SAVITRIBAI PHULE PUNE UNIVERSITY, PUNE

SYLLABUS FOR

University Department

Master of Science

In

Organic Chemistry

PART-I and II

(Semester I, II, III and IV-choice based Credit system**)**

w.e.f. July 2018

Total Number of Credits: 80

Semester I		
Subject Code	**Subject Title**	**Number of Credits**
IC 120	Symmetry, Group Theory and Spectroscopy	4
OC 130	Reaction Mechanisms in Organic Chemistry	4
PC 140	Kinetics and Thermodynamics in Chemistry	4
Elective Courses (any one)		
IC 125	Physical Methods in Inorganic Chemistry and Main Group Chemistry	4
OC 135	Stereochemistry of Organic Reactions	4
PC 145	Chemical Mathematics and Elements of Computer Programming	4
Practicals for First Year		
IC 128	Experiments in Inorganic Chemistry	4
OC 138	Experiments in Organic Chemistry	4
PC 148	Experiments in Physical Chemistry	4
Semester II		
IC 220	Coordination and Bioinorganic Chemistry	4
OC 230	Synthetic Organic Chemistry and Spectroscopy	4
PC 240	Chemical Bonding and Molecular Spectroscopy	4
Total Number of Credits: 40		
Semester III		
OC 330	Pericylic Reactions, Photochemistry and Free Radical Chemistry	4
OC 331	Advanced Stereochemistry	4
Practicals for Second Year		
OC 338	Experiments in Organic Chemistry I	4
OC 339	Experiments in Organic Chemistry II	4
Elective Courses (any two)		
OC 335	Carbanions and Aromaticity in Chemistry	4

OC 336	Advance Reaction Mechanism	4
OC 337	Spectroscopic Methods in Structure Determination	4
Semester IV		
OC 430	Synthetic Organic Chemistry	4
OC 431	Asymmetric Synthesis, Chemistry of Carbohydrates	4
Elective Courses (any two)		
OC 435	Biogenesis of Organic Compounds and peptides	4
OC 436	Structure Determination and Chromatographic Technics	4
OC 437	Research Project	4
Total Number of Credits: 40		

UGC recommended courses (Additional 10 credits)		
Subject Code	**Subject Title**	**Number of Credits**
	Cyber Security/Information Security	4
	Skill Based Credits	4
	Human Rights Education	2

Courses which can be opted by students from outside departments:

Sub. Code	**Subject Title**	**Number of Credits**
Core courses		
	Semester- I	
OC 130	Reaction Mechanism's in Organic Chemistry	4
	Semester- II	
OC 230	Synthetic Organic Chemistry and Spectroscopy	4
	Semester- III	
OC 330	Pericylic Reactions, Photochemistry and Free Radical Chemistry	4
	Semester- IV	
OC 431	Asymmetric Synthesis, Chemistry of Carbohydrates	4
Elective Courses		
	Semester- I	

OC 135	Synthetic Organic Chemistry and Spectroscopy	4
	Semester- III	
OC 335	Carbanions and Aromaticity in Chemistry	4
OC 336	Advanced Reaction Mechanism	4
	Semester- IV	
OC 435	Biogenesis of Organic Compounds and Peptides	4
OC 436	Structure Determination and Chromatographic Technics	4

SEMESTER-I

IC 120: Symmetry, Group Theory and Spectroscopy (4Credits, 60L)

1. Definitions and theorems of group theory, subgroups, classes. **(4L)**

2. Molecular symmetry and symmetry groups - symmetry elements and operations. Symmetry planes reflections, inversion centre, proper / improper axes and rotations, products of symmetry operations , symmetry point groups ,classes of symmetry operations, classification of molecular point groups. **(10L)**

3. Representations of groups. Great orthogonality theorem, character tables, properties of characters of representations. **(8L)**

4. Group theory and quantum mechanics. Wave function as bases for irreducible presentation. **(2L)**

5. Symmetry Adapted Linear Combinations - (SALC) - projection operators and their use to construct SALC. **(6L)**

6. Molecular Orbital Theory.
   Transformation properties of atomic orbitals, MO's for Sigma bonding in ABn molecules, tetrahedral AB_4 case, Hybrid orbital's, MO's for pi bonding in ABn molecules. **(10L)**

7. Application of group theory to infrared spectroscopy (Ref.-2, Chapter-8)
   Introduction, selection rules, polyatomic molecules, possible vibration in a linear molecule, bending modes, symmetry of vibrations and their IR activity, Group vibration concept and its limitations, IR spectra related to symmetry of some compounds, IR spectra of complex compounds. **(10L)**

8. Raman spectroscopy:
   Theory of Raman spectroscopy, Instrumentation, Sample handling and Illumination, structural analysis , polarization measurements, quantitative analysis , applications of Raman spectroscopy, other types of Raman spectroscopy, Comparison of Raman and Infrared spectroscopy, Problems (Ref. 7: p.533-549) (Ref.8: p.321-336) **(10L)**

Books

1. Chemical applications and group theory F.A. Cotton, 3rd edition, John Wiley & Sons Asia Pvt. Ltd. (1999).
2. Group theory and its chemical applications: P.K Bhattacharya, 2nd edn, Himalaya pub. India,(1989).
3. Molecular symmetry and group theory -A. Vincent.
4. Symmetry in Chemistry: H.H. Jaffe' and M. Orchin, Dover Publications Inc, New York,(2002).
5. Symmetry in Inorganic Chemistry: J.P Fackler.
6. Principles of Materials Science and Engineering: William F. Smith (1980) (Chapter 3)
7. Instrumental analysis – By Douglas A .Skoog, F. James Holler, Stanley R. Crouch (Publisher:Cengage Learing India Pvt. Ltd . New Delhi , 2007)

8. Instrumental method of analysis (7th edition) By- H.H. Willard , L.L. Merritt. Jr. J.A. Dean and F.A. Settle,Jr (Publisher: CBS Publishers and distributors Pvt .Ltd. (Copyright – Wordsworth publishing copy USA .2000).

OC 130: Stereochemistry and Reaction Mechanism **(4 Credits, 60L)**

Aromatic Electrophilic substitution reactions **(15)**

Arenium ion mechanism, orientation and reactivity, energy profile diagram, calculation of partial rate factor, the ortho/ para ratio, Ipso substitution, Orientation in other ring systems such as Naphthalene, Anthracene, six and five membered heterocycles, Diazonium coupling, Vilsmeier reaction, Gattermann–Koch reaction etc. The $ArSN^1$, benzyne and SNR1, mechanisms, reactivity effect of substrate structure, leaving group and attacking nucleophile.

Kineticandnon-kineticmethods **(7)**

Hammond Postulate, Curtin-Hammett Principle, Microscopic Reversibility, Kinetic/Thermodynamic Control, First, Second and Pseudo-First Order Kinetics, trapping of intermediate(s), competition experiments, testing proposed/common intermediate, isolation and identification, characterization using spectral methods of product and intermediate, Cross-over experiments, Structure variation methods, Stereochemical analysis, Isotope labeling, Techniques to study radicals, Transient spectroscopy.

Hammett equation: **(8)**

Substituent constant, reaction constant, +ve, -ve rho values, reaction with small -ve rho values, interpretation of mechanism using rho values, non-linear Hammett plots, kinetic isotopic effect, entropy of activation.

Molecular rearrangement and reaction intermediate **(15)**

Structure, generation and stability of carbenes, nitrenes, carbocations and carbanions intermediates. Rearrangement reactions *viz*. Beckmann, Curtius, Hofmann, Lossen, Favorskii, Baeyer-Villiger, Wolff, Claisen, Pummerer, Wagner-Meerwin, Stevens, Dienone-Phenol, Sommelet-Hauser, Benzilic acid, Benzidine, Cope, Fries and Schmidt reaction.

Basic Concept of Stereochemistry of Organic Compounds **(15)**

Origin of Stereochemistry, Optical activity, Chirality and molecular symmetry, axial and central chirality. Projection formulae, Configuration (D/L, d/l, R/S, E/Z configuration in C, N, S, P containing compounds), Allenes, biphenyls and spiranes nomenclature and enantiomerism. Optical activity in biphenyls, spiranes, allenes and helical structures. Enantiomeric and distereomeric relationship, Isomerism in molecules with more than one chiral center, Pseudo-asymmetry, Prochirality. Enantomeric excess.

Books/References:

1. Organic Chemistry by J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford)
2. Advanced Organic Chemistry by J. March 6^{th} Edition
3. Advance Organic Chemistry (part A and B) by A. Carey and R. J. Sundberg
4. Stereochemistry of carbon compound by E. L. Eliel
5. Stereochemistry of organic compound by Nasipuri
6. The Hammett equation, C. D. Johnson, Cambridge University Press (1973)

PC 140: Kinetics and Thermodynamics in Chemistry (4 credits, 60L)
Chemical Kinetics: (2 credits, 30L)

1. Recapitulation:
   Rate of Reaction, empirical rate law, rate constants, order, molecularity, half-life and life time of reaction. Zeroth first and second, third and half-integral order reactions, methods to determine order of the reactions and temperature dependence of reaction rates (5L)
2. Complex reactions:
   Rate laws for complex reactions, parallel reaction with example of nuclear reactions and fluorescence decay, opposing reactions, rate constants by temperature jump method, consecutive reactions, rate determining step and steady state approximation (7L)
3. Approximate methods to solve complex reactions:
   Steady state and pre-equlibrium approximations, Lindemann mechanism for the unimolecular reaction. Enzyme catalysis – Michaelis Menton Mechanism, Lineweaver and Eadie plots, Chain reactions: free radical polymerization, oscillating reactions (8L)
4. Method of studying fast reactions:
   Flash photolysis, stop flow technique, pump and probe methods (3L)
5. Molecular reaction dynamics:
   Collision theory for bi-molecular reactions (derivation expected), steric factor, Transition state theory, Eyring equation (derivation expected)-thermodynamic aspects –entropy. – enthalpy and free energy of activation, effect of dielectric constant on the ionic reactions, primary and secondary salt effect, effect of pressure on the reaction rates. Linear free energy relationships (7L)

Text Books:

1. Atkins' Physical Chemistry, Peter Atkins and Julio e Paula ninth edition Oxford University Press 2011.
2. Physical Chemistry, D.A. McQuarrie, Viva Book private limited, 1998.
3. Chemical Kinetics, K. J Laidler, Third edition, Pearson Education Inc., 1987.

Thermodynamics (2 Credits, 30L)

1. Zeroth, first and second law of thermodynamics, dependence of enthalpy, free energy and entropy on pressure and temperature, free energy change and equilibrium constant, partial molar quantities–Maxwells equations and their applications, Third law of thermodynamics and its applications, residual entropy
   (13L)
2. Thermodynamics of Real Gases
   Concept of activity, choice of standard states, Methods of determining activity coefficient and activity coefficient, variation of activity and activity coefficient of a gas with pressure and temperature, concept of fugacity, fugacity of a gas in mixture of real gases (7L)
3. Statistical Thermodynamics
   Boltzmann distribution law, partition functions and ensembles, calculation of translational, rotational and vibrational partition functions, statistical thermodynamics and Third Law of Thermodynamics, internal energy, heat capacity, entropy, free energy, equilibrium constants (10L)

Text/Reference Books

1. Physical Chemistry, P. W. Atkins, Sixth Edition, Oxford University Press, Oxford (1998).
2. Physical Chemistry, T. Engel and P. J. Reid, Benjamin-Cummings (2005).
3. Physical Chemistry, G. M. Barrow, Fifth Edition, Tata McGraw Hill, New Delhi.

Elective Courses **(any one)**

IC 125: Physical Methods in Inorganic Chemistry and Main Group Chemistry
(4Credits, 60L)

(a) Main Group elements: (30 Lectures)

1. Hydrogen & its compounds (2L)
Hydrides, classification, e- deficient, e- precise & e- rich hydrides PH3,SbH3,AsH3, Selenides, Tellurides.

2. Alkali & alkaline earth metals (4L)
Solutions in non-aqueous Media. Application of crown ethers in extraction of alkali & alkaline earth metals.

3. Organometallic compounds of Li, Mg, Be, Ca, Na (2L)
Synthesis, properties, uses & structures.

4. Boron group (4L)
Boron Hydrides, preparation, structure & bonding with reference to LUMO, HOMO, interconversion of lower & higher boranes, Metalloboranes, Carboranes.

5. Carbon group (4L)
Allotropes of Carbon, C60 and compounds (fullerenes), Intercalation compounds of Graphite, Carbon nanotubes, synthesis, properties, structure-single walled, multiwalled, applications, classification of organometallic compounds. Organometallic compounds of B, Si, Sn,Pb, Ga, As, Sb, Bi. Structures, Synthesis, Reactions

6. Nitrogen group (4L)
Nitrogen activation, Boron nitride, Oxidation states of nitrogen & their nterconversion PN & SN compounds NOx & their redox chemistry

7. Oxygen group (4L)
Metal selenides & tellurides, oxyacids & oxoanions of S & N, Ring, Cage and Cluster compounds of p-block elements. Silicates, including Zeolites

8. Halogen group (4L)
Interhalogens, Pseudohalogen, synthesis, properties & applications, structure, oxyacids & oxoanions of Hallogens Bonding.

9. Noble gases (2L)
Synthesis, properties, uses, structure & bonding with respect to VSEPR.

(b) Physical Methods in Inorganic Chemistry (30 Lectures)

1. Crystal Structure and Crystal geometry (08)

Space Lattice and basic unit cells, Crystal systems and Bravais Lattices, Classification of space lattice by crystal systems and their structures, the relation between interatomic distance (d) and atomic radius(R) of cubic unit cells. The Atomic Packing factor of BCC, FCC and HCP unit cell and their examples, Atomic positions in cubic unit cells with origin at eight corners of the cube, directions in Cubic Unit Cells, Direction Indices in cubic unit cells, Miller indices for crystallographic planes in Cubic unit cells, Crystallographic planes in Hexagonal unit cell, Miller-Bravais indices. Volume, planar and linear density calculations of cubic unit cells, application of Miller indices in solving crystal structures, problems of all the topics.

2. NMR of Inorganic Compounds (10)

Concept of nuclear spin and resonance, fundamentals of coupling (homonuclear heteronuclear) and decoupling, coupling constants. Predicting Intensity of NMR lines by binomial, trinomial, tetranomial etc Pascal triangles Examples of ^{11}B and ^{10}B NMR, ^{1}H and ^{11}B NMR spectra of of BH_4^-, $Me_4{}^{11}B_2H_2$, $Me_2B(\mu\text{-}H)_2BH_2$, second order coupling in diborane, Effect of natural abundance. Structure elucidation by ^{19}F and ^{31}P NMR spectroscopy. Examples: ^{19}F NMR spectra of interhalogen compounds, ^{19}F and ^{31}P NMR to deduce structures of PF_3R_2 type compounds, ^{31}P NMR of Wilkinson catalyst, geometrical isomers of platinum compounds, *trans effect* and *meridonial*, *facial* isomers of rhodium compounds. General trends in chemical shifts, factors influencing chemical shift-geometry, electronegativity, charge and oxidation state, coordination number, effect of ligands, coordination effect on transition metal. General trends in coupling constant, factors influencing coupling constant- gyromagnetic ratio, periodicity, ‘s’ character in the bond, hybridization, coordination number, electronegativity, trans effect, inter bond angles lone pairs and oxidation state.

3. Mössbauer spectroscopy(12)

Basic principles of ^{57}Fe Mössbauer spectroscopy, instrumentation, spectral parameters

a) Mössbauer Parameters- Isomer Shifts, quadrupole splitting, Magnetic hyperfine interaction.

b) Application of Mössbauer spectroscopy with respect to

i) Oxidation states of metal ion in compounds

ii) Structural elucidation

iii) Covalent and ionic compounds

iv) High spin low spin behavior

v) Magnetically ordered compounds

Books:

1. Advanced Inorganic Chemistry: F. A. Cotton, G. Wilkinson,C. A. Murollo, M. Bochmann, 6th edn. (2003).
2. Inorganic Chemistry: D. F. Shriver and P.W. Atkins, 4th edn. Oxford (2003).
3. Concise inorganic Chemistry, J.D.Lee 4Th edition (Chapman and Hall)
4. Physical Methods in Chemistry, R. S. Drago, Saunders, Harcourt Brac Javanovich College Publishers, (1992).
5. NMR spectroscopy in Inorganic Chemistry, J. A. Iggo, Oxford University press (2001).
6. Mössbauer Spectroscopy and Transition Metal Chemistry, P. Gütlich,R. Link, A. Trautwien, Springer-Verlag (1978).
7. Mössbauer Spectroscopy, N.N. Greenwood, T.C. Gibb, Chapman and Hall Ltd. (1971).
8. Instrumental method of analysis (7th edition) By- H.H. Willard , L.L. Merritt. Jr. J.A. Dean and F.A. Settle,Jr (Publisher: CBS Publishers and distributors Pvt .Ltd. (Copyright – wardsworth publishing copy USA .2000).

OC 135: Stereochemistry and Reaction Mechanism (4 Credits, 60L)

Aromatic Electrophilic substitution reactions (15)

Arenium ion mechanism, orientation and reactivity, energy profile diagram, calculation of partial rate factor, the ortho/ para ratio, Ipso substitution, Orientation in other ring systems such as Naphthalene, Anthracene, six and five membered heterocycles, Diazonium coupling, Vilsmeier reaction, Gattermann–Koch reaction etc. The $ArSN^1$, benzyne and SNR1, mechanisms, reactivity effect of substrate structure, leaving group and attacking nucleophile.

Kinetic and non-kinetic methods (7)

Hammond Postulate, Curtin-Hammett Principle, Microscopic Reversibility, Kinetic/Thermodynamic Control, First, Second and Pseudo-First Order Kinetics, trapping of intermediate(s), competition experiments, testing proposed/common intermediate, isolation and identification, characterization using spectral methods of product and intermediate, Cross-over experiments, Structure variation methods, Stereochemical analysis, Isotope labeling, Techniques to study radicals, Transient spectroscopy.

Hammett equation: (**8**)

Substituent constant, reaction constant, +ve, -ve rho values, reaction with small -ve rho values, interpretation of mechanism using rho values, non-linear Hammett plots, kinetic isotopic effect, entropy of activation.

Molecular rearrangement and reaction in termediate (15)

Structure, generation and stability of carbenes, nitrenes, carbocations and carbanions intermediates. Rearrangement reactions *viz.* Beckmann, Curtius, Hofmann, Lossen, Favorskii, Baeyer-Villiger, Wolff, Claisen, Pummerer, Wagner-Meerwin, Stevens, Dienone-Phenol, Sommelet-Hauser, Benzilic acid, Benzidine, Cope, Fries and Schmidt reaction.

Basic Concept of Stereochemistry of Organic Compounds (15)

Origin of Stereochemistry, Optical activity, Chirality and molecular symmetry, axial and central chirality. Projection formulae, Configuration (D/L, d/l, R/S, E/Z configuration in C, N, S, P containing compounds), Allenes, biphenyls and spiranes nomenclature and enantiomerism. Optical activity in biphenyls, spiranes, allenes and helical structures. Enantiomeric and distereomeric relationship, Isomerism in molecules with more than one chiral center, Pseudo-asymmetry, Prochirality. Enantomeric excess.

Books/References:

1. Organic Chemistry by J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford)
2. Advanced Organic Chemistry by J. March 6thEdition
3. Advance Organic Chemistry (part A and B) by A. Carey and R. J. Sundberg
4. Stereochemistry of carbon compound by E. L. Eliel
5. Stereochemistry of organic compound by Nasipuri
6. The Hammett equation – C. D. Johnson, Cambridge University Press (1973)

PC 145: Chemical Mathematics and Elements of Computer Programming

(4 Credits, 60L)

Chemical Mathematics (3 Credits, 45 L)

1. Functions, differential and integral calculus, limits, derivative, physical significance, basic rules of differentiation, maxima and minima, applications in chemistry, exactand inexact differential, Taylor and McLaurin series, curve sketching, partial differentiation, rules of integration, definite and indefinite integrals, integral involving exponential and Gaussian functions. (27L)
2. Differential equations
   Separation of variables, homogeneous, exact, linear equations, equations of second order, series solution method. (6L)
3. Probability
   Permutations, combinations and theory of probability (4L)
4. Vectors, matrices and determinants
   Vectors, dot, cross and triple products, introduction to matrix algebra, addition and multiplication of matrices, inverse, adjoint and transpose of matrices, unit and diagonal matrices, (4L)
5. Special functions, Gamma functions, hermite polynomials, Legendre polynomials, Laguerre functions – definitions and recursion relation (no proof required) (4L)

Elements of Computer Programming (1 credit, 15L)

Hardware and software, binary and decimal numbers, constants and variables, assignment statement, flow chart and their use, IF and GO TO statements, Do loops. Input, output and format statements, Subroutines, function subprograms, Algorithms, Introduction to programming languages (15L)

Text Books

1. The Chemical Maths Book, E. Steiner, Oxford University Press (1996).
2. Maths for Chemists, Volumes 1 and 2, Martin C. R. Cockett and Graham Doggett, Royal Society of Chemistry , Cambridge (2003).
3. Computers and Common Sense *R. Hunt and Shelley*, Prentice Hall, New Delhi (1998)

4. Computer Programming in Fortran-90 V. *Rajaraman*, Prentice Hall, New Delhi (1990)
5. Computer and Chemistry: introduction to programming and numerical methods *T. R. Dickson*, Freeman (1968)
6. Computer programs for chemistry *D. F. Detar* W. A. Benjamin Inc, New York Vol. 1-3 (1968-69)

Practicals for First Year

IC 128: Experiments in Inorganic Chemistry (4 Credits, 9 weeks)

1**.** Ore Analysis: At least two of the following:
a. Determination of silica and manganese in pyrolusite .
b. Determination of copper and iron from chalcopyrite.
c. Determination of silica and iron from hematite

2. Alloy analysis (At least two of the following)
a. Determination of tin & lead from solder.
b. Determination of iron & Chromium from mild steel.
c. Determination of copper and nickel from cupronickel.

3. Inorganic Synthesis and purity determination (any five)
a. Cis-trans potassium di-aquo di-oxalato chromate (III)
b. Chloro penta-ammino cobalt (III) chloride
c. Nitro penta-ammino cobalt (III) chloride
d. Nitrito penta-ammino cobalt (III) chloride
e. Bis,2-4 pentanedionato cobalt (II) and cobalt (III)
f. Potassium tri-oxalato aluminate

4. Ion-exchange chromatography
Separation of mixture of Zn(II) and Mg(II) using Ammberlite IRA 400 anion exchanger and quantitative estimation of separated ions Zn(II) and Mg(II)
(a) Chelation in Nickel complexes: Preparation of Ni (II) ethylenediamine complexes and studying their absorption spectra.
(b) Solution state preparation of [Ni(en)3]S2O3, [Ni(H2O)6]Cl2, [Ni(NH3)6]Cl2. Record the absorption spectra in solution of all three complexes and analyze it. Arrange the ligands according to their increasing strength depending on your observation

5. Instrumental methods of analysis.
a. Colorimetry.
1. Simultaneous determination of Cr & Mn.
2. Determination of Keq of M-L Systems such as ,
Fe (III) - salicylic acid, Fe (III)-Sulphosalicylic acid
Fe (III) - b -resorcilic acid by Job's & Mole- ratio method.
b. Determination of iron by solvent extraction technique in a mixture of Fe3+ + Al 3+ & Fe3+ + Ni2+ using 8- hydroxyquinoline reagent.
c. Study of aquation of [Fe(o-phen)3] in acid solution by spectrophotometry.
d. Conductometry (Ref.- 5)

i.Verification of Debye Hückle theory of ionic conductance for strong electrolytes KCl,BaCl2.K2SO4, K3[Fe(CN)6]
ii.Structural determination of metal complexes by conductometric measurement
iii. To study complex formation between Fe(III) with sulfosalicylic acid by conductometry
e New Experiments : (any one)
i. Data analysis, error analysis, least squares method. Plot of Born Maeyer to determine for 1:1 type molecule to determine internuclear separation. Characterization of metal ligand bonding using IR spectroscopy.
ii. Computer Applications: (1) Electronic structure, vibrational characteristics and charge distributions in first row transition metal complexes. (2) Visualizing frontier MO's.
iii. Analysis of Electronic spectra of transition metal complexes at least for one system (dn Oh or Td) and calculation of Crystal Field parameters, inter electronic repulsion parameter and bonding parameter.

References:

1. Textbook of Quantitative Analysis, A. I. Vogel. 4th edn (1992).
2. Inorganic Electronic spectroscopy: A.B.P.Lever, 2nd edn Elsevier Science Publishers, New York, (1984).
3. Inorganic Synthesis (Vol. Series)
4. Practical Manual made By Department of Chemistry, University of Pune
5. Experiments in Chemistry, D.V.Jahagirdhar, Himalaya Publishing House

Practical course:

OC-138: Organic Chemistry practical (Departmental Course) (**4 Credits**)

1. Practical techniques: Crystallization, fractional crystallization, distillation, fractional distillation, sublimation, thin layer chromatography and column chromatography.
2. Derivatives: Acetyl, 2,4-DNP, anilide, amide, aryloxy acetic acid etc.
3. At least two Oxidation and Reduction reactions
4. Single stage preparations (6 preparations) based on regio-selective and chemo selective principals
5. Two stage preparations (6 preparations)

Note-i) Preparations preferred to be club with various technics and ii) Preparation preferred to be on the aromatic substitution, Nucleophilic substitution, Free radical substitution, Addition, Elimination Condensation, Rearrangements, Oxidation, Reduction etc.

PC 148: Experiments in Physical Chemistry (4 Credits)

Conductometry:

1. Hydrolysis of NH4Cl or H3COONa or aniline hydrochloride
2. Solubility of a sparingly soluble salt.
3. Hydrolysis of ethyl acetate by NaOH.
4. Determination of DG, DH, and DS of Silver Benzoate by conductometry.

Potentiometry:

1. Stability constant of a complex ion.
2. Solubility of a sparingly soluble salt.
3. Determination of dissociation constant of acetic acid.

4. Estimation of halide in mixture.
5. pH metry.
6. Hydrolysis of aniline hydrochloride.
7. Determination of the acid and base dissociation constants of an amino acid and hence the isoelectric point of the acid.
8. To determine the amount of aspirin in the given tablet.

Colorimetry:

1. Analysis of a binary mixture.
2. Copper EDTA photometric titration.
3. Determination of stability constant of ferricsalicylate complex by colorimetric measurements

Radioactivity:

1. Half-life of a radioactive nuclide.
2. Determination of Emax of beta radiation and absorption coefficients in Al.
3. Counting errors.

Chemical kinetics:

1. Kinetic decomposition of diacetone alcohol by dilatometry.
2. Determination of an order of a reaction.
3. Bronsted primary salt effect.
4. Kinetics of the reduction of methylene blue by ascorbic acid.

Non-Instrumental:

1. Freundlich and Langmuir isotherms for adsorption of acetic acid on active charcoal.
2. Molecular weight by steam distillation.
3. Glycerol radius by viscosity.
4. Partial Molar volume (Pycnometry)
5. Determine the viscosities of mixtures of different compositions of liquids and find the composition of a given mixture.

Computer applications:

1. Least square fitting of experimental data.

Each candidate should perform a minimum of 20 experiments with at least two experiments from each technique.

Text Books

1. Findlay's Practical Physical Chemistry, B. P. Levitt and J.A. Kitchener 9th Edition, Longmans, London (1972).
2. Experiments in Physical Chemistry by J. M. Newcombe, R. J. Denaro, A. R. Rickett, R.M.W Wilson, Pergamon (1962).
3. Senior Practical Physical Chemistry, 5th Edition, B. D. Khosla, V. S. Garg and A. Khosla, R. Chand (1987).

SEMESTER II

IC 220: Coordination & Bioinorganic Chemistry (4Credits, 60L)

(a) Coordination Chemistry

1. Concept & Scope of ligand Fields. **(1L)**

2. Energy levels of transition metal ions, Free ion terms, spin –orbit coupling. **(7L)**

3. Effect of ligand fields on energy levels of transition metal ions, weak cubic ligand field effect on Russell-Saunders terms, strong field effect, correlation diagrams, Tanabe-Sugano diagrams, Spin-pairing energies. **(8L)**

4. Electronic spectra of complexes, band intensities, band energies, band width & shapes, spectra of 1st, 2nd & 3rd row ion and rare earth ion complexes, spectrochemical & Nephelauxetic series, charge transfer & luminescence spectra, calculations of Dq, B, ı parameters. **(8L)**

5. Magnetic properties of complexes, paramagnetism,1st & 2nd ordered Zeeman effect, quenching of orbital angular momentum by Ligand fields, Magnetic properties of A,E,T ground terms in complexes, spin free–spin paired equilibria **(6L)**

(b) Bioinorganic Chemistry

6. Overviews of Bioinorganic Chemistry. **(2L)**

7. Principles of coordination Chemistry related to Bioinorganic–Proteins, nucleic acids and other metal binding biomolecules **(6L)**

8. Choice, uptake and assembly of metal containing units in Biology **(6L)**

9. Control and utilization of metal ion concentration in cells. **(6L)**

10. Metal ion folding and cross –linking of biomolecules. **(6L)**

11. Binding of metal ions and complexes to biomolecular active Centers **(4L)**

Books:

1. Ligand field theory & its application: B. N. Figgis & M. A. Hitchman Wiely VCH publ. (2000), Chapters 5, 6, 8,9,11.

2. Principles of Bioinorganic Chemistry: S.J.Lippard & J.M Berg, University science books, Mill Valley, California (1994), Chapters- 1,2,3,5,6,7,8.

3. Inorganic Chemistry: D. F. Shriver & P. W. Atkins, Oxford (1999).

4. Inorganic Electronic spectroscopy: A.B.P.Lever, 2nd edn Elsevier Science Publishers, New York, (1984).

5. Biological Chemistry of the Elements: R. J. P. Williams & F. R. DeSalvia, Oxford University Press-(1991).

6. Bioinorganic Chemistry: Inorganic elements in the Chemistry of life: An introduction and guide:W.Kaim,B.Schwederski,VCH,(1991).

OC 230 – Synthetic Organic chemistry and Spectroscopy (4 credits, 60L)

Oxidation and Reduction: (**12**)

Oxidation Reactions: CrO_3 (Jones reagent) PDC, PCC, $KMnO_4$, MnO_2, Swern Oxidation, SeO_2, $Pb(OAc)_4$, Pd/C, OsO_4, m-CPBA, O_3, $NaIO_4$, HIO_4, R_3SiH, Bu_3SnH, Reaction of NBS. Reduction viz. Wilkinson's catalyst, metal hydrides, $NaCNBH_3$, NH_2NH_2, DIBAL, Zn, etc. Stereochemistry involved in hydrogenation, hydroboration, B.V. oxidation, $KMnO_4$, OsO_4, $Pb(OAc)_4$, oxymercuration, Wilkinson's catalyst, O_3, $NaIO_4$, HIO_4 etc.

Ylids:Phosphours, sulphur and nitrogen, synthesis and applications (**5**)

Organo-metallic chemistry: (**10**)

Li, Zn, Cu, Mg, Al, Si etc., Hydroboration and synthesis of borane reagents and its use in oxidation and protonation.

Spectroscopy: (**18**)

Basics of UV, IR and NMR. Instrumentation and recording of spectra of UV, IR and NMR, Elementary ideas of NMR, integration, chemical shifts etc. Factors affecting chemical shifts, Coupling (First order, analysis), Problems based on UV, IR and NMR.

Heterocyclic Chemistry: (**15**)

Structure, reactivity, synthesis and reactions of pyrrole, furan, thiophene, pyridine, indole, benzofuran, quinolone and isoquinoline.

Books/References:

1. Carey and Sundberg. (Ed. IV), Part B – Adv. Organic Chemistry.
2. H.O. House, Synthetic Organic Chemistry.
3. Norman R.O.C. Organic Chemistry.
4. Advanced Organic Chemistry by J. March 6^{th}Edition
5. Silversteine and Basser, Spectrometric Identification of Organic Compounds.
6. P.S. Kalsi, Organic Spectroscopy.
7. J. Bellamy, Infrared spectra of Complex molecules.
8. I Fleming, Organic Spectroscopy.
9. J. Clayden, N.Greeves et. al Organic Chemistry
10. Pavia Spectroscopy of Organic Compounds
11. Heterocyclic Chemistry – J. A. Joule, K. Mills and G. F. Smith

PC 240: Chemical Bonding and Molecular Spectroscopy (4 Credits, 60 L)

Chemical Bonding (2 Credits, 32 L)

1. Recapitulation, quantization, Postulates of Quantum mechanics, Schrödinger equation, particle in a box, particle in 3-D box, degeneracy, hydrogen-like atoms (no derivation), atomic orbitals. (12 L)
2. Variational method, many electron atoms, orbital angular momentum, electron spin, wave functions of many electron atoms, Pauli exclusion principle, spin-orbit interaction, fine structure, vector atom model, spectral terms. (5 L)
3. Molecular orbital theory, Born-Oppenheimer approximation, H2 molecule, homo and hetero-nuclear diatomic molecules, MO diagrams of simple triatomic molecules. (5 L)
4. Valence bond theory of simple molecules, quantitative treatment of hydrogen molecule and related systems, hybridization, comparison of VBT and MOT. (4 L)
5. Hückel theory of conjugated hydrocarbons, Electron densities, Bond orders and free valence indices, Illustrations (6 L)

Text Books

1. Quantum Chemistry, I. Levine, 5th Edition, Prentice Hall (1999).

Reference Books

1. Valence, C. A. Coulson, ELBS (1974).
2. Introduction to Quantum Mechanics- with Applications to Quantum Chemistry, L. Pauling and E. B. Wilson, Dover Publishers (1999).
3. Orbitals in Chemistry, V. Gil, Cambridge University Press (2000).

Molecular Spectroscopy (2 Credits, 28 L)

1. Recapitulation, regions of electromagnetic spectrum, width and intensity of spectral lines. (2 L)
2. Rotational spectra: classification of molecules based on the moment of inertia, Schrodinger equation of rigid rotor, diatomic molecules, effect of isotopic substitution, centrifugal distortion, linear triatomic molecules, symmetric top molecules, stark effect. (5 L)
3. Infrared spectra: quantum mechanical harmonic oscillator, diatomic molecule, Morse potential, overtone and hot bands, polyatomic molecules, skeletal and normal vibrations (6 L)
4. Vibrational rotational spectra, fine structure in diatomic molecules, break down of the Born-Oppenheimer approximation, effect due to nuclear spin, parallel and perpendicular vibrations. (4 L)
5. Raman Spectra: classical and quantum theory of Raman effect, stokes and antistokes lines, polarizability ellipsoid, rotational Raman spectra, selection rule, vibrational raman spectra, rule of mutual exclusion, elucidating structure from the combined infrared and Raman spectra, rule of mutual exclusion (6 L)
6. Electronic spectra: Born-Oppenheimer approximation, molecular progression, term symbols, Franck-Condon principle, dissociation energies, oscillator strength, rotational fine structure, fortrat parabola, predissociation, photoelectron spectroscopy (5 L)

Text Books

1. Fundamentals of Molecular Spectroscopy, C. M. Banwell and E. McCash, Tata McGraw Hill, 4th Edition (1994).
2. Molecular Spectroscopy, J. Machale, Prentice Hall, NJ, USA (1999).
3. Vibrating Molecules, P. Gans, Chapman and Hall, UK (1971).

SEMESTER-III

OC-330: Pericylic Reactions, Photochemistry and Free Radical Chemistry

(4 credits 60L)

Pericyclic reactions (20)

Recapitulation of molecular orbitals, their symmetry properties, Woodward –Hoffmann's conservation of orbital symmetry property rule and its application to the ground state and excited state electrocyclic reactions, Cycloaddition, Chelotropic, Sigmatropic reactions etc. Fukui's HOMO and LUMO orbitals and its application to the ground state and excited state electrocyclic reactions. Synthesis of Endiandric acid and Citral (through pericyclic reactions and BASF synthesis).

Photochemistry: (14)

Principles of photochemistry, Orbital symmetry considerations, Excited states and their properties, experimental set up for photochemical reactions; Photochemical reactions of olefin, carbonyl, aromatic substrates and their applications in organic synthesis. Reactions viz. Isomerization, Patterno-Buchi, Barton, Norrish type I and II etc. Rearrangement reactions viz. di-π-methane, oxa di-π- and aza di-π-methane etc. Photochemical aromatic substitution reaction, Reactions with singlet oxygen. Applications of photochemical methods in synthesis of Isocumene, Cedrene and Hirsutene**.**

Free radicals in organic synthesis (12)

Formation, stability and detection of long and short lived radicals, homolysis and free radical displacements, addition and rearrangement of free radicals, Baldwins rules of ring closer, radical cyclizations and their applications in synthesis

Heterocyclic drug and natural product synthesis (14)

Chemistry of heterocycles containing two heteroatoms: Pyrazines, pyradiazins, pyrimidines,1,2; 1,3 and 1,4 diaoxazines and thiazines: pyrazole pyrazolines and imidazoles, imidazolines, Transition metals in heterocyclic C-N, C-O bond formations, Synthesis of chloroquine, Papavarine, Amlodipine, Bromouidine, Ranitidine, Vit-B6, Tryptophan, Thiamine, Histidine, Heterocyclic chemistry carbenes and their applications in the synthesis.

Books/References:

1. Advanced Organic Chemistry, Part A, F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007).
2. Radicals in Organic Synthesis B. Giese, Pergamon press (1986)
3. Organic Photochemistry: A visual approach, Jan Kopecky, VCH publishers (1992).
4. Excited states in Organic Chemistry, J.A. Barltrop and J.D. Coyle, John Wiley & sons
5. Oganic Photochemistry, O. Kan
6. Norman R.O.C. Organic Chemistry.
7. Conservation of orbital symmetry, R. B. Woodward and R. Hoffmann; Verlag Chemie, weinheim (1970).
8. Orbital Symmetry : A problem solving approach- R. E. Lehr and A. P. Marchand; Academic (1972).
9. Organic reactions and orbital symmetry, 2nd Ed. T. L. Gilchrist and R. C. Storr; Cambridge, University Press.
10. Modern Heterocyclic Chemistry, L. A. Paquette (Benjamin).
11. Heterocyclic Chemistry – J. A. Joule, K. Mills and G. F. Smith

OC-331: Advanced Stereochemistry (4 credits, 60L)

Conformation and reactivity in acyclic compounds (6)

Dimethyl butane, pentane, ethylene glycol, haloalkanes, stillbene dichloride, ethanol, halo-ethanol, carbonyl compounds, oxime, imide, amide, ester, acid etc.

Stereochemistry of Six membered rings (6)

Conformation and Reactivity of cyclohexane, cyclohexanone, cyclohexene, cyclohexane-alkylidene. 2-Alkyl, 3-alkyl ketone effect, 2-haloketone effect, Allylic strain. Steric assistant and steric acceleration and reactivity of six membered rings such as saponification, solvolysis, rearrangement, epoxidation of halohydrins, opening of epoxide, substitution, elimination, pyrolytic elimination, merger of substitution and elimination, NGP, amine nitrous acid reaction, enolisation, ketonisation, reduction, catalytic hydrogenation of

cyclohexanone, oxidation of cyclohexanol.

Rings other than six membered ring (12)

Three, four, five membered, rings and larger than 6-membered medium rings, conformational effects in medium rings, transannular effects, concept of I strain, fused rings and bridged rings

Stereochemistry of natural products (6)

Strychnine, podophyllotixin, Taxol and problems based on stereochemistry

Fused rings and bridged rings (14)

Bicyclic and polycyclic, Occurrence, availability, stereochemical restrictions and reactions of norbornyl system, correlation of axial dissymmetry and center of dissymmetry.

Determining Enantiomer Composition (8)

Measuring specific rotation, NMR method, Shifting reagents for NMR Analysis, Determining the enantiomer composition of chiral glycols or cyclic ketones, Chromatographic methods, Capillary electrophoresis with enantioselective supporting electrolyte, Determining absolute configuration, X-ray diffraction methods, Chiroptical methods, Chemical interrelation method, Prelog's method, Horeau's method, NMR Method for relative Configuration determination etc.

ORD and CD: Theory and its application in determination of stereoisomers **(8)**

Books/References:

1. Stereochemistry of Carbon Compounds E. L. Eliel
2. Stereochemistry of Carbon Compounds E. L. Eliel and S. H. Wilen
3. Organic Chemistry J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press.)
4. Stereochemistry of organic compounds, Nasipuri
5. Organic Chemistry, Cram, Hammond, Hendrickson
6. Principal and applications of asymmetric synthesis, G. Qianglin, Y. Minglin, A. Chan (Willey)

Practical Courses

4. **OC– 338** Preparations of stereo selective reaction (**4- credits**)

i) Two stage preparations based on stereo selective reaction (minimum six)

ii) Three stage preparations based on name reactions with chemoselective, and stereoselective reaction

5. OC – 339 Advanced Synthesis (small project of 4-5 step reactions) **(4 Credits)**

OC-335: Carbanions and Aromaticity Chemistry (4 credits 60L)

Carbanions in Organic Chemistry (22)

Ionization of carbon hydrogen bond and prototopy, Base and acid catalysed halogenation of ketones, keto-enol equilibria, structure and rate in enolisation, concerted and carbanion mechanism for tautomerism,carbanion character in phenoxide and pyrrolyl anions, geometry of carbanions, hydrolysis of haloforms, Aldol, Mannich, Cannizzaro, Darzens, Dieckmann, Claisen Baylis-Hillman reactions, Knoevenagel, benzoin condensation, alkylation of enolates and stereochemistry thereof, Conjugate additions. Directed enaolate alkylation, aldol reaction

and its application natural product synthesis, Enamines and imine anions in organic synthesis etc.

Aromaticity (8)

Criteria of aromaticity energy, Structural and electronic criteria, Relationship among the energetic, Structural and electronic criteria of aromaticity, Inscribed polygon method for monocyclic compounds The Annulenes-cyclobutadiene, Benzene, Cyclooctatetraene, [10] Annulenes, [12], [14], and [16] Annulenes, [18] Annulene and larger annulenes, other related structures-Kekulene, Fullerene, Aromaticity in charged rings, Heteroaromatic systems, Fused-ring systems, Compounds with exocyclic double bonds, Substituted aromatics, Other aromatic compounds, Mesoionic compounds, The dianion of squaric acid, Mobius aromaticity, Homoaromaticity etc.

Designing in Organic Synthesis (22)

Synthons and Chirons, Retrosynthetic analysis and synthesis, Chiron definition, types, application of Chiron use of carbohydrates, alpha-amino acid, alphahydroxy acids and terpenes in selected natural product, Umpolung in organic synthesis

Protection and deprotection of functional groups viz. hydroxyl, amino, carboxyl and carbonyl, alkene and alkyne **(8)**

Books/References:

1. Mechanism and structure in Organic Chemistry – E. S. Gould (Holt, Rinehart and Winston)
2. Advanced organic chemistry Part, A. F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007)
3. Advanced organic chemistry by J. March, 6th Ed.
4. Organic Chemistry, J. Clayden, N. Greeves, S. Warren and P. Wothers. (2001 or later)
5. Aromaticity, P. Garratt

OC 336 Advanced Reaction Mechanism (Optional) (4 credits 60L)

Stereoelectronic effect on reactivity (18)

Geometric constraint on SN^2 reaction, E1,E2, E1cB reactions, dioxiranes and per-acid reactions, Cope /Coreys Winter reaction, Bayer Villiger rearrangements, Baldwins rules of ring closer, Exocyclic enolate alkylations, intramolecular aldol reactions.Introduction of hyperconjugation and NBO analysis, Rple of hyperconjugation in cyclohexane, sigma acceptor abilities, Epimerization equilibrium heterocycles, some recent examples.

Aldol reaction (12)

soft enolaisation, Chiral auxillaries in aldol reactions Aldehyde and enolate facial selectivity, double stereodifferentiating aldol reactions, Zimmerman traxler transition state, Polar Felkin vs Comforth, application of aldole natural produt synthesis.

Hydrogen (18)

Weak and strong H bond, Hydrogen bonding Classical vs non-classical intermolecular forces, Donor acceptor vs electronic views, Prototypical H bonds, Charge and resonance assisted H bonds, Cooperative and anti-cooperative network, Symmetric H bond. H bond length by X-ray. Use of IR, 1H and 3C NMR, Raman, X-ray for N-H-N, N-H-O-N-X, NH-C, C-H-N/O/X etc determination. Use of H bonding in explaining reaction mechanism, H bond assisted organic reactions, application of H bonding in drug interactions, and peptides and proteins.

Structure determination of natural products. **(12)**

Structure elucidation of natural products by spectroscopy and degradative methods: Examples of natural products from following classes of secondary metabolites Alkaloids, Flavonoids, Sterols, Coumarins Triterpenes, Xanthones, each 2-3 examples.

Books/References:

1. Mechanism and structure in Organic Chemistry – E. S. Gould (Holt, Rinehart and Winston)
2. Advanced Organic Chemistry part-A. F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007)
3. Advanced Organic Chemistry by J. March, 6th Ed.
4. Organic Chemistry, J. Clayden, N. Greeves, S. Warren and P. Wothers (2001)
5. Modern Organic Synthesis by M. H. Nantz et al.
6. Organic Chemistry I.L Finar 6th Edition
7. Modern Methods in Stereoselective Aldol Reactions by by Rainer Mahrwald, 2013

OC-337: Spectroscopic Methods in Structure Determination (4 credits 60L)

^{1}H NMR

(12)

Recapitulation of basic principles, Fourier Transform technique, Pulse sequence and relaxation processes. Use of integration in the quantative determination of isomers, Factors affecting chemical shifts (inductive, resonance and anisotropic effect with examples), chemical shift of different types of protons (alkane, alkene, alkyne and allene), aromatic protons and effect of substituent, different types of spin coupling, first order analysis of spectra, Ramsay mechanism of spin coupling, roofing effect with example, different spin systems (AB, AM, AX, ABX/AMX spin systems with examples), calculations of line intensities and chemical shifts in AB spin system, factors affecting coupling constants (dihedral angle, Karplus equation-graph, electronegativity, bond order, hybridization, bond angle with examples), non-equivalence due to restricted rotations, rate processes. Effect of high field NMR for simplification of spectra, Shift reagents. Spin decoupling and Nuclear Overhauser effect with examples. NMR of Intra & intermolecular hydrogen bond, C---H---N, C---H---O, Ar-H---O=C etc., explanation of NMR with X-ray, determination of stereoisomer using NMR,

^{13}C NMR (10)

Elementary ideas, instrumental difficulties, FT technique advantages and disadvantages. Proton Noise Decoupling technique advantages and disadvantages, off-resonance technique, Chemical shifts of solvents, factors affecting chemical shifts, analogy with 1H NMR, calculations of chemical shift of hydrocarbons, effect of substituents on chemical shifts, different types of carbons (alkene, alkyne and allene), chemical shift of aromatic carbons and effect of substituent. Chemical shifts of carbonyl, nitrile, oxime carbons.

Two dimensional (2D) (8)

NMR techniques, principle and pulse technique, DEPT with 3 different angles, ^{1}H-1H COSY, ^{1}H, ^{13}C COSY, (HETCOR, HMQC), CIDNP, interpretation of 2D spectra and examples.

Mass spectrometry (16)

Principal and theory, instrumentation, various methods of ionizations, field ionization, FAB, MALDI, californium plasma, different detectors (magnetic analyzer, ion cyclotron analyzer, quadruple mass filter, time of flight). Importance of HRMS, Rules of fragmentation of different functional groups, factors controlling fragmentation. Fragmentation of different types of compounds like alkanes alkenes, aromatic compounds, carbonyl compounds, nitriles etc.

Problems on spectroscopy (10)

Problems based on joint application of UV, IR, ^{1}H and ^{13}C NMR, 2D and Mass (including reaction sequence.

X-ray: Application of Single Crystal X-ray in organic chemistry, ORTEP diagram **(4)**

Books/References:

1. Introduction to Spectroscopy D. L. Pavia, G.M. Lampman, G. S. Kriz, 4th Ed. (Harcourt college publishers).
2. Spectrometric Identification of Organic Compounds R. M. Silverstein, F. X. Webster, 6th Ed. John Wiley and Sons.
3. Spectroscopic Methods in Organic Chemistry, D. H. Williams and I. Flemming McGraw Hill.
4. Absorption Spectroscopy of Organic Molecules, V. M. Parikh
5. Nuclear Magnetic Resonance, Basic Principles, Atta-Ur-Rehman, Springer- Verlag (1986).
6. One and Two dimensional NMR Spectroscopy, Atta-Ur-Rehman, Elsevier (1989).
7. Organic Structure Analysis, Phillip Crews, Rodriguez, Jaspars, Oxford University Press (1998).
8. Organic Structural Spectroscopy, J. B. Lambert, Shurvell, Lightner, Cooks, Prentice-Hall (1998).
9. Organic Structures from spectra, Field L. D., Kalman J.R. and Sternhell S. 4th Ed. John Wiley
10. NMR Spectroscopy of Organic Compounds. Jackmann and Sternhell S
11. Modern X-Ray Analysis on Single Crystals: A Practical Guide by Peter Luger, 2014

Semester IV 3 Courses **12 credits** + 1 course inter sectional option **4 credits + 1 project 4 credit** = **20 credits**

OC 430: Synthetic Organic Chemistry (4 credits, 60L)

Transition metals in Organic Synthesis (24)

Introduction, basic concepts, TS metal complexes, 16-18 electron rule, oxidation states, ligands, oxidative addition, reduction elimination, association, dissociation, transmetallation, migratory insertion. Wacker, Trost-Tsuji, Heck, Sonogashira, Stille, Suzuki, carbonylative Suzuki and stile, Negishi, Kumada, Hiyama, Buchwald-Hartwig, Buchwald-Goldberg, carbonylative amination. Ni-catalyzed homo coupling and carbonylation, Ni-allyl complexes. Alkene-alkene metathesis, En-yne metathesis, alkyne-alkyne metathesis, Hydrogenation: Wilkinson's, Knowles, Noyori etc. Hydroformylation, Hydrocarboxylation, Pausan-Khand, Nicholas, Mn and Co catalyzed carbonylation. Fe-cat. Carbonylation, protection of diene, Cr. Metal-arene complexes. Jacobsen, Sharples epoxidation and dihydroxylation, Click reactions and Benzyne Chemistry

Organo-Bornes (**06**)

Preparation and there reactivity, Applications in synthesis of alcohol, amine, halognation, protonolysis and C-C bond formation. Reactions with alkyne, synthesis of E and Z alkene, Z,Z diene, E,E diene, preparation of allyl borane and their application.

Synthesis of natural products and drug molecules (30)

Synthesis based on disconnection approach and direct associative approaches. Juvobione (minimum 4 approaches) Strychnine (Overmann, Woodward), prostoglandins F2 (Corey and Stokes), Penicillins, Estrone, Mifepristone (Vollard) and Taxol.

Books/References:

1. Modern Synthetic Reactions H. O. House (Benjamin)
2. Organic Chemistry J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press)
3. Designing of Organic Synthesis – S. Warren (Wiley)
4. Some modern methods of organic synthesis – W. Carruthers (Cambridge)

5. Organic Synthesis – M. B. Smith
6. Organometallics in organic synthesis J. M. Swan and D. C. Black (Chapman and Hall)
7. Advanced organic chemistry, Part B F. A Carey and R. J. Sundberg 5th edition (2007)
8. Palladium in Organic Synthesis by Richard Heck
9. Organo Nickel Compounds by Jolly
10. Comprehensive organometallic chemistry, Vol. 1-8
11. Chiron approach in organic synthesis, S. Hanessian (relevant chapters for chirons)
13. Carbocyclic non-benzenoid aromatic compounds, D. Lloyd
14. Classics in total synthesis, K. C. Nicolaou and E. J. Sorensen; VHC (1996)
15. P. A. Wender and J. J. Howbert J. Am. Chem. Soc. 103, 688-690 (1981)
16. Henning Hopf et al Eur. J. Org. Chem., 567-581, (2005) and references cited therein.
17 Mehta**,** G.; Reddy, A. V. J. Chem. Soc., Chem. Commun**.** 1981, 456-457 and references cited therein

OC-431: Asymmetric synthesis, Chemistry of carbohydrates (4 credits, 60L)

Asymmetric synthesis (34)

Recapitulation of Stereochemical concepts- enantiomers, diastereomers, homotopic andheterotopic ligands, stereoselective and stereospecific reactions, prochirality, Chemo-, regio-, diastereo- and enantio-controlled approaches; Chirality transfer, Asymmetric inductions; Chiralpools, Chiral auxiliaries, chiral reagents and catalysts, and templates; Self-regeneration of stereo-center

Asymmetric reduction reactions: Reduction of Ketones and Imines: Hydrogenation of Ketones, Hydrogenation and Transfer Hydrogenation of Imines and , Transfer Hydrogenation of Ketones, Reduction of Ketones Using Enantioselective Borohydride Reagents, Diseteroselective reduction of olefins, Reduction by BINAL-H, Asymmetric Hydroformylation, Diastereoselective Syn-Reduction of β-Hydroxy -Ketones, Diastereoselective Anti-Reduction of β-Hydroxy Ketones,

Asymmetric C-C bond forming reaction: Simmon-Smith reaction, aldol reaction, Murayama aldol reaction, Shibasaki bi-metallic catalyst system; RAMP SAMP based alkylation strategy, Meyers oxazoline and bis-lactam based methods; Michael reaction, Henry reaction (Nitro aldol), Baylis-Hillman-Morita reactions, Asymmetric allylation, Asymmetric cycloaddition reactions, Asymmetric hydroformylation.

Use of chiral auxiliaries in asymmetric hydrogenation, asymmetric epoxidation and asymmetric dihydroxylation (other than Sharpless). Epoxidation of Cyclic Enones and Acyclic Enones, Epoxidation with Metal(salen) Complexes, Epoxidation using Metal–Porphyrin-Based catalysts, Epoxidation of Electron-Deficient alkenes, Epoxidation with iminium, Epoxidation of aldehydes

Synthesis of chiral natural products: The Synthesis of Erythronolide , The synthesis of 6-Deoxyerythronolide, The synthesis of Rifamycin S , Kishi's synthesis in 1980 , Kishi's synthesis in 1981, Masamune's synthesis, Synthesis of the o-side chain of the taxol, The enantioselective synthesis of (R)-4-Hydroxy-2Cyclopentenone

Advanced Carbohydrate Chemistry (12)

Introduction of sugars, structures of triose, tetrose, pentose, hexose. Fisher projection, D- and L-configuration, Conversion of Fisher projection to furanose and pyranose form, Haworth Structure, 4C1 and 1C4 Conformations, anomeric effect, Reactions of five and six carbon sugars, glycoside formation, acetonide formation, reduction, synthesis of D-glyceraldehyde, Killani- Fischer Synthesis, glucal formation and reactions, Ferrier and Hanesian Reaction, Ferrier rearrangement. Utilisation of the basic concepts of carbohydrate chemistry in the

synthesis of (S) Propanediol, (R) and (S) – Epichlorohydrin, L (+)-Alanine, 11-Oxaprostaglandin F2 (-) Multistratin, (-) Pentenomycin, (-) Shikimic acid, Carbonolide B.

Advanced stereoselective reactions: (**6**)

Carbocuperation, carboalumination, Tebbe, Petasis olefinations, Takai reaction, Alkyne bond forming reactions, cyclopropanation reaction.

Organocatalyst:SynthesisandApplications (8)

Imine and enamine cat reaction, thiourea and urea cat reaction, counter ion catalyzed reaction, hydrogen bonding and somo activation, cascade reaction, organo catalyzed and metal catalyzed reactions, heterocyclic carbenes and metal catalyzed reactions. Synthesis of drug and natural products using organo catalyzed reaction.

Books:

1. Asymmetric Reactions and Processes in Chemistry: Ernest L. Eliel
2. Catalytic Asymmetric Synthesis: 2nd Ed., Iwao Ojima
3. Asymmetric Organocatalysis: From Biomimetic Concept to Applications in Asymmetric Synthesis: David MacMillan
4. Organic Chemistry, J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press.)
5. Asymetric synthesis Vol.1-5 by J. D. Morrison
6. Chirotechnology:Industrial synthesis of optically active compounds, R. A. Sheldon
7. Organic Chemistry, R. P. Morrison and R. N. Boyd
8. Organic Chemistry, I. L. Finar, volume II
9. Chiron approach in organic synthesis – S. Hanessian
10. An introduction to Medicinal Chemistry, Grham L. Patric, Oxford press
11. The organic chemistry of drug design and drug action- R.B. Silverman
12. Exploring OSAR fundamentals and applications in chemistry and biology-Corwin Hansch and Albert Leo

Optional (Any One)

OC-435 Biogenesis of Organic Compounds and Peptides (4 credits 60L)

Biogenesis (**30**)

Terpenes: sesquiterpenes, triterpenes and chloesterol, alkaloids : polyketide Biogenesis of terpenes mono terpenes, Sesquiterpenes, Triterpenes, Steroids, Biogenesis of Alkaloidsornithine based(pyrrolizidine), Lysine based(quinolizidine and indolizidine),Pyridine based, Tyrosine and modified tetrahydroisoquinoline based alkaloids, Phenethylisoquinoline and terpinoid tetrahydroisoquinoline (Amaryllidaceae alkaloids) anthranilic acid based, simple Indole and terpinoid indole, Biogenesis of polyketides – saturate and unsaturated fatty acids, Arachidonic acid cascades – prostaglandins, Aromatics derived from polyketides, Synthesis of Prostaglandins, Thromboxane, Leukotriene in nature and lab

Chemistry of amino acids, peptides, nucleotides, nucleosides (15)

Chiral Synthesis of alpha and Beta amino-acid, Difficulties involved in synthesis of peptides, Importance of peptides in drug discovery, Protection and deprotection of amino acids: General aspects, need for protection, minimal versus global protection, protection of amino group by acid and base labile groups, protection of carboxyl group, concept of orthogonal protection in peptide synthesis, importance of side-chain functional group protection and details of protective groups used for masking individual amino acids, methods used for deprotection. Coupling reactions in peptide synthesis Side reactions in peptide synthesis: Deletion peptides, side reactions initiated by proton abstraction, protonation, and over-

activation and side reactions of individual amino acids. Principle of solid phase peptide synthesis, t-BOC and FMOC protocols, various solid supports and linkers: Activation procedures, peptide bond formation, deprotection and cleavage from resin, low and high HF cleavage protocols, formation of free peptides and peptide amides, purification and case studies, site-specific chemical modifications of peptides. Chemistry of nucleosides and nucleotides. Antibiotics-penicillins, cephalosporins, macrolides, aminosides, cyclins, oflaxacin, Crixivan (Nicolaeue).

Mechanism of biological processes (15)

Selectivity of enzyme mediated reactions and its comparison with synthetic reactions
Mechanisms involving vitamin B1, B2, B6, Biotin, NAD/NADP-NADH/NADPH, Folic acid, Riboflavin

Books

1. Peptides: Synthesis, structure and applications, Bernd Gutte
2. Organic Chemistry, H. Dugas
3. Biochemistry by Zubay Chapter 11.
4. Organic Chemistry Chapter 50, J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press.)
5. Secondary metabolism by J.Mann
6. Medicinal Natural products by P. M. Dewick

OC-436 Structure Determination and Chromatographic Techniques (4 credits 60L)

Structure elucidation: (22)

Typical structure elucidation insights for natural products by combination of classical, spectroscopic, synthetic and degradative methods depicting examples
Use of spectroscopic techniques such as ^{1}H NMR, ^{13}C NMR, NOE, DEPT, HMQC, HMBC, COSY, NOESY, HRMS and FAB mass for structural elucidation of selected natural products. Importance of chromatographic separation, mass analyzers, atmospheric pressure ionisation techniques: ESI, APPI, APCI. Interpretation of API mass spectra: Molecular weight determination, typical fragmentation behavior for individual functional groups: (i) Phosphorous (ii) Sulfur (iii) Nitrogen (iv) Oxygen. halogen substituent's. Alkyl and aryl substitution on the aromatic ring, polycyclic aromatic hydrocarbons, alkenes and alkynes. Liquid chromatography - electrospray ionization - mass spectrometry (LC-ESI-MS) to the detection and determination of antibiotics drugs, antidiabetics, anti-tumor, antiretroviral drugs. EI-MS of small molecular mass of selected drugs fragmentation information. (Workshops on structural determinations)
Use of X-Ray, Raman spectra for structure determinations

Chromatographic techniques in organic chemistry (22)

Chromatographic theory chromatographic methods, mechanism of separation. Column efficiency, Band broadening and resolution, (HETP) theoretical plates. Types of chromatography viz. TLC, GC, HPLC, HPTLC, Ion exchange chromatography, over pressure layer chromatography (OPLC), centrifugal chromatography, Counter-current chromatography, droplet counter-current chromatography, affinity, size exclusion and ion-pair. Electrophoresis, its principle and capillary electrophoresis. Introducing or injection (split, split less, split-split less and purge and trap. Chromatographic detectors (UV-VIS, conductivity detector for IEC, FID, NPD, PID, RI, Diode array and ECD. Introduction to gas chromatography, GC-MS and LC-MS techniques. Operational modes of HPLC (Reverse and Normal phase) quantitative analysis and applications. Chiral columns and its applications.

Optimization of the separation methods regarding retention, selectivity and resolution of analytes. Integration methods of chromatograms. Interpretation of spectra.

Organic Chemistry of Drug Design (16)

Organic chemistry of drug design and drug action-quantitative structure activity relationship Hammett equation, Taft equation Hansch analysis-derivations and application in drug design, illustration with examples Lypophilicity effect measurements of lipophilic identification of active part molecular graphics and lead modifications SAR by mass and NMR, Combinatorial chemistry- general aspects, split synthesis, peptide and non-peptide libraries, Drug receptor interactions enzyme inhibiter and drug target, Stereo selectivity and drug action, stereo selective synthesis of Ibuprofen, crixivan, propranol etc.

OC- Research Project 437

Research Project and experimental. **(4 credits)**

Theory of research methodology: Aim of project, writing record book, writing lab report, literature survey, importance of purification methods, Computational designing of molecules, lab safety etc. Presentation of research reports: abstracts, posters, orals, seminars, symposium, interviews, Impact factors, Journals, writing papers, reviews with examples.

Experimental work – Based on synthesis of natural products.

Students are required to submit written record and present details of the project to be pursued in semester-III. This should include the purpose and basis of the project, stating aims, objectives and probable outcomes, be able to supplement these with necessary information, literature review towards it, and process for the project itself.

LABORATORY SAFETY

The following safety rule applies **at all times** in the laboratory rooms.

• No open food or drink is permitted at any time, whether a lab is in progress or not.
• No eating, drinking, or chewing of gum or tobacco is permitted.
• Never taste anything at all while in the lab rooms.

The following additional rules apply **while a laboratory session is in progress**.

• The lab is restricted to the students enrolled in the course. Visitors, especially children, are not allowed.
• You must wear goggles for eye protection during every laboratory period, until all students have completed all their experiments. Even if you wear prescription glasses or contact lenses, you need to wear goggles as well.
• Report all accidents to your laboratory instructor immediately.
• Know the location of the two main exits from the room, eye washes, safety shower, fire alarms, fire blanket and fire extinguishers. (First Aid box, nearest hospital)
• If a chemical comes in contact with your eye, immediately flush the eye with a gently flowing source of water from the eyewash. If you wear contact lenses, remove them. Continue flushing for at least 15 minutes. Use your thumb and forefinger to hold your eyelids away from the eyeball, move your eyes continuously up and down and sideways to flush out thoroughly behind the eyelids and behind the eyeball. Notify the laboratory instructor immediately. Promptly seek medical attention. If someone else in the lab has a chemical in their eye, help them get to the eyewash and help them operate it!
• Clothing must offer you good protection against chemical spills and splashes.
• No high heeled shoes open toed shoes, sandals, or shoes made of loosely woven material not allowed.
• Legs must be covered by your clothing.
• No smoking is allowed in chemical laboratories.

• Every student must wear protective eye shields at all times in the laboratory. This is to protect you from your neighbor's mistakes as well as your own.
• Carry out experiments which produce toxic chemicals or vapors, and/or are likely to be violent, in a fume cupboard.
• Fire is a serious hazard in the laboratory and is usually caused by the careless handling of organic solvents. These must not be heated using a Bunsen burner.
• Do not peer into the mouth of a test tube which is being heated or in which a reaction may be occurring.
• If the clothing is splashed by a corrosive liquid, strip the clothing and treat the skin immediately. As a first treatment washing with water is generally appropriate, call a demonstrator to assist you.
• Wear a laboratory coat at all times in the practical laboratory to protect you and your cloths.
• Always carry a small towel to the laboratory to assist you in handling hot objects in addition to tongs.
• Bunsen burners may only be used in the fume cupboard or keep it away from the inflammable solvents.
• Most organic compounds are combustible. Those with low boiling points and high vapor pressure at room temperatures may present a serious fire hazard. Ether, for example, which has a boiling point of 35°C, may be ignited by a flame removed by sixteen feet. Hence, it is never permissible to heat over an open flame any substance in an open vessel containing such volatile liquids. Steam bath are ideal for this purpose.

Fire

Fire is one of the most serious and most likely hazards to occur in a laboratory. The most generally useful fire extinguisher in the laboratory is the carbonodioxide cylinder which can be safely used with most chemicals and electric equipment, and is clean.
Asbestos blankets are useful for smoothening small fires and burning clothing.

• Chemical Hazards

Most compounds are highly toxic when injected orally. Many chemicals are poisonous, corrosive, carcinogenic or explosive.
• Corrosive chemicals such as acids and alkalis are stored in low shelves and opened with care.
• One should never taste any compound and odors of substances should be detected with extreme care.
• Mouth pipetting is always potentially dangerous and some form of safety pipette must be used instead.
• Sensitive tissues, for example, the eye should not be needlessly exposed to vapors. One should never place his/her face directly over a reaction mixture.
• It is mandatory that each student study each experiment prior to undertaking any laboratory Procedure in order to understand the implications of the particular experiment.
• Dangers chemicals obtained from commercial sources usually carry a warning printed in the bottle. These warnings should be followed.
• It is the duty of all members of laboratory staff to co-operate in the prevention of accidents.
• In addition to the welfare of the staff of the laboratory there is concern for preservation of the building, equipment, furnishing and apparatus.

Courses which can be opted by students from outside departments:

Core courses Semester-I

OC 130: Stereochemistry and Reaction Mechanism (4 Credits, 60L)

Aromatic Electrophilic substitution reactions (15)

Arenium ion mechanism, orientation and reactivity, energy profile diagram, calculation of partial rate factor, the ortho/ para ratio, Ipso substitution, Orientation in other ring systems such as Naphthalene, Anthracene, six and five membered heterocycles, Diazonium coupling, Vilsmeier reaction, Gattermann–Koch reaction etc. The $ArSN^1$, benzyne and SNR1, mechanisms, reactivity effect of substrate structure, leaving group and attacking nucleophile.

Kineticandnon-kineticmethods (7)

Hammond Postulate, Curtin-Hammett Principle, Microscopic Reversibility, Kinetic/Thermodynamic Control, First, Second and Pseudo-First Order Kinetics, trapping of intermediate(s), competition experiments, testing proposed/common intermediate, isolation and identification, characterization using spectral methods of product and intermediate, Cross-over experiments, Structure variation methods, Stereochemical analysis, Isotope labeling, Techniques to study radicals, Transient spectroscopy.

Hammett equation: **(8)**

Substituent constant, reaction constant, +ve, -ve rho values, reaction with small -ve rho values, interpretation of mechanism using rho values, non-linear Hammett plots, kinetic isotopic effect, entropy of activation.

Molecular rearrangement and reaction intermediate (15)

Structure, generation and stability of carbenes, nitrenes, carbocations and carbanions intermediates. Rearrangement reactions *viz*. Beckmann, Curtius, Hofmann, Lossen, Favorskii, Baeyer-Villiger, Wolff, Claisen, Pummerer, Wagner-Meerwin, Stevens, Dienone-Phenol, Sommelet-Hauser, Benzilic acid, Benzidine, Cope, Fries and Schmidt reaction.

Basic Concept of Stereochemistry of Organic Compounds (15)

Origin of Stereochemistry, Optical activity, Chirality and molecular symmetry, axial and central chirality. Projection formulae, Configuration (D/L, d/l, R/S, E/Z configuration in C, N, S, P containing compounds), Allenes, biphenyls and spiranes nomenclature and enantiomerism. Optical activity in biphenyls, spiranes, allenes and helical structures. Enantiomeric and distereomeric relationship, Isomerism in molecules with more than one chiral center, Pseudo-asymmetry, Prochirality. Enantomeric excess.

Books/References:

1. Organic Chemistry by J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford)
2. Advanced Organic Chemistry by J. March 6^{th} Edition
3. Advance Organic Chemistry (part A and B) by A. Carey and R. J. Sundberg
4. Stereochemistry of carbon compound by E. L. Eliel
5. Stereochemistry of organic compound by Nasipuri
6. The Hammett equation, C. D. Johnson, Cambridge University Press (1973)

Semester-II

OC 230 – Synthetic Organic chemistry and Spectroscopy (4 credits, 60L)

Oxidation and Reduction: (**12**)

Oxidation Reactions: CrO_3 (Jones reagent) PDC, PCC, $KMnO_4$, MnO_2, Swern Oxidation, SeO_2, $Pb(OAc)_4$, Pd/C, OsO_4, m-CPBA, O_3, $NaIO_4$, HIO_4, R_3SiH, Bu_3SnH, Reaction of NBS. Reduction viz. Wilkinson's catalyst, metal hydrides, $NaCNBH_3$, NH_2NH_2, DIBAL, Zn, etc. Stereochemistry involved in hydrogenation, hydroboration, B.V. oxidation, $KMnO_4$, OsO_4, $Pb(OAc)_4$, oxymercuration, Wilkinson's catalyst, O_3, $NaIO_4$, HIO_4 etc.

Ylids:Phosphours, sulphur and nitrogen, synthesis and applications (**5**)

Organo-metallic chemistry: (**10**)

Li, Zn, Cu, Mg, Al, Si etc., Hydroboration and synthesis of borane reagents and its use in oxidation and protonation.

Spectroscopy: (**18**)

Basics of UV, IR and NMR. Instrumentation and recording of spectra of UV, IR and NMR, Elementary ideas of NMR, integration, chemical shifts etc. Factors affecting chemical shifts, Coupling (First order, analysis), Problems based on UV, IR and NMR.

Heterocyclic Chemistry: (**15**)

Structure, reactivity, synthesis and reactions of pyrrole, furan, thiophene, pyridine, indole, benzofuran, quinolone and isoquinoline.

Books/References:

1. Carey and Sundberg. (Ed. IV), Part B – Adv. Organic Chemistry.
2. H.O. House, Synthetic Organic Chemistry.
3. Norman R.O.C. Organic Chemistry.
4. Advanced Organic Chemistry by J. March 6^{th}Edition
5. Silversteine and Basser, Spectrometric Identification of Organic Compounds.
6. P.S. Kalsi, Organic Spectroscopy.
7. J. Bellamy, Infrared spectra of Complex molecules.
8. I Fleming, Organic Spectroscopy.
9. J. Clayden, N.Greeves et. al Organic Chemistry
10. Pavia Spectroscopy of Organic Compounds
11. Heterocyclic Chemistry – J. A. Joule, K. Mills and G. F. Smith

Semester III

OC-330: Pericylic Reactions, Photochemistry and Free Radical Chemistry

(4 credits 60L)

Pericyclic reactions (20)

Recapitulation of molecular orbitals, their symmetry properties, Woodward –Hoffmann's conservation of orbital symmetry property rule and its application to the ground state and excited state electrocyclic reactions, Cycloaddition, Chelotropic, Sigmatropic reactions etc. Fukui's HOMO and LUMO orbitals and its application to the ground state and excited state electrocyclic reactions. Synthesis of Endiandric acid and Citral (through pericyclic reactions and BASF synthesis).

Photochemistry: (14)

Principles of photochemistry, Orbital symmetry considerations, Excited states and their properties, experimental set up for photochemical reactions; Photochemical reactions of olefin, carbonyl, aromatic substrates and their applications in organic synthesis. Reactions

viz. Isomerization, Patterno-Buchi, Barton, Norrish type I and II etc. Rearrangement reactions viz. di-π-methane, oxa di-π- and aza di-π-methane etc. Photochemical aromatic substitution reaction, Reactions with singlet oxygen. Applications of photochemical methods in synthesis of Isocumene, Cedrene and Hirsutene**.**

Free radicals in organic synthesis (12)

Formation, stability and detection of long and short lived radicals, homolysis and free radical displacements, addition and rearrangement of free radicals, Baldwins rules of ring closer, radical cyclizations and their applications in synthesis

Heterocyclic drug and natural product synthesis (14)

Chemistry of heterocycles containing two heteroatoms: Pyrazines, pyradiazins, pyrimidines,1,2; 1,3 and 1,4 diaoxazines and thiazines: pyrazole pyrazolines and imidazoles, imidazolines, Transition metals in heterocyclic C-N, C-O bond formations, Synthesis of chloroquine, Papavarine, Amlodipine, Bromouidine, Ranitidine, Vit-B6, Tryptophan, Thiamine, Histidine, Heterocyclic chemistry carbenes and their applications in the synthesis.

Books/References:

1. Advanced Organic Chemistry, Part A, F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007).
2. Radicals in Organic Synthesis B. Giese, Pergamon press (1986)
3. Organic Photochemistry: A visual approach, Jan Kopecky, VCH publishers (1992).
4. Excited states in Organic Chemistry, J.A. Barltrop and J.D. Coyle, John Wiley & sons
5. Oganic Photochemistry, O. Kan
6. Norman R.O.C. Organic Chemistry.
7. Conservation of orbital symmetry, R. B. Woodward and R. Hoffmann; Verlag Chemie, weinheim (1970).
8. Orbital Symmetry : A problem solving approach- R. E. Lehr and A. P. Marchand; Academic (1972).
9. Organic reactions and orbital symmetry, 2nd Ed. T. L. Gilchrist and R. C. Storr; Cambridge, University Press.
10. Modern Heterocyclic Chemistry, L. A. Paquette (Benjamin).
11. Heterocyclic Chemistry – J. A. Joule, K. Mills and G. F. Smith

Semester-IV

OC-431: Asymmetric synthesis, Chemistry of carbohydrates (4 credits, 60L)

Asymmetric synthesis (34)

Recapitulation of Stereochemical concepts- enantiomers, diastereomers, homotopic andheterotopic ligands, stereoselective and stereospecific reactions, prochirality, Chemo-, regio-, diastereo- and enantio-controlled approaches; Chirality transfer, Asymmetric inductions; Chiralpools, Chiral auxiliaries, chiral reagents and catalysts, and templates; Self-regeneration of stereo-center

Asymmetric reduction reactions: Reduction of Ketones and Imines: Hydrogenation of Ketones, Hydrogenation and Transfer Hydrogenation of Imines and , Transfer Hydrogenation of Ketones, Reduction of Ketones Using Enantioselective Borohydride Reagents, Diseteroselective reduction of olefins, Reduction by BINAL-H, Asymmetric Hydroformylation, Diastereoselective Syn-Reduction of β-Hydroxy -Ketones, Diastereoselective Anti-Reduction of β-Hydroxy Ketones,

Asymmetric C-C bond forming reaction: Simmon-Smith reaction, aldol reaction, Murayama aldol reaction, Shibasaki bi-metallic catalyst system; RAMP SAMP based alkylation strategy, Meyers oxazoline and bis-lactam based methods; Michael reaction, Henry reaction (Nitro aldol), Baylis-Hillman-Morita reactions, Asymmetric allylation, Asymmetric cycloaddition reactions, Asymmetric hydroformylation.

Use of chiral auxiliaries in asymmetric hydrogenation, asymmetric epoxidation and asymmetric dihydroxylation (other than Sharpless). Epoxidation of Cyclic Enones and Acyclic Enones, Epoxidation with Metal(salen) Complexes, Epoxidation using Metal–Porphyrin-Based catalysts, Epoxidation of Electron-Deficient alkenes, Epoxidation with iminium, Epoxidation of aldehydes

Synthesis of chiral natural products: The Synthesis of Erythronolide , The synthesis of 6-Deoxyerythronolide, The synthesis of Rifamycin S , Kishi's synthesis in 1980 , Kishi's synthesis in 1981, Masamune's synthesis, Synthesis of the o-side chain of the taxol, The enantioselective synthesis of (R)-4-Hydroxy-2Cyclopentenone

Advanced Carbohydrate Chemistry (12)

Introduction of sugars, structures of triose, tetrose, pentose, hexose. Fisher projection, D- and L-configuration, Conversion of Fisher projection to furanose and pyranose form, Haworth Structure, 4C1 and 1C4 Conformations, anomeric effect, Reactions of five and six carbon sugars, glycoside formation, acetonide formation, reduction, synthesis of D-glyceraldehyde, Killani- Fischer Synthesis, glucal formation and reactions, Ferrier and Hanesian Reaction, Ferrier rearrangement. Utilisation of the basic concepts of carbohydrate chemistry in the synthesis of (S) Propanediol, (R) and (S) – Epichlorohydrin, L (+)-Alanine, 11-Oxaprostaglandin F2 (-) Multistratin, (-) Pentenomycin, (-) Shikimic acid, Carbonolide B.

Advanced stereoselective reactions: (**6**)

Carbocuperation, carboalumination, Tebbe, Petasis olefinations, Takai reaction, Alkyne bond forming reactions, cyclopropanation reaction.

Organocatalyst:SynthesisandApplications (8)

Imine and enamine cat reaction, thiourea and urea cat reaction, counter ion catalyzed reaction, hydrogen bonding and somo activation, cascade reaction, organo catalyzed and metal catalyzed reactions, heterocyclic carbenes and metal catalyzed reactions. Synthesis of drug and natural products using organo catalyzed reaction.

Books:

1. Asymmetric Reactions and Processes in Chemistry: Ernest L. Eliel
2. Catalytic Asymmetric Synthesis: 2nd Ed., Iwao Ojima
3. Asymmetric Organocatalysis: From Biomimetic Concept to Applications in Asymmetric Synthesis: David MacMillan
4. Organic Chemistry, J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press.)
5. Asymetric synthesis Vol.1-5 by J. D. Morrison
6. Chirotechnology:Industrial synthesis of optically active compounds, R. A. Sheldon
7. Organic Chemistry, R. P. Morrison and R. N. Boyd
8. Organic Chemistry, I. L. Finar, volume II
9. Chiron approach in organic synthesis – S. Hanessian
10. An introduction to Medicinal Chemistry, Grham L. Patric, Oxford press
11. The organic chemistry of drug design and drug action- R.B. Silverman
12. Exploring OSAR fundamentals and applications in chemistry and biology-Corwin Hansch and Albert Leo

Elective Courses

Semester-I

OC 135: Stereochemistry and Reaction Mechanism (4 Credits, 60L)

Aromatic Electrophilic substitution reactions (15)

Arenium ion mechanism, orientation and reactivity, energy profile diagram, calculation of partial rate factor, the ortho/ para ratio, Ipso substitution, Orientation in other ring systems such as Naphthalene, Anthracene, six and five membered heterocycles, Diazonium coupling, Vilsmeier reaction, Gattermann–Koch reaction etc. The $ArSN^1$, benzyne and SNR1, mechanisms, reactivity effect of substrate structure, leaving group and attacking nucleophile.

Kinetic and non-kinetic methods (7)

Hammond Postulate, Curtin-Hammett Principle, Microscopic Reversibility, Kinetic/Thermodynamic Control, First, Second and Pseudo-First Order Kinetics, trapping of intermediate(s), competition experiments, testing proposed/common intermediate, isolation and identification, characterization using spectral methods of product and intermediate, Cross-over experiments, Structure variation methods, Stereochemical analysis, Isotope labeling, Techniques to study radicals, Transient spectroscopy.

Hammett equation: (**8**)

Substituent constant, reaction constant, +ve, -ve rho values, reaction with small -ve rho values, interpretation of mechanism using rho values, non-linear Hammett plots, kinetic isotopic effect, entropy of activation.

Molecular rearrangement and reaction in termediate (15)

Structure, generation and stability of carbenes, nitrenes, carbocations and carbanions intermediates. Rearrangement reactions *viz*. Beckmann, Curtius, Hofmann, Lossen, Favorskii, Baeyer-Villiger, Wolff, Claisen, Pummerer, Wagner-Meerwin, Stevens, Dienone-Phenol, Sommelet-Hauser, Benzilic acid, Benzidine, Cope, Fries and Schmidt reaction.

Basic Concept of Stereochemistry of Organic Compounds (15)

Origin of Stereochemistry, Optical activity, Chirality and molecular symmetry, axial and central chirality. Projection formulae, Configuration (D/L, d/l, R/S, E/Z configuration in C, N, S, P containing compounds), Allenes, biphenyls and spiranes nomenclature and enantiomerism. Optical activity in biphenyls, spiranes, allenes and helical structures. Enantiomeric and distereomeric relationship, Isomerism in molecules with more than one chiral center, Pseudo-asymmetry, Prochirality. Enantomeric excess.

Books/References:

1. Organic Chemistry by J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford)
2. Advanced Organic Chemistry by J. March 6^{th}Edition
3. Advance Organic Chemistry (part A and B) by A. Carey and R. J. Sundberg
4. Stereochemistry of carbon compound by E. L. Eliel
5. Stereochemistry of organic compound by Nasipuri
6. The Hammett equation – C. D. Johnson, Cambridge University Press (1973)

Semester III

OC-335: Carbanions and Aromaticity Chemistry (4 credits 60L)

Carbanions in Organic Chemistry (22)

Ionization of carbon hydrogen bond and prototopy, Base and acid catalysed halogenation of ketones, keto-enol equilibria, structure and rate in enolisation, concerted and carbanion mechanism for tautomerism,carbanion character in phenoxide and pyrrolyl anions, geometry of carbanions, hydrolysis of haloforms, Aldol, Mannich, Cannizzaro, Darzens, Dieckmann, Claisen Baylis-Hillman reactions, Knoevenagel, benzoin condensation, alkylation of enolates and stereochemistry thereof, Conjugate additions. Directed enaolate alkylation, aldol reaction and its application natural product synthesis, Enamines and imine anions in organic synthesis etc.

Aromaticity (8)

Criteria of aromaticity energy, Structural and electronic criteria, Relationship among the energetic, Structural and electronic criteria of aromaticity, Inscribed polygon method for monocyclic compounds The Annulenes-cyclobutadiene, Benzene, Cyclooctatetraene, [10] Annulenes, [12], [14], and [16] Annulenes, [18] Annulene and larger annulenes, other related structures-Kekulene, Fullerene, Aromaticity in charged rings, Heteroaromatic systems, Fused-ring systems, Compounds with exocyclic double bonds, Substituted aromatics, Other aromatic compounds, Mesoionic compounds, The dianion of squaric acid, Mobius aromaticity, Homoaromaticity etc.

Designing in Organic Synthesis (22)

Synthons and Chirons, Retrosynthetic analysis and synthesis, Chiron definition, types, application of Chiron use of carbohydrates, alpha-amino acid, alphahydroxy acids and terpenes in selected natural product, Umpolung in organic synthesis

Protection and deprotection of functional groups viz. hydroxyl, amino, carboxyl and carbonyl, alkene and alkyne **(8)**

Books/References:

1. Mechanism and structure in Organic Chemistry – E. S. Gould (Holt, Rinehart and Winston)
2. Advanced organic chemistry Part, A. F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007)
3. Advanced organic chemistry by J. March, 6th Ed.
4. Organic Chemistry, J. Clayden, N. Greeves, S. Warren and P. Wothers. (2001 or later)
5. Aromaticity, P. Garratt

OC 336 Advanced Reaction Mechanism (Optional) (4 credits 60L)

Stereoelectronic effect on reactivity (18)

Geometric constraint on SN^2 reaction, E1,E2, E1cB reactions, dioxiranes and per-acid reactions, Cope /Coreys Winter reaction, Bayer Villiger rearrangements, Baldwins rules of ring closer, Exocyclic enolate alkylations, intramolecular aldol reactions.Introduction of hyperconjugation and NBO analysis, Rple of hyperconjugation in cyclohexane, sigma acceptor abilities, Epimerization equilibrium heterocycles, some recent examples.

Aldol reaction (12)

soft enolaisation, Chiral auxillaries in aldol reactions Aldehyde and enolate facial selectivity, double stereodifferentiating aldol reactions, Zimmerman traxler transition state, Polar Felkin vs Comforth, application of aldole natural produt synthesis.

Hydrogen (18)

Weak and strong H bond, Hydrogen bonding Classical vs non-classical intermolecular forces, Donor acceptor vs electronic views, Prototypical H bonds, Charge and resonance assisted H

bonds, Cooperative and anti-cooperative network, Symmetric H bond. H bond length by X-ray. Use of IR, 1H and 3C NMR, Raman, X-ray for N-H-N, N-H-O-N-X, NH-C, C-H-N/O/X etc determination. Use of H bonding in explaining reaction mechanism, H bond assisted organic reactions, application of H bonding in drug interactions, and peptides and proteins.

Structure determination of natural products. **(12)**

Structure elucidation of natural products by spectroscopy and degradative methods: Examples of natural products from following classes of secondary metabolites Alkaloids, Flavonoids, Sterols, Coumarins Triterpenes, Xanthones, each 2-3 examples.

Books/References:

1. Mechanism and structure in Organic Chemistry – E. S. Gould (Holt, Rinehart and Winston)
2. Advanced Organic Chemistry part-A. F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007)
3. Advanced Organic Chemistry by J. March, 6th Ed.
4. Organic Chemistry, J. Clayden, N. Greeves, S. Warren and P. Wothers (2001)
5. Modern Organic Synthesis by M. H. Nantz et al.
6. Organic Chemistry I.L Finar 6th Edition
7. Modern Methods in Stereoselective Aldol Reactions by by Rainer Mahrwald, 2013

Semester-IV

OC-435 Biogenesis of Organic Compounds and Peptides (4 credits 60L)

Biogenesis (**30**)

Terpenes: sesquiterpenes, triterpenes and chloesterol, alkaloids : polyketide Biogenesis of terpenes mono terpenes, Sesquiterpenes, Triterpenes, Steroids, Biogenesis of Alkaloidsornithine based(pyrrolizidine), Lysine based(quinolizidine and indolizidine),Pyridine based, Tyrosine and modified tetrahydroisoquinoline based alkaloids, Phenethylisoquinoline and terpinoid tetrahydroisoquinoline (Amaryllidaceae alkaloids) anthranilic acid based, simple Indole and terpinoid indole, Biogenesis of polyketides – saturate and unsaturated fatty acids, Arachidonic acid cascades – prostaglandins, Aromatics derived from polyketides, Synthesis of Prostaglandins, Thromboxane, Leukotriene in nature and lab

Chemistry of amino acids, peptides, nucleotides, nucleosides (15)

Chiral Synthesis of alpha and Beta amino-acid, Difficulties involved in synthesis of peptides, Importance of peptides in drug discovery, Protection and deprotection of amino acids: General aspects, need for protection, minimal versus global protection, protection of amino group by acid and base labile groups, protection of carboxyl group, concept of orthogonal protection in peptide synthesis, importance of side-chain functional group protection and details of protective groups used for masking individual amino acids, methods used for deprotection. Coupling reactions in peptide synthesis Side reactions in peptide synthesis: Deletion peptides, side reactions initiated by proton abstraction, protonation, and over-activation and side reactions of individual amino acids. Principle of solid phase peptide synthesis, t-BOC and FMOC protocols, various solid supports and linkers: Activation procedures, peptide bond formation, deprotection and cleavage from resin, low and high HF cleavage protocols, formation of free peptides and peptide amides, purification and case studies, site-specific chemical modifications of peptides. Chemistry of nucleosides and nucleotides. Antibiotics-penicillins, cephalosporins, macrolides, aminosides, cyclins, oflaxacin, Crixivan (Nicolaeue).

Mechanism of biological processes (15)

Selectivity of enzyme mediated reactions and its comparison with synthetic reactions
Mechanisms involving vitamin B1, B2, B6, Biotin, NAD/NADP-NADH/NADPH, Folic acid, Riboflavin

Books

1. Peptides: Synthesis, structure and applications, Bernd Gutte
2. Organic Chemistry, H. Dugas
3. Biochemistry by Zubay Chapter 11.
4. Organic Chemistry Chapter 50, J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press.)
5. Secondary metabolism by J.Mann
6. Medicinal Natural products by P. M. Dewick

OC-436 Structure Determination and Chromatographic Techniques (4 credits 60L)

Structure elucidation: (22)

Typical structure elucidation insights for natural products by combination of classical, spectroscopic, synthetic and degradative methods depicting examples
Use of spectroscopic techniques such as ^{1}H NMR, ^{13}C NMR, NOE, DEPT, HMQC, HMBC, COSY, NOESY, HRMS and FAB mass for structural elucidation of selected natural products. Importance of chromatographic separation, mass analyzers, atmospheric pressure ionisation techniques: ESI, APPI, APCI. Interpretation of API mass spectra: Molecular weight determination, typical fragmentation behavior for individual functional groups: (i) Phosphorous (ii) Sulfur (iii) Nitrogen (iv) Oxygen. halogen substituent's. Alkyl and aryl substitution on the aromatic ring, polycyclic aromatic hydrocarbons, alkenes and alkynes. Liquid chromatography - electrospray ionization - mass spectrometry (LC-ESI-MS) to the detection and determination of antibiotics drugs, antidiabetics, anti-tumor, antiretroviral drugs. EI-MS of small molecular mass of selected drugs fragmentation information. (Workshops on structural determinations)
Use of X-Ray, Raman spectra for structure determinations

Chromatographic techniques in organic chemistry (22)

Chromatographic theory chromatographic methods, mechanism of separation. Column efficiency, Band broadening and resolution, (HETP) theoretical plates. Types of chromatography viz. TLC, GC, HPLC, HPTLC, Ion exchange chromatography, over pressure layer chromatography (OPLC), centrifugal chromatography, Counter-current chromatography, droplet counter-current chromatography, affinity, size exclusion and ion-pair. Electrophoresis, its principle and capillary electrophoresis. Introducing or injection (split, split less, split-split less and purge and trap. Chromatographic detectors (UV-VIS, conductivity detector for IEC, FID, NPD, PID, RI, Diode array and ECD. Introduction to gas chromatography, GC-MS and LC-MS techniques. Operational modes of HPLC (Reverse and Normal phase) quantitative analysis and applications. Chiral columns and its applications. Optimization of the separation methods regarding retention, selectivity and resolution of analytes. Integration methods of chromatograms. Interpretation of spectra.

Organic Chemistry of Drug Design (16)

Organic chemistry of drug design and drug action-quantitative structure activity relationship Hammett equation, Taft equation Hansch analysis-derivations and application in drug design, illustration with examples Lypophilicity effect measurements of lipophilic identification of active part molecular graphics and lead modifications SAR by mass and NMR, Combinatorial chemistry- general aspects, split synthesis, peptide and non-peptide libraries, Drug receptor

interactions enzyme inhibiter and drug target, Stereo selectivity and drug action, stereo selective synthesis of Ibuprofen, crixivan, propranol etc.