Publishing.
4. Abraham D. J., Lewis F. L., BurgerA. *Burgers Medicinal Chemistry and Drug Discovery* Vol.5, 6th Edn., 2003, Hoboken N.J.Wiley,
5. Silverman R.B. *The Organic Chemistry of Drug Design and Drug Action,* 2nd Edn., Academic Press. 2012.
6. Hansch C. and Leo, A. *Exploring QSAR: Fundamental and applications in Chemistry and Biology,* American Chemical Society (1995)
7. Patrick,G. *Medicinal Chemistry*, Oxford University Press (2000)

Practicals suggested:

1. Purification Techniques of Solvents by Fractional Distillation and Vacuum Distillation

2. Thin Layer Chromatography Technique and Purification of commercially available drugs/ Synthesized Compounds by Column Chromatography.

3. Preparation of Acid/Basic Salts of Drugs and Evaluation of their Physicochemical Properties. (Benzilic Acid & Sodium Benzoate)

4. Synthesis & Purification of following Compounds using:

(i) Precipitation or recrystallization.

(ii) Synthesis of Benzimidazole.

(iii) Synthesis of Anthranilic Acid.

(iii) Synthesisof Sulphanilamide.

(iv) Synthesis of benzoic acid from benzyl alcohol.

(v) Synthesis of 1,4 – dihydropyridine.

5. Computational modeling of drug design /use of softwares may be demonstrated to students.

Suggsted books/references:

1. J. Mendham, R.C. Denney, J.D. Barnes, M.J.K Thomas,*Vogel's Textbook of Quantitative Chemical Analysis*, 6th Edition, Pearson's Education Ltd.
2. Ashutosh Kar, *Advanced Practical Medicinal Chemistry*, New Age International Ltd. (2004).
3. B.S. Furniss, A.J. Hannaford, P.W.G. Smith, A.R. Tatchell, *Vogel's Textbook of Practical Organic Chemistry*, 5th edition (2008), Pearson's Education Ltd

(The list of experiments and books are purely suggestive; University/institute may incorporate further changes in number of experiments and books/refererences (updated version from time to time) based on course design and available infrastructure facilities).

CH-DSE-352: Electrochemistry

(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

At the end of the course the students will be able to understand:

1. Basic principle of laws of electrochemistry
2. About chemical cells and their functions
3. About electrodes, EMF measurement.
4. About potentiometric titrations and their applications.

UNIT-1:

Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-Hückel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules. Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

UNIT-2:

Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions basedon half-cell potentials, applications of electrolysis in metallurgy and industry. Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb2O3 electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and Transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

UNIT-3: Electroanalytical methods:

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points.

Techniques used for the determination of pKa values.

UNIT-4: Electrical and Magnetic Properties of Atoms and Molecules:

Basic ideas of electrostatics, Electrostatics of dielectric media, Clausius-Mosotti equation, Lorenz-Laurentz equation, Dipole moment and molecular polarizabilities and their measurements. Diamagnetism, paramagnetism, magnetic susceptibility and its measurement, molecular interpretation.

Recommended /reference books

1. Atkins,P.W. & Paula,J.D. *Physical Chemistry*, 10th Ed., Oxford University Press (2014).
2. Castellan,G. W. *Physical Chemistry,* 4th Ed., Narosa (2004).
3. Mortimer, R. G. *Physical Chemistry* 3rd Ed., Elsevier: NOIDA, UP (2009).
4. Barrow, G. M., *Physical Chemistry* 5th Ed., Tata McGraw Hill: New Delhi (2006).
5. Engel,T.& Reid,P. *Physical Chemistry,* 3rd Ed., Prentice-Hall (2012).
6. Rogers,D.W. *Concise Physical Chemistry,* Wiley (2010).
7. Silbey, R.J.; Alberty, R.A. & Bawendi, M.G. *Physical Chemistry,* 4th Ed., John Wiley & Sons,Inc. (2005).

Suggested laboratory experiments
(University/institute may incorporate further changes in number of experiments and books/refererences)

1. Determination of pH of a given solution using glass electrode.
2. Determination of cell constant.
3. Determination of equivalent conductance, degree of dissociation, and dissociation constant of weak acid.
4. Conductometric titration: strong acid *vs*. strong base, weak acid *vs*. strong base.
5. Potentiometric titration: strong acid *vs*.strong base, weak acid *vs* strong base, potassium dichromate *vs* mohr's salt.

Recommended books/reference books:

1. Khosla,B.D.; Garg,V.C. & Gulati,A.Senior *Practical Physical Chemistry*, R. Chand &Co., New Delhi (2011).
2. Ahluwalia,V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry*, Universities Press.
3. Garland, C.W.; Nibler, J.W. & Shoemaker,D.P. *Experiments in Physical Chemistry* 8th Ed.;

McGraw-Hill: NewYork (2003).

CH-DSE-353: Organic Spectroscopy and Applications

(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

At the end of the course the students will be able to understand:

1. Basic principles of spectroscopy.
2. About their applications

UNIT-1: Basic Principles of UV-Spectroscopy

Application of Woodward-Fiser rule in interpretation of Organic compounds: Application of visible, ultraviolet and infrared spectroscopy in organic molecules. Electromagnetic radiation, electronic transitions, λ_{max} & ε_{max}, chromophore, auxochrome, bathochromic and hypsochromic shifts. Application of electronic spectroscopy and Woodward rules for calculating λ_{max} of conjugated dienes and α,β – unsaturated compounds.

UNIT-2: Basic principles of IR Spectroscopy

Identification of Functional groups of various classes of organic compounds: Infrared radiation and types of molecular vibrations, functional group and fingerprint region. IR spectra of alkanes, alkenes and simple alcohols (inter and intramolecular hydrogen bonding), aldehydes, ketones, carboxylic acids and their derivatives (effect of substitution on >C=O stretching absorptions).

UNIT-3: Basic principles of NMR (^{1}H and ^{13}C NMR) Spectroscopy

Application of Chemical Shifts, Splitting of signals, Spin coupling and Overhauser effect in interpretation of NMR spectra, Isotopic exchange.

UNIT-4: Basic principles of Mass Spectroscopy

Application of fragmentation rule in characterization of organic compounds. Problems on structure elucidation of organic compounds based on spectral data.

Recommended Books/References:

1. R.M. Silverstein, G.C.Bassler & T.C.Morrill, *Spectroscopic Identification of Organic Compounds*, John Wiley & Sons.
2. John R.Dyer, *Applications of absorption spectroscopy of organic compounds*, Prentice Hall, India (2012).
3. William Kemp, *Organic Spectroscopy*, 3rd Edition, Mc Millan.

4. P.S. Kalsi, *Spectroscopy of Organic Compounds,* New Age International.
5. Y.R. Sharma, *Elementary Organic Spectroscopy*, Revised Edition, S. Chand Publishing.

Suggested laboratory experiments

1. Purification method for liquid, solid organic substance (distillation, recrystallization, chromatorgrapy)

2. Analysis of spectra of UV-Vis, FTIR, NMR and Mass of simple organic compounds. (students may be encouraged to prepare simple organic compounds following given protocol (azodyes, acetanilides, benzoic acid, etc.) (or may use commercially available organic compounds) and can be trained to identify/analyze important peaks/functionality, determine mass of the molecules (mass-spectra). They can submit a report regarding their analysis to course teacher.

CH-DSE- 354: Nuclear and Radiation Chemistry

(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

After completion of the course, the learner can be able to understand:

1. Nucleus and its classifications.
2. Types of nuclear reactions,
3. Measurement of radioactivity and their applications
4. Nuclear pollution and safety measurements

UNIT-1: Radioactivity and nuclear reactions

Nucleus and its classification, nuclear forces, nuclear stability, binding energy, nuclear models. Radioactive decay (Radioactive elements, general characteristics of radioactive decay, decay kinetics- decay constant, half life, mean life period), units of radioactivity, Transient and secular equilibria, Carbon dating and its usefulness.
Nuclear reactions: Bethe notation, types of nuclear reactions (n, p, α, d and γ), conservation of quantities (mass-energy and linear momentum) in nuclear reactions, reaction cross-section, compound nucleus theory and nuclear reactions. Nuclear fission: the process, fragments, mass distribution, and fission energy.

UNIT-2: Measurement and Types of nuclear reactions

Measurement of radioactivity, idea about accelerator and detectors, Van de Graaaf and linear acceletors, synchrontrons, Geiger-Muller detector, Scintillaton detectors, Type of nuclear reactions, Nuclear fission, Nuclear fusion, Nuclear reactor: classification of reactors, the natural uranium reactor, breeder reactor. Nuclear fusion and stellar energy.

UNIT-3: Radiation chemistry

Radiation chemistry: Elementary ideas of radiation chemistry, radiolysis of water and aqueoussolutions, unit of radiation chemical yield (G-value), radiation dosimetry (Fricke's dosimeter), units of radiation energy (Rad, Gray, Rontgen, RBE, Rcm, Sievert).

UNIT-4: Nuclear pollution and Safety measurements

Nuclear pollution and Radiological safety: Interaction of radiation with matter, Radiolysis of water, Radiation dosimetry. Radio active isotopes and their applications, Isotopic dilution analysis, Neutron activation analysis, disposal of nuclear waste, nuclear disaster and its management (nuclear accidents and holocaust –discussion about case studies).

Recommended Books/references:

1. Friendlander G, Kennedy G and Miller J. M. *Nuclear and Radiochemistry*, Wiley Interscience
2. Harvey,B.G. *Introduction to Nuclear Physics & Chemistry*, Prentice–Hall,
3. OvermanR.T, *Basic concept of Nuclear Chemistry*, Chapman &Hall.
4. A.N.Nesmeyanov, *Radiochemistry*, MIR Publication, Moscow.
5. SpinksJ.W.T. and Woods R.J. *An Introduction toRadiation Chemistry*, Wiley
6. Arnikar H.J., *Essentials of Nuclear Chemistry*, Wiley Eastern, Second Edition.

Suggested laboratory practicals:

1. The safe laboratory use of radionuclide and radioisotopes
2. Demonstration of activity on Geiger-Muller and scintillation based counter.
3. Liquid scintillation counting, alpha spectrometry, gamma spectrometry–to identify and quantify radioisotopes
4. Occurrence of radon daughter particles in environmental samples.
5. Liquid-liquid separation/extraction of radionuclide from environmental samples/water samples.
6. Isotopic application in removal process adsorption / ion exchange.

(The above list is just suggestive. More experiments can be added/incorporated based on

facility/expertise available. Since above experiments require certified labs which may not be available at all places, therefore, it is advised that institute/university/teacher may arrange/allow academic visit of students to nuclear chemistry labs in the country following proper procedure and to prepare comprehensive report of the visit/viva voce of students which can also form a lab course until available facilities are available).

SEMESTER-VI

CH-DSE 361: Heterocyclic Chemistry
(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

Learning objectives :

1. To study various heteroatomic systems
2. To study their syntheticapproachesandreactivities.

UNIT-1: Three-membered rings heterocycles

Three-membered rings with one hetero atom: Chemistry of oxiranes, aziridines and episulphides- synthetic approaches and reactivities.

UNIT-2: Three-membered heterocycles

Three-membered heterocycles with two heteroatoms: oxaziranes, diaziridines and diazirines-synthetic approaches and reactivities.

UNIT-3: Four-membered heterocycles

Four-membered heterocycles: oxitanes, azatidanes and thietanes -synthetic approaches and reactivities. Natural products: Synthesis of Peniciline and cephalosporine.

UNIT-4: Five-membered aromatic heterocycles:

1. With one heteroatom: furans, pyrroles and thiophenes –general synthetic approaches, properties and reactivities.
2. With two heteroatoms: oxazoles, isoxazoles, imidazoles, thiazoles, pyrazoles and isothiazoles- general synthetic approaches and reactivities.
3. With three and four heteroatoms: triazoles and tetrazoles -synthetic approaches, properties and reactivity.

UNIT-5: Condensed five-membered Heterocycles:

Benzofuran, indoles and benzothiazoles –general synthetic approaches, with greater emphasis on the chemistry of Indoles.

Recommended Books/references:

1. J.A. Joule,K. Mills, *Heterocyclic Chemistry*, Wiley,2010.
2. A.R.Parikh, H.Parikh, R.Khunt, *The Essence of heterocyclic Chemistry*, New Age International Publication.
3. L.A.Paquette, W.A.Benjamin, *Principles of Modern Heterocyclic Chemistry*, NewYork,1968.
4. J.A.Jouleand and G.F.Smith, *Heterocyclic Chemistry*, VanNostrand, London,1978.
5. *Comprehensive Heterocyclic Chemistry. The structure, reactions, synthesis and use of Heterocyclic compounds*, (Ed.A.R. KatritzkyandC. W. Rees),.Vol 1-8, Pergamon Press,1984.
6. A.R.Katritzky, *Handbook o fHeterocyclic Chemistry*, Pergamon Press,1985.
7. Van der plas, H. C. *Ring transformations of Heterocycles,Vols 1and2*, Academic Press,1974.

Suggested laboratory experiments:

1. Identification of heteroatoms (S,N,X) in given organic compounds in lab.

2. Identification/separation of simple organic compounds containing hetero atoms using column chromatography/TLC) in lab.

3. Spectroscopic identification of simple organic compounds (spectra may be provided to the students and teachers may help the students to identify the compounds using spectra). Melting point/boiling point of the compounds may be checked for itspurity.

4. Teacher may guide the students for preparation of : Indigo (using aldol condensation reaction of 2-nitrobenzaldehyde with acetone in basic condition).

(Depending upon laboratory facilities, more preparation of heterocyclic group of compounds may be incorporated by teacher).

CH-DSE 362: Organometallic and Bioinorganic Chemistry

(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

Learning objectives :

This course aims to make the students to learn

1. Various oxidation states of some first row transition metals
2. Classifications of organometallic compounds
3. Structures and bonding in organometallic compounds
4. Roles of alkali and alkaline earth metals ions in biological systems

UNIT-1: Chemistry of 3d metals

Oxidation states displayed by Cr, Fe, Co, Ni and Co. A study of thefollowing compounds (including preparation and important properties); Peroxo compounds of Cr, $K_2Cr_2O_7$, $KMnO_4$, $K_4[Fe(CN)_6]$, sodiumnitroprusside, $[Co(NH_3)_6]Cl_3$, $Na_3[Co(NO_2)_6]$.

UNIT-2: Organometallic Compounds

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn,Fe, Co and Ni using VBT. pi-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of backbonding.

Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls.

UNIT-3: Metal Alkyls

Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicenter bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.

UNIT-4: Ferrocene

Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.

Definition and Classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p and multicentre bonds). Structures of methyl lithium, Zeiss salt and ferrocene. EAN rule as applied to carbonyls. Preparation, structure, bonding and properties of mononuclear and polynuclear carbonyls of 3d metals. pi-acceptor behaviour of carbon monoxide. Synergic effects (VB approach)- (MO diagram of CO can be referred to for synergic effect to IR frequencies). Organometallic compounds of Mg and Li –Use in synthesis of organic compounds.

UNIT-5: Bioinorganic chemistry

A brief introduction to bio-inorganic chemistry. Role of metal ions present in biological systems with special reference to Na^+, K^+ and Mg^{2+} ions: Na/K pump; Role of Mg^{2+} ions in energy production and chlorophyll. Role of Ca^{2+} in blood clotting, stabilization of protein structures and structural role (bones).

Recommended books/reference books

1. Lippard, S.J. & Berg, J.M. *Principles of Bioinorganic Chemistry,* Panima Publishing Company, 1994.
2. Cotton, F.A. & Wilkinson, G, *Advanced Inorganic Chemistry* Wiley-VCH,1999.
3. Basolo, F., and Pearson, R.C. *Mechanisms of Inorganic Chemistry*, John Wiley & Sons, NY, 1967.
4. Greenwood, N.N. & Earnshaw, A. *Chemistry of the Elements*, Butterworth-Heinemann, 1997.
5. R. C. Mehrotra, A. Singh; *Organometallic Chemistry*, New Age International.

List of Laboratory experiments

(Necessary infrastructure may be developed and adequate precaution should be maintained to conduct such experiments; instructor may demonstate the experiment to students).

1. Reaction of metal with halide – preparation of Grignard reagent. (only demonstration purpose)
2. Grignard preparation of dye (malachite green (using methyl benoate)/crystal violet (using diethyl carbonate) (starting material asp-bromo N,N-dimethylaniline) (only demonstration purpose)
3. Preparation of various Schiff base-metal complexes and their identification using spectroscopy.

CH-DSE: 363: Introduction to Nanochemistry and Applications

(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

Learning objectives :

This course aims to provide the students a brief idea about

1. Nanoscience, nanostructure and nanotechnology
2. Properties of nanomaterials
3. Different synthetic routes
4. Characterization of nanomaterials

UNIT-1: Introduction to nanoscience, nanostructure and nanotechnology (basic idea)

Overview of nanostructures and nano-materials, classification, (cluster, colloid, nanoparticles, and nanostructures - Spheroid, Wire, Rod, Tube, and Quantum Dot); Calculation of percentage of surface atom and surface to volume ratio of spherical, wire, rod, and disc shapes nanoparticles.

UNIT-2: Properties of nanomaterials

Size dependent properties of nanomaterials (basic idea with few examples only): Quantum confinement, Electrical, Optical (Surface Plasmon resonance), variation in colors (Blueshift & Redshift), Magnetic, thermal and catalytic properties.

UNIT-3: Synthetic routes

Synthesis of Nanomaterials: Brief introduction about Top-down and Bottom-up approaches and self-assembly techniques of nanoparticles synthesis, Solvothermal process, Examples of preparation of gold and silver metallic nanoparticles, self-assembled nanostructures-control of nanoarchitecture-onedimensional control. Carbon nanotubes and inorganic nanowires.

UNIT-4: Material characterization techniques

Material characterization techniques (basic idea of use of following instruments in nanomaterial characterization need to be emphasized): Electron microscopic technique, diffraction technique, photoelectron spectroscopy, zeta-potential measurement; Examples of use of nanomaterials in environmental remediation and biology (few practical examples of use of materials can be discussed).

Recommended Books/References books:

1. C.N.R. Rao, A. Muller, A.K.Cheetam, *The Chemistry of Nanomaterials: Synthesis, Properties and Applications*, Willey-VCH Verlag, Germany, 2005.
2. G.Cao, *Nanostructures and Nanomaterials: Synthesis, Properties and Appications*, Imperial College Press, London, 2004.
3. R.W.Kelsall, I.W.Hameley, M.Geoghegan, *Nanoscale Science and Technology*, John Wiley & Sons, England, 2005.
4. Charles P. Poole and Frank J Owens, *Introduction to nano technology*, Wiley Interscience, 2003.
5. Pradeep,T., *A textbook of nanoscience and nanotechnology*, TataMcGraw Hill Education Pvt.Ltd., NewDelhi, 2012.

List of Laboratory Experiments suggested:

1. Synthesis of ZnO nanoparticles.
2. Preparation of Silver nanoparticles. (Diverse nanoparticles can be prepared by various routes).
3. Verification of Beer-Lambert law using nano-particles (above prepared nano-particles may be used for the study).

(Depending upon the availability of infrastructure facilities, instructor may encourage the students to prepare bimetallic nano-particles, etc. and characterized them, study their various properties like magnetism, adsorption, etc.)

CH-DSE 364: Biochemistry

(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

Learning objectives :

This course aims to provide the students a brief idea about

1. Biological importance of carbohydrates
2. Classifications and structures of proteins
3. Enzymes as catalysts
4. Lipids and nucleic acids

UNIT-1: Carbohydrates

Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle.

UNIT-2: Proteins

Classification, biological importance; Primary, secondary and tertiary structures of proteins: α-helix and β- pleated sheets, Denaturation of proteins.

UNIT-3: Enzymes

Nomenclature, Characteristics (mention of Ribozymes), Classification; Active site, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme inhibitors, Biocatalysis in Green Chemistry and Chemical Industry.

UNIT-4: Lipids

Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications.

UNIT-5: Structure of DNA/RNA

Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Genetherapy.

Recommended Books/References:

1. Berg, J.M., Tymoczko, J.L. and Stryer, L. *Biochemistry*. VI the Edition. W.H. Freeman and Co. (2006)
2. Nelson, D.L., Cox, M.M. and Lehninger, A.L. *Principles of Biochemistry*. IV Edition, W.H. Freeman and Co. (2009)
3. Murray, R.K., Granner, D.K., Mayes, P.A.and Rodwell, V.W. *Harper's Illustrated Biochemistry.* XXVIII edition. Langemedical Books/ McGraw-Hill (2009)

Suggested Practical in Biochemistry

1. Quantitative estimation of protein using Lowry's method. Determine the concentration of the unknown sample.
2. Action of salivary amylase at optimum conditions.
3. Effect of pH on the action of salivary amylase.
4. Effect of temperature on salivary amylase
5. Effect of inhibitor on salivary amylase
6. Study of the activity of Trypsinusing fresh tissue extracts.
7. Effect of temperature, organic solvents, on semi-permeable membrane.

8. Isolation of Genomic DNA from E.Coli

(The above course structure/number of classes and list of experiments are suggestive. Faculty/academic bodies may incorporate revision /may incorporate text and reference books as per need).

SEMESTER VII

CH-DSE-471: Advanced Analytical Chemistry

(40 lectures of 60 minutes each)

L	T	P	Cr
5	1	0	6

After completion of the course, the learner can be able to understand:

1. Statistical methods in chemical analysis
2. Theory and applications of polarography, atomic absorption spectroscopy and chromatography
3. Theory and applications of thermogravimetric analysis

UNIT 1: Statistical methods in chemical analysis

Theory of error and treatment of quantitative data, accuracy and precision, ways of expressing accuracy and precision, Normal error curve and its equation. Useful statistical tests with equation, test of significance, the F-test, the students t-test, the Chi-test, the correlation coefficient, confidence limit of the mean, comparison of two standard values, comparison of two standard values, comparison of standard deviation with average deviation, comparison of mean with true values, regression analysis (least square method).

UNIT 2: Polarography

Current-voltage relationship, theory of polarographic waves, instrumentation, qualitative and quantitative applications.

UNIT 3: Atomic Absorption spectroscopy

Atomic absorption spectroscopy, instrumentation, theory and applications including trace elements analysis.

UNIT 4: Thermal analysis

Theory, methodology, instrumentation and applications of theromogravimetric analysis (TGA/DTA),

and differential scanning calorimetry (DSC).

UNIT 5: Chromatography

Principles of chromatography, paper, column and thin layer chromatography, ion-exchange chromatography, Gas-liquid chromatography, HPLC.

Recommended books/references:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.,* Pearson, 2009. 100
2. Willard, H.H. *et al.*: *Instrumental Methods of Analysis*, 7th Ed. Wardsworth Publishing
3. California, USA, 1988.
4. Christian, G.D, *Analytical Chemistry*, 6th Ed. John Wiley & Sons, New York, 2004.
5. Harris, D.C.: *Exploring Chemical Analysis*, 9th Ed. New York, W.H. Freeman, 2016.
6. Skoog, D.A. Holler F.J. & Nieman, T.A. *Principles of Instrumental Analysis*
7. Mikes, O. *Laboratory Hand Book of Chromatographic & Allied Methods*, Elles Harwood John Wiley 1979.
8. Ditts, R.V. *Analytical Chemistry; Methods of separation*, van Nostrand, 1974.
9. Khopkar, S. M., *Basic Concepts of Analytical Chemistry*, New Age (Second edition) 1998

CH-DSE-472: Polymer Chemistry- I

(40 lectures of 60 minutes each)

L	T	P	Cr
5	1	0	6

After completion of the course, the learner can be able to understand:

1. The mechanism of polymer material formation.
2. Molecular weight and structure property relationship.
3. Characterization of polymers.

UNIT 1: Polymers and polymerization

Polymer, monomer, examples of polymers, classification, polymerization process, degree of polymerization, addition polymers, condensation, co-polymerization, kinetics of addition polymerization process.

UNIT 2: Polymeric Structure and Property Relationship

Structure of polymers - Linear, branched, cross linked, and network polymers, molecular weight (number average, weight average, viscosity average) and distribution of molecular weight, polydispersity index, crystallinity in polymer, melting temperature and glass transition temperature, Volumetric properties - molar volume, density, Van der Waals volume – Coefficient of linear thermal expansion and volumetric thermal expansion - Pressure volume temperature (PVT) relationship.

UNIT 3: Macromolecules

Number average and weight average molecular weights (molar masses). Theory and instrumentation ofdetermination of molar mass by Osmometry, viscometry, light scattering and ultra-centrifugation methods. General idea about kinetics and mechanism of polymerisation reactions. Emulsion polymerisation. Stereochemistry and average end-to-end distance of polymers.

UNIT 4: Characterization of Polymers

Molecular Weight Determination by Light Scattering, Osmometry, End-Group Analysis, Viscosity, Gel Permeation Chromatography; Application of FTIR, UV-visible, NMR, and Mass Spectroscopy for identification of polymers.

Recommended books/References:

1. D.W. Van Krevelen and P.J. Hoftyzen, *Properties of Polymer*, 3rd Edition Elsevier Scientific,

   Publishing Company Amsterdam - Oxford - Newyork. 1990.
2. J.E. Mark, Ed. AIP, *Physical Properties of Polymers*, Hand Book, Williston, Vt, 1996.
3. S K Gupta and Anil Kumar, *Reaction Engineering of Step Growth Polymerization* , Plenum Press, 1987
4. George Odian, *Principles of Polymerization*, McGraw-Hill Book Co., New York (1970).
5. W. Billmeyer, *Text book of polymer science*, 3rd Edn., 2007, Wiley- Interscience Publishers, NewYork.
6. J. R. Fried, *Polymer Science and Technology*, (2005), PHI publication.

SEMESTER VIII

CH-DSE-481: Advanced Materials Chemistry

(40 lectures of 60 minutes each)

L	T	P	Cr
5	1	0	6

Learning objectives:

1. To make the student learn about the crystal structures, the different techniques employed for the synthesis of compounds and methods for growing single crystals and how to characterize them.
2. To learn about the fundamentals of nanomaterials.
3. To learn about the properties and applications of namomaterials.

UNIT 1: Crystal structure of solids

Fundamental of lattices, unit cell, atomic coordinates, Bravais lattices, crystal direction and planes, few important crystal structures.

Synthesis of Inorganic solids; solid state, solution phase and vapor phase synthesis; precipitation, hydrothermal, sol-gel, surfactant based synthesis. Growth of single crystals.

UNIT 2. Crystal structure determination

X-ray diffraction, d-spacing formula, symmetrically absent reflections, Multiplicities, Scattering of X-rays by an atom and a crystal. Single crystal and powder diffraction.Electron and neutron diffraction.

UNIT 3: Nanomaterial fundamentals

Synthesis: Bottom-up vs. Top-down Methods. Solution phase synthetic methods. Role of surfactant in shape and size control of nanomaterials.

Characterization: XRD of nanomaterials, Electron microscopy (SEM, TEM, HRTEM and EDX) of nanomaterials, Scanning probe microscopy.

UNIT 4: Nanomaterial properties and applications

Magnetic properties of nanoparticles; superparamagnetism, ferromagnetism in antiferromagnetic nanoparticles and single domain to multidomain transition. Magnetic nanoparticles as MRI contrast agents.

Recommended books/References:

1. Zhen Guo and Li Tan; *Fundamentals and Applications of Nanomaterials.2009*, Artech House, London Publication.
2. B.D Fahlman; *Materials Chemistry*, Springer, 2004.
3. D.M. Adam; *Inorganic Solids: An introduction to concepts in solid-state structural chemistry*. John Wiley,1974.

CH-DSE-482: Polymer Chemistry II

(40 lectures of 60 minutes each)

L	T	P	Cr
5	1	0	6

Learning objectives:

1. To learn about the conducting polymers.
2. To learn about biopolymers and their classifications.
3. To learn about the applications of polymers in industry.

UNIT 1: Conducting polymers

Basic principles of conducting polymers, delocalized electronic states of conjugated polymers, polyanilines, polyacetylenes, polythiophene, applications of conducting polymers.

UNIT 2. Bio- polymers

Definition, classification, starch cellulose, chitin, polypeptides, polynucleic acids, classification of natural biodegradable polymers, synthetic biodegradable polymers, polyhydroxy alkanoates, polycarpolactone, poly(vinyl alcohol), polyacetic acid, application of biodegradable and biomedical polymers, contact lens, dental polymers, artificial heart, kidney, skin, and blood cells.

UNIT 3. Polymerization Chemistry

Industrial methods of polymerization such as a bulk, solution, emulsion, suspension.Stereochemistry of polymers and stereo-specific polymerization, Catalysts-their utility in polymers and stereo-specific polymerizations, Catalysts their utility in polymer manufacture, Zieglar-Natta, Metallocene and others.

UNIT 4. Fibers and elastomers

Thermoplastics and thermosetting, polyethylene, polypropylene, polyvinyl chloride(PVC), polyvinyl acetate (PVA), Natural fibers: cotton, wool, silk, rayon. Artificial fibers: polyamides(nylon 6 and nylon 66), acrylic acid, polyester (PET), phenolic resin (Bakelite) , amino resins, polyacrylonitrile (PAN). Elastomers: Structural requirement, natural and synthetic rubber, Compounding and elastomeric properties, vulcanization of rubber, reinforcement. Synthetic rubber: Styrene rubber (BUNA-S), Nitrene rubber (BUNA-N), Neoprene, Butyl rubber.

Recommended books/References:

1. Zhen Guo and Li Tan, *Fundamentals and Applications of Nanomaterials*.2009, Artech House, London Publication.
2. V. R. Gowariker, N. V.Viswanathan, J. Sreedhar, *Polymer science*, New Age International (P) Ltd., 2015 and 2019 editions.
4. P. J. Flory, *Principle of polymer chemistry*, Cornell University Press.
5. P. Ghosh, *Polymer Science and Technology*, Plastics, Rubber and composites, Tata McGraw Hill.

GENERIC ELECTIVE COURSES

Generic elective courses (GEC), 6 (six) credits each, are to be taken preferably from Physics, Mathematics, Biochemistry, Botany and Zoology.

Refer to the syllabi of the departments of Physics, Mathematics, Biochemistry, Botany and Zoology for the GE courses. Students can choose minimum of two GE papers from two different disciplines or four papers from one discipline.

Note : At least two mathematics papers are to be studied by the student for admission into M.Sc.(Chemistry).

GEC FOR OTHER DEPARTMENTS/DISCIPLINES

Both Honours and Pass students can chose the course as outlined in the pattern of modeled credit distribution. These courses with 6 credits each have the following credit pattern.

For Theory and practical based papers:

L	T	P	Cr
3	1	2	6

For Theory papers without Practical:

L	T	P	Cr
5	1	0	6

SEMESTER III

CH-GEC-230: Atomic structure, bonding, general organic chemistry and stereochemistry (40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

Learning Objectives:

1. To provide basic knowledge about ionic, covalent and metallic bonding and the Periodicity in properties with reference to the *s*- and *p*- block
2. To introduce a new concept of visualizing the organic molecules in a three dimensional space with the recapitulation of fundamentals of organic chemistry and to establish the applications of these concepts.

Learning Outcomes:

By the end of the course, the students will be able to:

1. Solve the conceptual questions using the knowledge gained by studying the quantum mechanical model of the atom, quantum numbers, electronic configuration, radial and angular distribution curves, shapes of s, p, and d orbitals, and periodicity in atomic radii, ionic radii, ionization energy and electron affinity of elements.
2. Draw the plausible structures and geometries of molecules using radius ratio rules, VSEPR theory and MO diagrams (homo- & hetero-nuclear diatomic molecules).
3. Understand and explain the differential behavior of organic compounds based on fundamental concepts learnt.

Section A: Inorganic Chemistry (Lectures: 20)

UNIT-1: Atomic Structure (Lectures: 10)

Bohr's theory and its limitations, Heisenberg uncertainty principle, Dual behaviour of matter and radiation, De-Broglie's relation, Hydrogen atom spectra, need of a new approach to atomic structure. Schrodinger equation and meaning of various terms in it. Significance of ψ and $\psi 2$, Schrödinger equation for hydrogen atom, radial and angular parts of the hydrogenic wave functions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (Only graphical representation), radial and angular nodes and their significance, radial distribution functions and the concept of the most probable distance with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers ml and ms. Shapes of s, p and d atomic orbitals, nodal planes, discovery of spin, spin quantum number (s) and magnetic spin quantum number (ms).
Rules for filling electrons in various orbitals, electronic configurations of the atoms, stability of half-filled and completely filled orbitals, concept of exchange energy, relative energies of atomic orbitals, anomalous electronic configurations.

UNIT- 2: Chemical Bonding and Molecular Structure (Lectures: 10)

Ionic Bonding: General characteristics of ionic bonding, energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds, statement of Born-Landé equation for calculation of lattice energy (no derivation), Born Haber cycle and its applications, covalent character in ionic compounds, polarizing power and polarizability, Fajan's rules. Ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.
Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization (H_2O, NH_3, PCl_5, SF_6, ClF_3, SF_4)
MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for ss, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals.

Section B: Organic Chemistry (Lectures: 20)

UNIT-3: Fundamentals of Organic Chemistry (Lectures: 08)

Electronic displacements: Inductive effect, electromeric effect, resonance, hyperconjugation. Cleavage of bonds: homolysis and heterolysis. Reaction intermediates: carbocations, carbanions and free radicals. Electrophiles and nucleophiles, Aromaticity: benzenoids and Hückel's rule.

UNIT 4: Stereochemistry (Lectures: 12)

Conformations with respect to ethane, butane and cyclohexane, interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations, concept of chirality (upto two carbon atoms). configuration: geometrical and optical isomerism; enantiomerism, diastereomerism and meso compounds). Threo and erythro; D and L; *cis – trans* nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E / Z nomenclature (for upto two C=C systems).

Practical:

Section A: Inorganic Chemistry - Volummetric Analysis

1. Estimation of oxalic acid by titrating it with $KMnO_4$.
2. Estimation of Mohr's salt by titrating it with $KMnO_4$.
3. Estimation of Fe(II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.
4. Estimation of Cu(II) ions iodometrically using $Na_2S_2O_3$.

Section B: Organic Chemistry

1. Purification of organic compound by crystallisation (from water and alcohol) and distillation.
2. Criteria of purity: Determination of M.P./B.P.
3. Separation of mixtures by chromatography (Thin Layer Chromatography): Measure the Rf value in each case (combination of two compounds to be given)

(The above course structure/number of classes and list of experiments are suggestive. Faculty/academic bodies may incorporate revision /may incorporate text and reference books as per need).

References:

1. Lee., J. D. (2010), *A new Concise Inorganic Chemistry*, Pearson Education.
2. Huheey, J.E.; Keiter, E.; Keiter, R. (2009), *Inorganic Chemistry: Principles of Structure and Reactivity*, Pearson Publication.
3. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), *Shriver and Atkin's Inorganic Chemistry*, Oxford
4. Sykes, P. (2005), *A Guide Book to Mechanism in Organic Chemistry*, Orient Longman.
5. Eliel, E. L. (2000), *Stereochemistry of Carbon Compounds*, Tata McGraw Hill.
6. Morrison, R. N.; Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Bahl, A; Bahl, B. S. (2012), *Advanced Organic Chemistry*, S. Chand.

8. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), *Vogel's Textbook of Quantitative Chemical Analysis,* 5th Edn.**,** John Wiley and Sons Inc,.
9. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), *Vogel's Textbook of Practical Organic Chemistry*, Pearson.

SEMESTER IV

CH-GEC-240: Chemical Energetics, Equilibria, Solutions and Hydrocarbons (40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

Learning Objectives:

1. To develop basic understanding of the chemical energetics, laws of thermodynamics, chemical and ionic equilibrium.
2. To acquaint the students with the functional group approach to study organic chemistry.
3. To establish applications of this concept structure, methods of preparation and reactions for the following classes of compounds: Aromatic hydrocarbons, alkyl and aryl halides, alcohols, phenols and ethers, aldehydes and ketones are described.

Learning Outcomes:

By the end of this course, students will be able to:

1. Understand the laws of thermodynamics, thermochemistry and equilibria.
2. Use the concepts learnt to predict feasibility of chemical reactions and to study the behaviour of reactions in equilibrium.
3. Use concepts learnt to understand stereochemistry of a reaction and predict the reaction outcome.
4. Design newer synthetic routes for various organic compounds.
5. Learn and identify many organic reaction mechanisms including free radical substitution, electrophilic addition and electrophilic aromatic substitution.

Section A: Physical Chemistry (Lectures:20)

UNIT-1: Chemical Energetics and equilibrium (Lectures: 15)

Review of thermodynamics and the laws of thermodynamics, important principles and definitions of thermochemistry, concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution, calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, variation of enthalpy of a reaction with temperature – Kirchhoff's equation, statement of third law of thermodynamics and calculation of absolute entropies of substances.

Free energy change in a chemical reaction, Thermodynamic derivation of the law of chemical equilibrium, distinction between G and Go, Le Chatelier's principle, relationships between Kp, Kc and Kx for reactions involving ideal gases.

UNIT-2: Solutions (Lectures: 5)

Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law-nonideal solutions. Vapour pressure, composition and temperature-composition curves of ideal and non-ideal solutions. Distillation of solutions, Lever rule, Azeotropes. Partial miscibility of liquids: Critical solution temperature; effect of impurity on partial miscibility of liquids. Immiscibility of liquids: principle of steam distillation, Nernst distribution law and its applications, solvent extraction.

Section B: Organic Chemistry (Lectures: 20)

UNIT-3: Aliphatic Hydrocarbons (Lectures: 15)

Alkanes:

Preparation: catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, Grignard reagent.

Reactions: Free radical substitution: Halogenation.

Alkenes:

Preparation: Elimination reactions: Dehydration of alcohols and dehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alk. $KMnO_4$) and trans-addition (bromine), addition of HX (Markownikoff's and anti-Markownikoff's oxidation addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration

Alkynes:

Preparation: Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetrahalides and dehydrohalogenation of vicinal-dihalides. Reactions: formation of metal acetylides and acidity of alkynes.

UNIT-4: Aromatic Hydrocarbons (Lectures: 5)

Structure and aromatic character of benzene, methods of preparation of benzene from phenol, benzoic acid and acetylene. Reactions**:** electrophilic substitution reactions in benzene citing examples of nitration, halogenation, sulphonation and Friedel-Craft's alkylation and acylation.

Practical:

Section A: Physical Chemistry

1. Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.
2. Determination of critical solution temperature and composition of phenol water system and study the effect of impurities on it.
3. Perform the following conductometric titrations:
a) Strong acid vs strong base
b) Weak acid vs strong base.

Section B: Organic Chemistry

Preparations: Recrystallization, determination of melting point and calculation of quantitative yields to be done in all cases

1. Benzoylation of amines/phenols
2. Oxime of aldehydes and ketones
3. 2,4-dinitrophenylhydrazone of aldehydes and ketones

References:

1. Castellan, G. W. (2004), *Physical Chemistry*, Narosa.
2. Kapoor, K.L. (2015), *A Textbook of Physical Chemistry*,Vol 1& 2, 6th Edition, McGraw Hill Education.
3. B.R.Puri, L.R.Sharma, M.S.Pathania, (2017), *Principles of Physical Chemistry,* Vishal Publishing Co.
4. Finar, I. L. *Organic Chemistry (Volume 1 & 2)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Morrison, R. N.; Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6. Bahl, A; Bahl, B. S. (2012), *Advanced Organic Chemistry*, S. Chand.
7. Khosla, B.D.; Garg, V.C.;Gulati, A.(2015), *Senior Practical Physical Chemistry*, R. Chand & Co.
8. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), *Vogel's Textbook of Practical Organic Chemistry*, Pearson.

(The above course structure/number of classes and list of experiments are suggestive. Faculty/academic bodies may incorporate revision /may incorporate text and reference books as per need).

SEMESTER V

CH-GEC-350: Ionic Equilibria, Electrochemistry and Functional Group Organic Chemistry **(40 lectures of 60 minutes each)**

L	T	P	Cr
3	1	2	6

Learning Objectives:

1. To learn about ideal and non-ideal solutions, Raoult's law, partially miscible and immiscible solutions and their applications.
2. To learn about electrolytic and galvanic cells, measurement of conductance and its applications, measurement of emf and its applications.
3. To learn about carbohydrates, amino acids, peptides and proteins are introduced through some specific examples. A relationship between structure, reactivity and biological properties of biomolecules is established through the study of these representative biomolecules.

Learning Outcomes:

By the end of the course, the students will be able to:

1. Explain the concepts of different types of binary solutions-miscible, partially miscible and immiscible along with their applications.
2. Explain the thermodynamic aspects of equilibria between phases and draw phase diagrams of simple one component and two component systems.
3. Explain the factors that effect conductance, migration of ions and application of conductance measurement.
4. Understand different types of galvanic cells, measurement of emf, calculations of thermodynamic properties and other parameters from the emf measurements.
5. Design newer synthetic routes for various organic compounds.

Section A: Physical Chemistry (Lectures: 20)

Unit 1: Ionic Equilibria (Lectures: 12)

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, Ostwald's dilution law, ionization constant and ionic product of water, ionization of weak acids and bases, pH scale, common ion effect, salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions, Henderson-Hasselbach equation. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle

UNIT 2: Electrochemistry (Lectures: 8)

Reversible and irreversible cells, concept of EMF of a cell, measurement of EMF of a cell, Nernst equation and its importance, types of electrodes, standard electrode potential, electrochemical series. thermodynamics of a reversible cell, calculation of thermodynamic properties: G, H and S from EMF

data. Calculation of equilibrium constant from EMF data, concentration cells with transference and without transference, liquid junction potential and salt bridge, pH determination using hydrogen electrode. Potentiometric titrations-qualitative treatment (acid-base and oxidation-reduction only).

Section B: Organic Chemistry (Lectures:20)

Unit 3: Alkyl and Aryl Halides (Lectures:10)

A) **Alkyl halides** (upto 5 carbons): Structure of haloalkanes and their classification as 1^0, 2^0& 3^0. Preparation: starting from alcohols (1^0, 2^0& 3^0) and alkenes with mechanisms. Reactions: Nucleophilic substitution reactions with mechanism and their types (SN1, SN2 and SNi), competition with elimination reactions (elimination vs substitution).
B) **Haloarenes**: Structure and resonance Preparation: Methods of preparation of chloro, bromo & iodobenzene from benzene (electrophilic substitution), from phenols (nucleophilic substitution reaction) and from aniline (Sandmeyer and Gattermann reactions).
Reaction: Nucleophilic aromatic substitution by OH group (Bimolecular Displacement Mechanism), Effect of nitro substituent on reactivity of haloarenes, Reaction with strong bases $NaNH_2/NH_3$ (elimination addition mechanism involving benzyne intermediate).

UNIT-4: Alcohols, Phenols, Ethers, Aldehydes and Ketones (Lectures:10)

Alcohols (upto 5 Carbon): Structure and classification of alcohols as 1^0, 2^0& 3^0. Preparation: Methods of preparation of 1^0, 2^0& 3^0 by using Grignard reagent, ester hydrolysis and reduction of aldehydes, ketones, carboxylic acids and esters. Reactions: Acidic character of alcohols and reaction with sodium, with HX (Lucas Test), esterification, oxidation (with PCC, alkaline $KMnO_4$, acidic $K_2Cr_2O_7$ and conc. HNO_3).
Phenols: Acidity of phenols and factors affecting their acidity. Preparation: Methods of preparation from cumene, diazonium salts and benzene sulphonic acid. Reactions: Directive influence of OH group and Electrophilic substitution reactions, *viz*. nitration, halogenation, sulphonation, Reimer-Tiemann reaction, reaction due to OH group: Schotten-Baumann reaction.
Ethers (Aliphatic & Aromatic): Williamson's ether synthesis, Cleavage of ethers with HI.
Aldehydes and ketones (Aliphatic and Aromatic): Preparation: from acid chlorides. Reactions: Nucleophilic addition, nucleophilic addition – elimination reaction including reaction with HCN, ROH, $NaHSO_3$. Iodoform test, Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation.Clemmensen reduction, Wolff Kishner reduction.

Practical:

Section A: Physical Chemistry

1. Preparation of buffer solutions: (i) Sodium acetate-acetic acid or (ii) Ammonium chloride-ammonium acetate.
2. Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

Section B: Organic Chemistry

Systematic qualitative analysis of organic compounds possessing monofunctional groups (Alcohols, Phenols, Carbonyl, -COOH). (Including Derivative Preparation).

(The above course structure/number of classes and list of experiments are suggestive. Faculty/academic bodies may incorporate revision /may incorporate text and reference books as per need).

References:

1. Castellan, G.W. (2004), *Physical Chemistry*, Narosa.
2. Kapoor, K.L., *A Textbook of Physical Chemistry,Vol 1& 3*, McGraw Hill Education.
3. B.R.Puri, L.R.Sharma, M.S.Pathania, (2017), *Principles of Physical Chemistry*, Vishal Publishing Co.
4. Morrison, R. N.; Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Finar, I. L. *Organic Chemistry (Volume 1 & 2)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
6. Khosla, B.D.; Garg, V.C.;Gulati, A.(2015), *Senior Practical Physical Chemistry*, R. Chand & Co.
7. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), *Vogel's Textbook of Practical Organic Chemistry*, Pearson.
8. Mann, F.G.; Saunders, B.C. (2009), *Practical Organic Chemistry*, Pearson Education.

SEMESTER VI

CH-GEC-360: Chemistry of s-, p-, d- and f- Block Elements, liquids, solids, Kinetic Theory and Chemical kinetics

(40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

Learning Objectives:

1. To illustrates the diversity and fascination of inorganic chemistry through the study of properties and utilities of s- and p-block elements and their compounds.
2. To introduce the students to d and f block elements and highlights the concept of horizontal similarity in a period and stresses on their unique properties.
3. To learn about the ideal gas law of kinetic theory of gases and explain why the real gases deviate from ideal behaviour.

Learning Outcomes:

By the end of the course, the students will be able to:

1. Understand the chemistry and applications of s- and p-block elements.
2. Understand chemistry of d and f block elements.
3. Derive ideal gas law from kinetic theory of gases and explain why the real gases deviate from ideal behaviour.
4. Explain Maxwell-Boltzmann distribution, critical constants and viscosity of gases.

Section A: Inorganic Chemistry (Lectures:20)

UNIT-1: s- and p- block elements (Lectures: 16)

Periodicity in s- and p-block elements with respect to electronic configuration, atomic and ionic size, ionization enthalpy, electronegativity (Pauling, Muliken, and Allred-Rochow scales). Allotropy in C, S, and P. Oxidation states with reference to elements in unusual and rare oxidation states like carbides and nitrides), inert pair effect, diagonal relationship and anomalous behaviour of first member of each group. Compounds of s- and p-block elements, diborane and concept of multicentre bonding. Structure, bonding and their important properties like oxidation/reduction, acidic/basic nature of the following compounds and their applications in industrial and environmental chemistry. Hydrides of nitrogen (NH_3, N_2H_4, NH_2OH) Oxoacids of P, S and Cl, Halides and oxohalides: PCl_3, PCl_5, $SOCl_2$ and SO_2Cl_2.

UNIT-2: Transition and inner transition Elements (3d and 4f series) (Lectures: 12)

General properties of elements of 3d series with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties and ability to form complexes.
Lanthanides and actinides: Electronic configurations, oxidation states displayed. Lanthanide contraction (causes and consequences), separation of lanthanides by ion exchange method.
A brief introduction to bioinorganic chemistry; role of metal ions in biological system.

Section B: Physical Chemistry (Lectures:20)

UNIT-3: Liquids and Solids (Lectures: 9)

Surface tension and its determination using stalagmometer, Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer, effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only).
Forms of solids, symmetry elements, unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of crystallography - law of constancy of interfacial angles.
Law of rational indices, Miller indices. X–ray diffraction by crystals, Bragg's law, structures of NaCl, KCl and CsCl (qualitative treatment only), defects in crystals. Glasses and liquid crystals.

UNIT-4: Kinetic Theory of Gases and Chemical Kinetics (Lectures: 11)

Postulates of kinetic theory of gases and derivation of the kinetic gas equation, deviation of real gases from ideal behaviour, compressibility factor, causes of deviation, van der Waals equation of state for real gases. Boyle temperature (derivation not required), critical phenomena, critical constants and their calculation from vander Waals equation.

Concept of reaction rates, effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction, derivation of integrated rate equations for zero, first and second order reactions, half–life of a reaction, general methods for determination of order of a reaction, Concept of activation energy and its calculation from Arrhenius equation.

Practical:

Section A: Inorganic Chemistry

Qualitative analysis of mixtures not more than four ionic species (two anions and two cations and excluding insoluble salts) out of the following:

Cations: NH^{4+}, Pb^{2+}, Bi^{3+}, Cu^{2+}, Cd^{2+}, Fe^{3+}, Al^{3+}, Co^{2+}, Ni^{2+}, Mn^{2+}, Zn^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, K^{+} Anions: CO_3^{2-}, S^{2-} , SO^{3-} , NO^{2-} , CH_3COO^{-}, Cl^{-}, Br^{-}, I^{-}, NO_3^{-},SO_4^{2-} , PO_4^{3-} , BO_3^{3-} , $C_2O_4^{2-}$, F^{-}. (Spot tests should be carried out wherever feasible)

Section B: Physical Chemistry

1. Determination of the surface tension of a liquid or a dilute solution using a stalagmometer.
2. Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald viscometer.
3. Study of the variation of viscosity of an aqueous solution with concentration of solute.

References:

1. Lee., J. D.(2010), *A new Concise Inorganic Chemistry*, Pearson Education.
2. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), *Shriver and Atkin's Inorganic Chemistry*, Oxford.
3. Miessler, G. L.; Tarr, D.A.(2014), *Inorganic Chemistry*, Pearson.
4. Castellan, G. W.(2004), *Physical Chemistry*, Narosa.
5. Kapoor, K.L. (2015), *A Textbook of Physical* Chemistry, Vol.1& 5, McGraw Hill Education.
6. B.R.Puri, L.R.Sharma, M.S.Pathania, (2017), *Principles of Physical Chemistry,* Vishal Publishing Co.
7. Svehla, G. (1996), *Vogel's Qualitative Inorganic Analysis*, Prentice Hall.
8. Khosla, B.D.; Garg, V.C.; Gulati, A.(2015), *Senior Practical Physical Chemistry*, R. Chand & Co.

(The above course structure/number of classes and list of experiments are suggestive. Faculty/academic bodies may incorporate revision /may incorporate text and reference books as per need).

SEMESTER VII

CH-GEC-470: Coordination Chemistry and Spectroscopy (40 lectures of 60 minutes each)

L	T	P	Cr
3	1	2	6

Learning Objectives:

1. To familiarize the students with coordination compounds which find manifold applications in diverse fields.
2. To learn the theories governing the formation of coordination compounds.
3. To disseminate the concepts and methodology of spectroscopy and its applications.

Learning Outcomes:

By the end of the course, the students will be able to:

1. Learn about the coordination compounds and structural and stereoisomerism in complexes.
2. Spectroscopy and its importance in chemistry.

Section A: Inorganic Chemistry (Lectures:20)

UNIT-1: Coordination Chemistry (Lectures: 8)

Brief discussion with examples of types of ligands, denticity and concept of chelate. IUPAC system of nomenclature of coordination compounds (mononuclear and binuclear) involving simple monodentate and bidentate ligands. Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

UNIT-2: Bonding in coordination compounds (Lectures: 12)

Valence Bond Theory (VBT): Salient features of theory, concept of inner and outer orbital complexes. Drawbacks of VBT.
Crystal Field Theory (CFT): Splitting of d orbitals in octahedral symmetry. Crystal field effects for weak and strong fields. Crystal field stabilization energy (CFSE), concept of pairing energy.Factors affecting the magnitude of Δ. Spectrochemical series.Splitting of d orbitals in tetrahedral and octahedral fields.

Section B: Spectroscopy (Lectures: 20)

UNIT-3: Introduction to Spectroscopy (Lectures: 10)

Spectroscopy and its importance in chemistry. Wave-particle duality. Electromagnetic radiation and its interaction with matter. Types of spectroscopy. Difference between atomic and molecular spectra.

Born- Oppenheimer approximation: Separation of molecular energies into translational, rotational, vibrational and electronic components.
Microwave (pure rotational) spectra of diatomic molecules. Selection rules. Structural information derived from rotational spectroscopy.
IR Spectroscopy: Selection rules, IR spectra of diatomic molecules. Structural information derived from vibrational spectra. Vibrations of polyatomic molecules. Group frequencies. Effect of hydrogen bonding (inter- and intramolecular) and substitution on vibrational frequencies.
Electronic Spectroscopy: Electronic excited states. Free electron model and its application to electronic spectra of polyenes. Colour and constitution, chromophores, auxochromes, bathochromic and hypsochromic shifts.

UNIT-4: Spectroscopic Methods in Structural Elucidation : (Lectures: 10)

UV-Visible spectroscopy: General electronic transitions, λmax & εmax, chromophores & auxochromes, bathochromic & hypsochromic shifts. Application of Woodward rules for calculation of λmax for the following systems: conjugated dienes - alicyclic, homoannular and heteroannular; α,β-unsaturated aldehydes and ketones, charge transfer complex.
Infrared (IR) Spectroscopy: Infrared radiation and types of molecular vibrations, significance of functional group & fingerprint region. IR spectra of alkanes, alkenes, aromatic hydrocarbons (effect of conjugation and resonance on IR absorptions), simple alcohols (inter and intramolecular hydrogen bonding and IR absorptions), phenol, carbonyl compounds, carboxylic acids and their derivatives (effect of substitution on >C=O stretching absorptions).

Practical:

Section A: Inorganic Chemistry

1. Estimation of the amount of nickel present in a given solution as bis - (dimethylglyoximato) nickel(II) or aluminium as oxinate in a given solution gravimetrically.
2. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.
3. Estimation of total hardness of a given sample of water by complexometric titration.

Section B: UV/Visible spectroscopy

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λmax values. Calculate the energies of the two transitions in different units (J molecule-1, kJ mol-1, cm-1, eV).
2. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of $K_2Cr_2O_7$
3. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.

(The above course structure/number of classes and list of experiments are suggestive. Faculty/academic bodies may incorporate revision /may incorporate text and reference books as per need).

References:

1. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A.(2010),*Shriver and Atkins Inorganic Chemistry,* W. H. Freeman and Company.
2. Miessler, G. L.; Fischer P.J.; Tarr, D.A.(2014), *Inorganic Chemistry*, Pearson.
3. Huheey, J.E.; Keiter, E.A., Keiter; R.L., Medhi, O.K. (2009), *Inorganic Chemistry- Principles of Structure and Reactivity*, Pearson Education.
4. Pfennig, B. W.(2015), *Principles of Inorganic Chemistry***.** John Wiley & Sons.
5. Kapoor, K.L. (2015), *A Textbook of Physical Chemistry*, Vol.4, 5th Edition, McGraw Hill Education.
6. Kapoor, K.L. (2015), *A Textbook of Physical Chemistry*, Vol.5, 3rd Edition, McGraw Hill Education.
7. B.R. Puri, L.R. Sharma, M.S. Pathania, (2017), *Principles of Physical Chemistry*, Vishal Publishing Co.
8. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C.(1989), *Vogel's Textbook of Quantitative Chemical Analysis,* John Wiley and Sons.
9. Marr, G.; Rockett, B.W. (1972), *Practical Inorganic Chemistry*, Van Nostrand Reinhold.
10. Khosla, B.D.; Garg, V.C.;Gulati, A.(2015), *Senior Practical Physical Chemistry*, R. Chand & Co.

SEMESTER VIII

CH-GEC-480: Chemistry of Food, Nutrition and Preservation

(40 lectures of 60 minutes each)

L	T	P	Cr
5	1	0	6

Learning objectives:

1. To know about the basic of human physiological system and food science
2. To learn about the nutrition and its importance
3. To learn about the food preservation and its utility.

Key words: Food, nutrition, preservation.

Learning Outcomes:

By the end of the course, the students will be able to:

1. Understand basic of human physiological system and food science
2. Nutrition and its importance

3. Learn about the food preservation and its utility.

UNIT-1: Basic of human physiological system and food science (Lecture: 13)

Digestive System: Structure and functions of G.I. tract, Process of digestion and absorption of food, Structure and functions of liver, gallbladder and pancreas. Basic concept on Food, Nutrition and Nutrients (Nutrition, Malnutrition and Health: Scope of Nutrition), Classification of Food, Classification of Nutrients.

UNIT-2: Nutrition (Lecture: 12)

Dietary fibers (composition, properties and Minerals and trace elements (biochemical and physiological role, bioavailability and requirement with examples), Vitamines (examples, biochemical and physiological requirments, deficiency and excesses), Water (requirement, water balance), basic idea about community nutrition (objective, importance of various programmes).

UNIT-3: Food preservation (Lecture: 15)

Definition, objectives and principles of food preservation.Different methods of food preservation. Preserved Products: Jam, Jelly, Marmalade, Sauces, Pickles, Squashes, Syrups-types, composition and manufacture, selection, cost, storage, uses and nutritional aspects,
Food Standards : ISI, Agmark, FPO, MPO, PFA, FSSAI.

Reference/suggested books

1. Roday S (2012): *Food Science and Nutrition*, 2nd Ed. Oxford University Press.
2. Mann J and Truswell S (2017) :*Essentials of Human Nutrition*, 5th Ed. Oxford University Press.
3. Wilson K and Walker J (2000): *Principles and Techniques of Practical Biochemistry*, 5th Ed. Oxford University Press.
4. Sadasivan S and Manikam K (2007): *Biochemical Methods*, 3rd Ed. New Age International (P) Ltd.
5. Oser B L (1965). *Hawk's Physiological Chemistry*, 14th Ed. McGraw-Hill Book
6. Gopalan C, Rama Sastri BV and Balasubramanian SC (2016): *Nutritive value of Indian Foods*, Indian Council of Medical Research.
7. Subalakshmi, G and Udipi, SA (2006), *Food processing and preservation*, 1st Ed. New Age International (P) Ltd.
8. Srilakshmi B (2018): *Food Science*, 7th Colour Ed. New Age International (P) Ltd.

ABILITY ENHANCEMENT COURSES (AECC)

SEMESTER- I

CH-AECC-111: English for communications

(30 lectures of 60 minutes each)

L	T	P	Cr
3	1	0	4

Learning Objectives:

1. Composition of english
2. Communicative skills
3. Writing and technical writing skills
4. Coherance
5. Drafting of letters, notices, minutes, etc.

Communication: Language and communication, differences between speech and writing, distinct features of speech, distinct features of writing.

Writing Skills: Selection of topic, thesis statement, developing the thesis; Introductory, developmental, transitional and concluding paragraphs, linguistic unity, coherence and cohesion, descriptive, narrative, expository and argumentative writing.

Technical Writing: Scientific and technical subjects; formal and informal writings; formal writings/reports, handbooks, manuals, letters, memorandum, notices, agenda, minutes; common errors to be avoided.

(The above course is suggestive. However, the course teacher/academic bodies may incorporate changes as per the need within corporation of appropriate textbooks, reference materials).

SEMESTER- II

CH-AECC-112: Environmental Science

(30 lectures of 60 minutes each)

L	T	P	Cr
3	**1**	**0**	**4**

After completion of the course, the learner can be able to understand:

1. Composition of atmosphere
2. Biogeochemical cycles
3. Hydrological cycle

4. Water quality parameters
5. Atomospheric chemical phenomon and environmental pollution
6. Water pollution, parameters of water pollution, treatment of polluted water

UNIT-1: Environment

Composition of atmosphere, temperature variation of earth atmospheric system (temperature vs.altitude curve), biogeochemical cycles of C,N,P,S and O system.

UNIT-2: Hydrosphere: Hydrological cycle, aquatic pollution and water quality parameters – Dissolve oxygen, biochemical oxygen demand, chemical oxygen demand, Analytical methods for the determination fluoride, chromium and arsenic, residual chlorine and chlorine demand, purification and treatment of municipal water and waste water.

UNIT-3: Atmosphere

Chemical composition of atmosphere – particle, ions, and radicals in their formation, chemical and photochemical reactions in atmosphere, smog formation, oxides of N, C, S, and O and their effect, pollution by chemicals, CFC, Green House Effect, acid rain, air pollution and control.

UNIT-4: Aquatic chemistry

Water and its necessities, various water quality parameters (DO, BOD, COD, conductivity, pH, alkalinity, hardness) and its determination, Industrial, municipal water treatment processes, Waste water treatment procedure (primary, secondary and tertiary), Solid waste treatment. Soil pollution and Noise pollution.

Recommended Books/References:

1. De. A.K. *Environmental Chemistry*, Wiley Eastern Ltd, 1990.
2. Miller T.G.Jr., *Environmental Science*, Wadsworth publishing House, Meerut Odum.E.P., 1971.
3. Odum,E.P. (1971) *Fundamentals of Ecology*, Third Edition, W.B.Saunders Co., Philadelphia
4. Sharma and Kaur, *Environmental Chemistry*, Krishna publishers, 2016.
5. S.M. Khopker, *Environmental Pollution, Monitoring and control*, NewAge International,2007.
6. G. S. Sodhi, *Fundamental Concepts of Environmental Chemistry* (Third Edition) Narosa (2009).

List of suggested laboratory practicals

Determination of water quality parameters in following aspect:

1. Determination of dissolved oxygen in given water (chemical method/instrumentation method).
2. Determination of Biological Oxygen Demand (BOD).
3. Determination of Chemical Oxygen Demand (COD).
4. Finding out percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by titration method ($AgNO_3$ and potassium chromate).
6. Estimation of total alkalinity of water samples (carbonate, bicarbonate) by titration method.
7. Estimation of SPM in air samples.

List of Recommended books/ReferenceBooks:

1. R.M. Felder, R.W.Rousseau: *Elementary Principles of Chemical Processes*, John Wiley & Sons, Inc. Publishers, NewDelhi (2005 edition).
3. J.A.Kent: *Riegel's Handbook of Industrial Chemistry*, CBS Publishers, NewDelhi.
4. S.S.Dara: *A Textbook of Engineering Chemistry*, S.Chand & Company Ltd. NewDelhi.
5. A.K.De, *Environmental Chemistry*: New Age International Pvt.,Ltd, NewDelhi.
6. S.M.Khopkar, *Environmental Pollution Analysis*: New Age Int. Publisher, NewDelhi.

(The list of experiments and books are purly suggestive; University/institute may incorporate further changes in number of experiments and books/refererences (updated version from time to time) based on course design and available infrastructure facilities).

SKILL ENHANCEMENT COURSES (SEC)

SEMESTER –I

CH-SEC-111: Computer Applications for chemistry

(30 lectures of 60 minutes each)

L	T	P	Cr
3	1	0	4

Learning outcomes:

After the completion of this course the learner will be able to:

1. Apply the basic operations of spreadsheet applications
2. Recognize advanced resources for accessing scholarly literature from internet
3. Utilize bibliography management software while typing and downloading citations
4. Operate various software resources with advanced functions and its open office substitutes

Keywords:

Spreadsheet, Googlesearch, Subscription, Bibliography, MS office, Image processing

UNIT-1: Spreadsheet Applications

Introduction of spreadsheet (MS Excel), application, formulas and functions, performing basic statistics using spreadsheet applications, creating basic graphs using spreadsheet applications, logical (Boolean) operators.

UNIT-2: Internet Resources

Advanced Google search operators and Boolean functions, Introduction to Google Scholar and accessing scholarly literature from Internet, Fake News and spotting the fake news, multimedia resources and podcasts, RSS/XML Feeds and feed subscription using a feedreader.

UNIT-3: Bibliography management

Introducing a bibliography management software (e.g. Endnote), Styles and Templates, Changing the bibliography style as per journal format, Citing while typing in the office application, downloading citations from Google Scholar.

UNIT-4: Other software resources

Introduction to advanced functions of MS Word and its Open Office substitutes including tracking changes, inserting page numbers and automatic table of contents, Google Docs and Forms, MS Power point, Microphotography and scale calibration with ImageJ, digital image processing (Paint.net or GIMP).

Suggested Readings

1. User manual and online user manual of respective e-softwares for the most updated content
2. Published books are not recommended as versions keep on updating very frequently; therefore, it is not easy to follow.

CH-SEC-112: Herbal Science & Technology

(30 lectures of 60 minutes each)

L	T	P	Cr
3	1	0	4

Learning outcomes:

On completion of this course the students will be able to;

1. Develop their understanding on Herbal Technology
2. Define and describe the principle of cultivation of herbal products.
3. List the major herbs, their botanical name and chemical constituents.
4. Evaluate the drug adulteration through the biological testing
5. Formulate the value added processing/storage/qualitycontrol for the better use of herbal medicine
6. Develop the skills for cultivation of plants and their value added processing/storage/quality control

UNIT-1: **Herbal Technology**

Definition and scope; Herbal medicines: history and scope; Traditional systems of medicine, and overview of AYUSH (Traditional Indian Systems of Medicine); Cultivation- harvesting-processing- storage of herbs and herbal products.

UNIT-2: Value added plant products

Herbs and herbal products recognized in India; Major herbs used as herbal medicines, nutraceuticals, cosmeticals and biopesticides, their Botanical names, plant parts used, major chemical constituents.

UNIT-3: Pharmacognosy

Systematic position, botany of the plant part used and active principles of the following herbs: Tulsi, Ginger, Curcuma, Fenugreek, Indian Gooseberry, *Catharanthus roseus*, *Withaniasomnifera*, *Centellaasiatica, Achyranthesaspera,* Kalmegh, Giloe (Tinospora), Saravar. Herbal foods, future of pharmacognosy.

UNIT-4: Analytical pharmacognosy

Morphological and microscopic examination of herbs, Evaluation of drug adulteration - types, methods of drug evaluation - Biological testing of herbal drugs –Phytochemical screening tests for secondary metabolites (alkaloids, flavonoids, steroids, triterpenoids, phenolic compounds). Plant gene banks, Cultivation of Plants and their value added processing/storage/quality control for use in herbal formulations, Introductory knowledge of Tissue culture and Micropropagation of some medicinal plants (*Withaniasomnifera*, neem and tulsi),

Suggested Readings

1. Agarwal, P., Shashi, Alok., Fatima, A. and Verma, A. (2013). *Current scenario of Herbal Technology worldwide:An overview*. *Int J Pharm Sci Res*; 4(11):4105-17.
2. Arber,Agnes.(1999). *Herbal Plants and Drugs*. MangalDeep Publications, Jaipur.
3. Varzakas, T., Zakynthinos, G, and Francis Verpoort, F. (2016). *Plant Food Residues as a Source of Nutraceuticals and Functional Foods*. Foods 5: 88.
4. Patri, F. and Silano, V. (2002). *Plants in cosmetics: Plants and plant preparations used as ingredients for cosmetic products-Volume 1*. ISBN978-92-871-8474-0,pp218.
5. AYUSH (www.indianmedicine.nic.in). *About the systems—An overview of Ayurveda*,*Yoga and Naturopathy*, *Unani*, *Siddha and Homeopathy.* New Delhi: Department ofAyurveda, Yoga and Naturopathy, Unani, Siddha and Homoeopathy (AYUSH), MinistryandFamily Welfare, Government of India.
6. Evans,W.C.(2009):*Trease and Evans PHARMACOGNOSY*. 16th Edition, SAUNDERS/Elsevier.
7. Sivarajan,V.V. and India, B.(1994). *Ayurvedic Drugs and Their Plant Sources.* Oxford & IBH Publishing Company, 1994-Herbs-570 pages.
8. Miller, L. and Miller,B. (2017). *Ayurveda & Aromatherapy: The Earth Essential Guide to Ancient Wisdom and Modern Healing.* Motilal Banarsidass, Fourth edition.
9. Kokate,C.K.(2003). *Practical Pharmacognosy*. Vallabh Prakashan,Pune.

CH-SEC-113: Water remediation & conservation studies

(30 lectures of 60 minutes each)

L	T	P	Cr
3	1	0	4

Learning outcomes:

On completion of this course the students will be able to:

1. Learn about the sources of water pollutants and the mechanisms of detoxification, bio-remediation and need of green chemistry.
2. Understand the importance of water conservation and erosion of soil and how to control the erosion.

UNIT-1: Water pollutants

Sources of water pollutants, pollutants, Industrial and human contribution, WHO recommendation about potable water, current scenario of drinking water quality, chemistry of toxicants like arsenic, fluoride, chromium, lead and mercury, cause and effects of water pollution, remediation, techniques involved such as adsorption, coagulation-filtration, Nalgonada techniques, reverse osmosis, activated charcoal detoxification, applications of non-toxic oxides and mixed oxides, regeneration and recycling, mechanisms of

detoxification, bio-remediation, need of green chemistry, future scope.

UNIT-2: Water conservation and erosion of soil

Introduction to water conservation and erosion of soil, forms of water erosion, factors affecting water erosion, types of water erosion, mechanics of water erosion control, agronomical measures of water erosion control, Terraces for water erosion control, Modeling of water-shed processes, Case study of water-shed modeling for water conservation and water quality.

Recommended Books/references:

1. Cittenden J.C.,TrussellJ.R.,HandD.W., HoweK.J.,Tchobanoglous G.,*Water Treatment: Principles and Design*, MWH publication.
2. De, A.K. *Environmental Chemistry*, Wiley Eastern
3. Clarson D., Dara S.S., *A textbook of Environmental Chemistry and Pollution Control,* S Chand & Co.
4. Edzwald J., *Water Quality & Treatment: A Handbook on Drinking Water,* Water Resources and Environmental Engineering Series)

SEMESTER- II

CH-SEC-121: Renewable Energies (solar and biogas)

(30 lectures of 60 minutes each)

L	T	P	Cr
3	1	0	4

Learning objectives:

1. To know the importance of renewable energy resources in the present context.
2. To learn various aspects of renewable energy.
4. To learn about solar mapping and basics of biomass sources
3. To familiarize with the techniques associated with the measurement and analysis of various renewable energy sources and studies of the composition of biomass.

UNIT-1: Renewable energy sources

Introduction to renewable energy sources – solar, wind, small hydro, biomass, geothermal and ocean energy, energy low in ecosystem, Solar Energy Resources, Solar radiation: Spectrum of EM radiation, sun structure and characteristics, extraterrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution.

Measurement of solar radiation Instruments: Sunshine recorder, Pyranometer, Pyrheliometer, Albedometer. Radiation measurement stations in India (NIWE, IMD etc.), solar radiation data, graphs, Meteonorm and NASA-SSE databases Hands-on measurement of beam, diffuse and total radiation

UNIT-2: **Solar mapping**

Solar mapping using satellite data, Typical MeteorologicalYear.

Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components.

UNIT-3: Biomass

Basics Biomass resources: plant derived, residues, aquatic and marine biomass, various wastes, photosynthesis. Biomass resource assessment, Estimation of woody biomass, non woody biomass and wastes, ASTM standards.
Bulk chemical properties Moisture content, proximate and ultimate analyses, calorific value, waste water analysis for solids.

Chemical composition of biomass: Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass, extractable, COD. Structural properties, Physical structure, particle size and size distribution, permeability.
Properties of microbial biomass: Protein estimation, flocculating ability, relative hydrophobicity of sludge, sludge volume index.

Suggested Readings

1. Mehmet Kanoglu, Yunus A. Cengel, John M. Cimbala; *Fundamentals and Applications of Renewable Energy*, 1st Edition, 2020 McGraw-Hill Education.
2. S. C. Bhatia, R. K. Gupta; *Textbook of Renewable Energy,* 2019 Woodhead Publishing India PVT. Limited.
3. Paul Matthews; *Introducing Renewable Energy*, 2015 Greenstream Publishing, United Kingdom.
4. S.R. Kalbande, V. M. Bhale, S.R. Sedani; *Textbook of Green Energy Technologies*, 2022 Narendea Publishing House.

CH-SEC-122: Biofertilizer

(30 lectures of 60 minutes each)

L	T	P	Cr
3	1	0	4

Learning outcomes:

On the completion of this course, the students will be able to;

1. Develop their understanding on the concept of bio-fertilizer
2. Identify the different forms of biofertilizers and their uses
3. Compose the Green manuring and organic fertilizers
4. Develop the integrated management for better crop production by using both nitrogenous and phosphate bio fertilizers

UNIT-1: Biofertilizer

General account about the microbes used as biofertilizer – Rhizobium – isolation, identification, mass multiplication, carrier based inoculants, Actinorrhizal symbiosis. *Azospirillum:* isolation and mass multiplication – carrier based inoculant, associative effect of different microorganisms. *Azotobacter*: classification, characteristics–crop response to *Azotobacter* in oculum, maintenance and mass multiplication.

UNIT-2: Cyanobacteria

Cyanobacteria (blue green algae), *Azolla* and *Anabaena azollae* association, nitrogen fixation, factors affecting growth, blue green algae and *Azolla* in rice cultivation.

UNIT-3: Mycorrhizal association

Mycorrhizal association: Types of mycorrhizal association, taxonomy, occurrence and distribution, phosphorus nutrition, growth and yield – colonization of VAM – isolation and inoculum production of VAM, and its influence on growth and yield of crop plants.

UNIT-4: Organic farming

Green manuring and organic fertilizers, Recycling of bio-degradable municipal, agricultural and Industrial wastes – biocompost making methods, types and method of vermin composting– field Application.

Suggested Readings

1. Dubey,R.C. (2005). *A Textbook of Biotechnology,* S. Chand & Co, NewDelhi.
2. John Jothi Prakash, E. (2004). *Outlines of Plant Biotechnology*. Emkay Publication, NewDelhi.
3. Kumaresan,V. (2005). *Biotechnology*, Saras Publications, NewDelhi.
4. NIIR Board. (2012). *The complete Technology Book on Biofertilizer and organic farming*. 2nd Edition. NIIR Project Consultancy Services.
5. Sathe, T.V. (2004) *Vermiculture and Organic Farming*. Daya publishers.
6. Subba Rao N.S. (2017). *Biofertilizers in Agriculture and Forestry*. Fourth Edition, Medtech.

CH-SEC-123: Chemistry in everyday life

(30 lectures of 60 minutes each)

L	T	P	Cr
3	1	0	4

Learning outcomes:

On the completion of this course, the students will be able to;

1. Develop their understanding on the energy production in human body
2. Understand the chemical aspects of some common health hazards
3. Understand the importance of vitamins, minerals and radical chemistry in living system
4. Develop the idea of materials chemistry in everyday life

UNIT-1: Respiration and energy production in human body

Respiration, Respiratory enzymes, brief outline of hemoglobin and myoglobin, oxygen transport mechanism in body, co-operativity, Respiration in lower animals, hemocyanine, hemerythrine. Energy production in body, ATP; enzyme responsible for food digestion, mechanism of food digestion, active site of cytochrome c-oxidase.

UNIT-2: Chemical aspects of some common health hazards

Anemia, sickle cell anemia, leukemia, blood pressure irregulation, blood sugar, arthritis,

carbon monoxide poisoning in mines, cyanide poisoning, fluorosis etc.

UNIT-3: Vitamins and minerals:

Need for vitamin in body, types of vitamins, water soluble and fat soluble vitamins, Vitamin B-12, vitamin- C (Cyanocobalamine), vitamin-D, Vitamin- K. Role of minerals in body, iodine deficiency and remedy.

UNIT-4: Significance of Radical chemistry in living system

Radical production in environment, superoxide and peroxide, health impact, action of radicals, cell mutation, diseases caused by free radical, cancer, radical quencher, anti-oxidants, natural anti-oxidants like vegetables, beverages like tea and coffee, fruits.
Radical destroying enzymes: Superoxide dismutase, catalase, peroxidase, mechanism of action.

UNIT-5: Chemistry of Materials

Soaps and Detergents – their action, Biofuels–production of biofuels and its utility as alternative fuel source, Fibers: natural fibers, cotton, wool, silk, rayon, artificial fibers, polyamides, acrylic acid, PVC, PVA; Examples of natural biodegradable polymers, cellulose, cellulose acetate, cellophane, soy protein, corn, zein protein, wheat gluten protein, synthetic biodegradable polymers. Use of polymeric materials in daily life.

Recommended Books/references:

1. Kaim W, *Bioinorganic Chemistry*,Vol 4, Brigitte Scwederski, Wiley, 1994.
2. Crichton, R.H. *Biological Inorganic Chemistry–An Introduction*, Elsevier, 2008.
3. BergJ.M.,Tymoczeko J.L.,Stryer l. *Biochemistry*, W.H.Freeman, 2008.
4. Bertini, I., Gray, H. B., Lippard, S. J. and Valentine, J. S. (1994) *Bioinorganic Chemistry.* University Science Books (1994)
5. Lippard S., Berg J.M. *Principles of Bioinorganic Chemistry*, University Science Books, 1994.
6. V.R. Gowariker, N.V. Viswanathan, J.Sreedhar, *Polymer Science*, NewAge International.