MODERN EDUCATION SOCIET'S
NOWROSJEE WADIA COLLEGE, PUNE
(Autonomous)

Affiliated to Savitribai Phule Pune University

New Syllabi (As per National Education Policy 2020)
M.Sc. II (Organic Chemistry)

Board of Studies (Chemistry)
(Faculty of Science and Technology)

NOWROSJEE WADIA COLLEGE, PUNE
(Autonomous)
Affiliated to Savitribai Phule Pune University

Title of the Course: M.Sc. II Organic Chemistry

“Syllabus”

Structure of the Course :

Basic structure/pattern (Framework) of the proposed postgraduate syllabus for M.Sc. II Organic Chemistry in the Nowrosjee Wadia College, Pune affiliated to Savitribai Phule Pune University.

Each Semester: 22 Credits

Total Credits: 44

Additional Mandatory Extra Credits

The course structure of the M.Sc. II Organic Chemistry
Semester III

Sr. No.	Course	Course Code	Major Core/ Major elective	Credits
1.	Organic Reaction Mechanism and Stereochemistry	CHO-601 MJ	Major Core	4T
2.	Advanced Spectroscopic Methods in Structure Determination	CHO-602 MJ	Major Core	4T
3.	Heterocyclic Chemistry	CHO-603 MJ	Major Core	2T
4.	Organic Synthesis Experiments-I	CHO-604 MJP	Major Core	2P
5.	Organic Synthesis Experiments-II	CHO-605 MJP	Major Core	2P
6.	Ternary Mixture Separation	CHO-606 MJP	Major elective	2P
7.	Retrosynthetic analysis	CHO-607(A) MJ	Major elective	2T
	Biogenesis	CHO-607 (B) MJ		
	Medicinal Chemistry	CHO-607 (C) MJ		
8.	Research Project (RP)	CHO-608 RP	RP	4

Semester IV

Sr. No.	Course	Course Code	Major Core/ Major elective	Credits
1.	Chemistry of Natural Products	CHO-651 MJ	Major Core	4T
2.	Advanced Synthetic Organic Chemistry	CHO-652 MJ	Major Core	4T
3.	Convergent Organic Synthesis	CHO-653 MJP	Major Core	2P
4.	Divergent Organic Synthesis	CHO-654 MJP	Major Core	2P
5.	Green Chemistry Experiments	CHO-655 MJP	Major elective	2P
7.	Introduction to Chemical Biology	CHO-656 (A) MJ		
	Asymmetric synthesis of organic compounds	CHO-656 (B) MJ		
	Methods in Determining Reaction Mechanism	CHO-656 (C) MJ		
8.	Research Project (RP)	CHO-657 RP	RP	6

SEMESTER III

CHO-601 MJ : Organic Reaction Mechanism and Stereochemistry (4 Credits) Major Core Course [60 L]

Aim and Objectives of the course:

Student should learn -

1. Stereochemistry of substituted cyclohexane and its reactions with physical and chemical properties.
2. Conformations of heterocyclic ring and stereochemical properties. Also, the concept of anomeric effect and I-strain.
3. Stereochemistry of fused bicyclic, polycyclic norborneyl compounds. I strain, Bredts rule, enantiomerism and symmetry elements.

Unit-I	**Free Radicals:** Generation, stability, reactivity, Free radical substitution, addition to multiple bonds, radicals in synthesis, Inter and intra-molecular bond formation via mercury hydride, tin hydride, thiol donors, cleavage of C-X, C-Sn, C-S, O-O bonds, Oxidative coupling, C-C bond formation in aromatics, SNAr reactions, Free Radicals in Organic Synthesis	**12L**
Unit-II	**Ylides:** Phosphorus Ylide- Wittig reaction, Modified Wittig reaction (Horner-Wadsworth-Emmons reaction) Nitrogen Ylide- Steven's reaction, Sommelet-Hauser reaction. Sulfur Ylide- Reactions involving Sulfonium and Sulfoxonium salts.	**8L**
Unit-III	**Condensation Reaction:** Aldol condensation, Cross Aldol condensation, Cannizaro's reaction, Cross Cannizaro's reaction, Claisen Condensation, Knoevenagel condensation, Dickmann cyclisation, Perkin reaction, Benzoin Condensation, Schmidt condensation	**10L**

	reaction.	
Section-II : Stereochemistry of cyclic, fused and bridged rings [30 L]		
Unit I	**Stereochemistry of Six membered and their reactions** Shape of cyclohexane ring, monsubstuted and disubstited cyclohexane, physical properties, conformation and chemicalreactivity in cyclohexanes, conformational effects in six membered rings containing unsaturation. Six membered heterocyclic rings. Conformations of polysubstituted cyclohexane, six membered rings with SP2 carbon, heterocycles with N and O, anomeric effect, stereochemical principles involved in reactions of six membered rings and other than six membered rings, concept of I- Strain.	**15 L**
Unit II	**Stereochemistry of fused and bridged ring systems** Five membered, rings larger than 6-membered medium rings,conformational effects in medium rings, transannular effects, concept of I strain Nomenclature, synthesis; stereochemical aspects of Perhydro phenanthrene, Perhydro anthracene, hydrindane, Steroids, Bicyclic and polycyclic, Occurrence, availability, sterochemical restrictions and reactions of norbornyl system,Bredt's Rule. Enantiomerism in biphenyls, allenes, alkylidene cycloalkane, spiranes- configurational nomencalture, correlation of axial dissymmtry and centrodissymmetry.	**15 L**

References

1. Organic chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press)
2. Organic synthesis – Michael B. Smith
3. Advanced organic chemistry, Part B – F. A Carey and R. J. Sundberg, 5th edition (2007).
4. Some modern methods of organic synthesis – W. Carruthers (Cambridge)
5. Name Reactions Jie Jack Li (Fourth Expanded Edition), Page No: 1-582.
6. Stereochemistry of carbon compounds - E. L. Eliel
7. Stereochemistry of carbon compounds - E. L. Eliel and S. H. Wilen

8. Organic Chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press.)
9. Stereochemistry of organic compounds –Nasipuri
10. Organic Chemistry, Cram, Hammond, Hendrickson
11. Stereochemistry of organic compounds- P. S. Kalsi
12. Organic stereochemistry – Jagdamba Singh
13. Topics in Stereochemistry (Volume 2) By Norman L. Allinger and Ernest L. Eliel.
14. Topics in Stereochemistry (Volume 8) By Ernest L. Eliel and Norman L. Allinger

Course outcomes:

Sr.No.	The student should understand
1	Reaction mechanisms in free radical
2	Should be able to write the mechanism
3	Should be able to predict the stereochemistry of product
4	Should be able to apply various rules of stereochemistry
5	Must be able to comment on stability of product

CHO- 602 MJ Structure Determination of Organic Compounds by Spectroscopic Methods [60L]

Aim and Objectives of the course:

Sr. No.	Student should learn
1	The basic nuclear magnetic resonance principle
2	Chemical shift, factors affecting chemical shift, spin multiplicity, coupling constants
3	Stereochemistry of organic compounds by spectral information
4	2-D techniques for complex organic compounds studies
5	Advance CMR techniques to find carbon skeleton
6	Genesis of organic compounds according to m/z ratio and applications of mass spectrometry

Spectral study of IR/NMR(PMR/CMR)/2-D/MS

Section-I: NMR Spectroscopy [30L]

Unit I	**Basic principles of NMR** Chemical shift, factors influencing chemical shift, deshielding, chemical shift values and correlation for protons bonded to carbons (aliphatic, olefinic, aldehydic, aromatic) and other nuclei (alcohols, phenols, enols, acids, amides and mercaptans), chemical exchange, effect of deuteration (Driving force), spin-spin coupling, (n+1) rule, complex spin- spin interaction between two, three, four and five nuclei (first order spectra), factors effecting coupling constant "J", classification of spin system like AB, AX, AX2, ABX, AMX, ABC, A2B2. Resonance of other nuclei like 31P, 19F	**8L**
Unit II	**Study of stereochemistry and spectra simplification techniques of organic compounds by NMR spectroscopy** Homotopic, enatiotopic and distereotopic protons, Chemical and Magnetic equivalence; First and second order splitting, Complex multiplicity patterns and coupling constants in asymmetric compounds; Simplification of complex spectra, NOE, Diastereomerism, Atrop or axial chirality, % Enantiomeric excess, chiral NMR solvents etc. in structure elucidation. Spin decoupling, simplification of complex spectra, nuclear magnetic double resonance, spin decoupling, contact shift reagents, solvent effects, nuclear Overhauser effect (NOE)	**8L**
Unit III	**2D NMR Techniques:** General idea about two dimensional NMR spectroscopy, Correlation spectroscopy (COSY)-Homo COSY (1H-1H), TOCSY, Hetero COSY (HMQC, HMBC), Homo and Hetero nuclear 2D resolved spectroscopy, NOESY and 2D-INADEQUATE experiments and their applications	**14L**
Section-II: CMR and Mass Spectroscopy [30 L]		
Unit IV	**13C NMR spectroscopy** FT NMR, Types of 13C NMR Spectra: un-decoupled, Proton decoupled, off resonance, APT, INEPT, DEPT, chemical shift, calculations of chemical shifts of aliphatic, olefinic, alkyne, aromatic, hetero aromatic and carbonyl carbons, factors affecting chemical shifts, Homo nuclear (13C-13C)	**8L**

	and Hetero nuclear (13C-1H) coupling constants	
Unit V	**Mass Spectrometry:** Principle, ionization methods like EI, CI, ES, MALDI and FAB- Fragmentation of typical organic compounds, Stability of fragments, Rearrangements, factors affecting fragmentation (Hydrocarbons, Hydroxy compounds, Ethers, Carbonyl Compounds, Amino acids) Rules of fragmentation of different functional groups, factors controlling fragmentation, HRMS, Determination of the elemental composition, Isotopic Abundance in structure establishment.	**8L**
Unit VI	**Combined Problems** Based on joint application of UV, IR, PMR, CMR, Mass and 2D spectra (Including reaction sequences)	**14L**

References:

1. Introduction to Spectroscopy –D. L. Pavia, G.M. Lampman, G. S. Kriz, 3rd 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 Mc Graw 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-Joseph B. Lambert, Shurvell, Lightner, Cooks, Prentice-Hall (1998).5
9. Organic structures from spectra - Field L.D., Kalman J. R. and Sternhell S. 4th Ed. John Wiley and sons Ltd.
10. Spectroscopic identification of organic compound - R M Silverstein,G C Bassler and TC Morril, John Wiley
11. Introduction to NMR spectroscopy - R. J. Abrahm, J. Fisher and P. loftus Wiley
12. Organic spectroscopy-William kemp, E L B with McMillan
13. Spectroscopy of organic molecule - P. S. Kalsi, Wiley, Esterna, New Delhi

14. Organic spectroscopy-RT Morrison and RN Boyd
15.Practical NMR spectroscopy - M. L. Martin, J. J. Delpench, and D J Martyin
16.Spectroscopic methods in organic chemistry - D H Willson, I Fleming
17.Spectroscopy in organic chemistry - C N R Rao and J R Ferraro
18.NMR –Basic principle and application - H Guntur
19.Interpretation of NMR spectra - Roy H Bible

Learning outcomes:

Sr.No.	The student should understand
1	To assign chemical shift values for various protons and carbons.
2	Complete analysis of first order, second order spectra and its simplification. Learn to identify the coupling patterns and its interpretation for stereochemical relationship of protons
3	To interprete the stereochemistry of complex structure
4	2-D spectroscopic analysis for corelation between carbon and protons
5	To write the complete genesis, and study of biomolecules
6	Interpretation and structural elucidation by using spectral data of unknown compounds

CHO-603 MJ: Heterocyclic Chemistry (2 Credits)
Major Core Course [30 L]

Aim and Objectives of the Course

Student should learn -

1. Synthesis of five and six membered aromatic heterocycles (N,O,S) and reactions
2. Synthesis of condensed heterocyclic compounds and its reactions 3.
4. Heterocyclic compounds more than two hetero atoms synthesis and its reactions
5. Small heterocyclic reactions (three and four membered)
6. Biological study of heterocyclic compounds

Unit I	**Five and six membered heterocycles with one and two hetero atoms:** Nomenclature and Synthesis of Furan, Pyrrole, Thiophene, Pyridine, Pyrazole, Imidazole, Oxazole, Isoxazole, Thiazole, Pyrimidines. Reactions of Pyrazole, Imidazole, Oxazole, Isoxazole, Thiazole, Pyrimidines.	**15 L**
Unit II	**Condensed five and six membered heterocycles with oneand two hetero atoms:** **Reactivity** of Benzofuran, Indole, Benzothiophene, Quinoline, Isobenzofuran, Isoindole, Iso-quinoline, Benzoxazole, Benzothiazole, Benzimidazole.	**8 L**

Unit III	**Five and six membered heterocycles with more than twohetero atoms:** **Reactivity** of 1,2,3-Triazole, 1,2,4-Oxadiazole, 1,2,5-Oxadiazole, Tetrazole, Purine	**3 L**
Unit IV	**Three and four membered heterocycles** **Reactivity** of Aziridines, Oxiranes, Thirienes, Azetidines, Oxitanes and Thietanes	**4 L**

Reference

1. Heterocyclic Chemistry by T. Gilchrist.
2. An Introduction to the Chemistry of Heterocyclic Compounds by RM Acheson.
3. Heterocyclic Chemistry by J A Joule and K. Mills.
4. Principles of Modern Heterocyclic Chemistry by A Paquette.

Learning Outcomes:

Sr.No.	The student should understand
1	Reactions of synthesis of heterocyclic compounds with mechanism
2	Understanding of reactivities of heterocyclic compounds with electrophile, nucleophile and other reagents
3	Applications of heterocyclic compounds as biological active compounds
4	Green synthesis techniques and its principles

CHO-604 MJP Organic Synthesis Experiment I Practical-I (2 credit: 30L)

Note:

The students should perform any 12 Synthesis from the following list. Students should acquire **pre-experiment** (Reading MSDS, purification of reactants and reagents, mechanism, stoichiometry, etc) and **post-experiment** skills (work-up, isolation and purification of products, physical constants characterization using any spectroscopic methods, etc.)

Solvent Free Carbon-Carbon Bond Formation / Oxidation/ Reduction reaction

1) Pinacol coupling reaction (Page 36)
2) Reformatsky reaction/Luche reaction (Page 36)
3) Knoevenagel condensation (Page 40)
4) Dieckmann condensation (Page 42)
5) Corrole Synthesis (Page 42)
6) Knoevenagel condensation, 3-carboxycoumarin (Page 45)

7) 3-(ethoxycarbonyl)-4-hydroxy-5-(1-hydroxyalkyl)-2-isoxazoline-2-oxide (Page 46)
8) Biginelli reaction (Page 46)
9) Claisen reaction(Page 47)
10)Pechmann reaction (Page 50)
11) calix[4]resorcinarene (Page 50)
12) secondary alcohol oxidation by K-10 clay (page 14)
13) Sulfide oxidation using MnO_2 (Page 21)
14) Oxidation using PCC (page 20)
15) Oxidation using MnO_2-silica of benzyl alcohol
16) Chalcone synthesis by using alumina (page 47)
17) Condensation of ninhydrin and dimedone by Ball mill process (page 52)
18) Reduction by using $NaBH_4$-Alumina (page 7)
19) Reduction of NO_2 by alumina supported hydrazine

References:

1. A Textbook of Practical Organic Chemistry - A. I. Vogel - ELBS with Longman, 5th Ed., (1989)
2. Laboratory Manual of Organic Chemistry - R. K. Bansal - Wiley Eastern 3rd Ed., (1994)
3. Advanced Practical Organic Chemistry - N. K. Vishnoi - Vikas 2nd Ed., (1996)
4. Practical Organic Chemistry, Al. Vogel (ELBS).
5. Microscale and Macro scale Preparations Williamson and Williamson.
6. Practical Heterocylic Chemistry, Fitton and Smalley (AP)
7. Organic Synthesis Collective Volumes, Vol I to VIII
8. Comprehensive Practical Organic Chemistry by V.K. Ahluwalia and Renu Aggarwal
9. Practical Chemistry, Fitton and Smalley
10. Solvent-free Organic Synthesis by Koichi Tanaka (Copyright © 2009 WILEY-VCH Verlag GmbH & Co. KGaA, Weinheim, ISBN: 978-3-527-32264-)

Aim and Objectives of the course:

Sr.No.	The student should understand
1	Reactions of solvent free
2	Should be able to setup microscale reactions
3	Should be able to monitor the reactions by TLC
4	Should be able to do the isolation of pure component after purification
5	Must be able to do the microscale workup with different conditions
6	Physical characterisation(mp/bp) and chemical characterisation
7	Spectral characterization and elucidation of structure

CHO-605 MJP Organic Synthesis Experiment I Practical-II (2 credit: 30L)

Note:

The students should perform any 12 Synthesis from the following list. Students should acquire **pre-experiment** (Reading MSDS, purification of reactants and reagents, mechanism, stoichiometry, etc) and **post-experiment** skills (work-up, isolation and purification of products, physical constants characterization using any spectroscopic methods, etc.)

A) Solvent-Free C–N Bond Formation

1. terephthalic acid dihydrazide (Page 205)
2. azomethine synthesis (Page 213)
3. diazepinone synthesis (Page 218)
4. dibenzyl sulfone Synthesis (Page 297)
5. Hydrozone derivatization by using silica gel (page 211)
6. Ortho phenylene diamine and oxalic acide adduct formation (page 235)

B) Solvent-Free C–S Bond Formation

1. 1,3-dithiolane synthesis (Page 299/300)

C) Solvent-Free C–X Bond Formation

1. Cinnamic acid/ stilbene halogenations (Page 319)
2. Phenol bromination using , *N*-bromosuccinimide (Page 320)

D) Solvent-Free N–N Bond Formation

1. Triazenes Synthesis (Page 335)
2. Beckmann rearrangement (Page 346)

E) Other Solvent-Free Reactions

1. Alumina-supported permanganate oxidation (Page 15)
2. Sulfide oxidation using MnO_2 (Page 21)
3. Oxidative coupling of thiol using MnO_2 (Page 22)
4. Iodine catalysed S-S bond formation of Cystine (Page 28)

F) Solvent free supramolecular assembly formation

1) Caffeine and oxalic acid (Page 420)
2) *rac-Bis*-beta-naphthol and benzoquinone
3) Isovaleraldehyde and pyrogallol

G) Other solvent-free synthesis (any three)

Aim and Objectives of the course:

Sr.No.	The student should understand
1	Reactions of solvent free
2	Should be able to setup microscale reactions
3	Should be able to monitor the reactions by TLC
4	Should be able to do the isolation of pure component after purification
5	Must be able to do the microscale workup with different conditions
6	Physical characterisation(mp/bp) and chemical characterisation

7	Spectral characterization and elucidation of structure

MJP-606 Ternary Mixture Separation [30L]

Separation of minimum 12 mixtures containing three components. The mixtures should also involve separation of nitrophenols, amino acids, low boiling and water soluble and insoluble compounds solids and liquids with **multifunctional groups**. The mixture separation should be carried out on micro-scale using ether or water.

The students should be able to

1. Understand and employ concept of type determination and separation
2. Meticulously record physical constants
3. Perform micro scale chemical elemental analysis
4. Perform qualitative estimation of functional groups
5. Recrystallize /distill the separated compounds
6. Extend these skills to organic synthesis

CHO-607(A) Retrosynthesis Analysis (Major Elective)

Unit-I	**Concepts of Retrosynthesis:** Retrosynthetic analysis, disconnection approach, Synthons, multiple step synthesis, functional group interconversion, Illogical two group interconversion, C-C disconnection, Donor & Acceptor synthons, two group disconnection, 1,5 related functional group disconnection, Umpolung, convergent synthesis, special methods for small rings, Heteroatom and Heterocyclic compounds, problems	**18L**
Unit-II	**Application of Retrosynthetic Approach**: Retrosynthesis and synthesis of Strychnine, Reserpine, Indolizomycin, and Erythronolide B	**12L**

References:

1. Designing of organic synthesis – S. Warren (Wiley)
2. Some modern methods of organic synthesis – W. Carruthers (Cambridge)
3. Organic chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press)
4. Organic synthesis – Michael B. Smith

Learning outcomes:

Sr.No.	The student should understand

1	Total symthesis planning to develop new methodologies
2	Applications of compounds and its derivatives
3	Case studies to enhance the understanding of synthetic methods
4	To gain the knowledge of retrosynthesis with all the aspects
5	Should be able to write the retrosynthesis of various functional groups
6	Able to understand the application by writing the retro of natural products

CHO-607(B)Biogenesis: The Building Blocks and Construction mechanism [2 credits, 30 L]

Aim and Objective of the Course

Sr.No.	Student should learn
1	From DMAPP/IPP biogenesis of terpenoids
2	Alkaloids biogenesis from ornithine, lysine, nicotinic acid, tyrosine and tryptophan
3	Shikimic acid pathway
4	Basic of reactions kinetics
5	Hammet plot and equations for kinetic study of reactions
6	DFT for energy profile diagram

Unit I	Terpenoids : Mono-, Sesqui-, Di-, tri-terpenoids and cholesterol	**6L**
Unit II	Alkaloids: Derived from ornithine, lysine, nicotinic acid, tyrosine and tryptophan	**8L**
Unit III	The Shikimate pathway: Cinnamic acids, lignans and lignin, coumarins, flavonoids and stilbens, isoflavanoids and terpenoid quinones.	**8L**
Unit IV	A case study: Alkaloids isolated from the Roots of Piper nigrum	**8L**

Reference:

1. Natural Product Biosynthesis: Chemical Logic and Enzymatic Machinery by Christopher T Walsh, Yi Tang
2. From Biosynthesis to Total Synthesis: Strategies and Tactics for Natural Products- Editor Alexandros L. Zografo
3. Medicinal Natural Products: A Biosynthetic Approach, 3rd Edition By Paul M. Dewick
4. J. Nat. Prod. 2004, 67, 1005-1009.
5. J. Org. Chem. 2005, 70, 4, 1164–1176

Learning Outcomes:

1. Reactions of synthesis of heterocyclic compounds with mechanism
2. Understanding of reactivity's of heterocyclic compounds with electrophile, nucleophile and other reagents
3. Applications of heterocyclic compounds as biological active compounds
4. Various applications in fields of medicinal chemistry
5. Green synthesis techniques and its principles
6. Recent trends of green synthesis and its need

CHO-607 (C) Medicinal Chemistry (2-Credits; 30 L)

Unit I	**Introduction to Peptides and proteins**: Introduction to Peptides and proteins: Proteins as biological catalyst Nucleic acids, Metabolism, Chemistry of cofactors/coenzymes, Chemistry of TPP, PLP, Folic Acid and other vitamins, Principle of drug design, Chemistry of diseases and Drug development, Proton pump inhibitors and Problem solving	**10L**
Unit II	**Introduction to medicinal Chemistry.** History, drug targets, Drug discovery, design and development, Case Study: Design of Oxamniquine	**5L**
Unit III	**Pharmacokinetics and Pharmacodynamics of drug:** Drug absorption, distribution, metabolism, elimination and toxicity, drug metabolism, biotransformation, Drug receptor interactions, Hansch Equation and significance of terms involved in it.	**5L**
Unit IV	**Structure and activity Relationship** QSAR, Applications of SAR and QSAR in drug design, physio-chemical parameters lipophilicity, partition coefficient, electronic ionization constant, Mode of action, limitations and adverse effect of Antibiotics, Beta lactam antibacterial agents (Penicillins), Tetracyclins, Sulphonamides , Chloramphenicol, Antifungals ((Amphotrecin-B.,), Antiviral (,Acyclovir,) Antimalarial (Quinolines), Quinolones	**10L**

References:

1. Medicinal Chemistry and Drug Discovery by Burger
2. Introduction to Medicinal Chemistry by Grham and Patrick
3. Introduction to Drug Design by J. R. Dimmock and S.S. Pandeya
4. The Organic Chemistry of Drug Design and Drug Action, 3rd Edition, R. B. Silverman, Academic Press, 2014
5. Wilson and Gisvold's Text Book of Organic Medicinal and Pharmaceutical Chemistry, Ed Robert F Dorge, 12th Edition, 2010

Course Outcomes:

1. Understand and write the structure of protein, nucleic acids.
2. Should be know the drug discovery and development.
3. Pharmacokinetics and pharmacopeia for drug interaction and Hansch equation
4. Understanding of QSAR and SAR and applications. Information of drugs and its activity
5. Knowing the mode of action, limitations and adverse effects of various drugs.

CHO-608	**Research Project (RP)**	**60L**

SEMESTER IV

CHO-651 MJ : Chemistry of Natural Products and Protection - De-protection, Carbohydrates and Chiron Approach chemistry

(4 Credits) Major Core Course [60 L]

Aim and Objectives of the course: 1. Natural product isolation 2. To plan synthesis of natural products with stereochemistry		
Section-I: Chemistry of Natural Products [30 L]		
Unit I	**Chemistry of Natural Products** Understanding and planning of total synthesis while maintaining the stereochemistry. A case study: Longifolene	**12 L**
Unit II	**Total Synthesis of** i. Hirsutellone B ii. Ribisins A and B iii. Vannusals	**18 L**

Section-II: Protection - De-protection, Carbohydrates and Chiron Approach chemistry [30L]

Unit I	**Protection - De-protection** Protection and de-protection of functional group in organicsynthesis: **a. Hydroxyl group**: alkyl ether, benzyl ether, acyl, PMB, Trityl, TMS, TBDMS, THP, MOM, MEM, MIP ether. **b. Diol:** Acetone, Cyclohexanone **c. Amines**: Benzyl, Acyl, CBZ, BOC, FMOC **d. Carboxyl group** : Ester, DCCI, DIPCDI **e. Ketone and aldehydes** : Glycol, Thio-glycol, Ketal,Acetal, orthoesters as protecting groups	**10L**
Unit II	**Basics of Carbohydrates** Introduction of sugars, structures of monosaccharides, triose,tetrose, pentose, hexose, D/L forms of aldoses and ketoses in Fisher projections, cyclic hemiacetal forms of monosaccharides, representation of monosaccharide structure(Haworth projection and Chair conformation), The structure of Glucose, the anomeric configuration, mutarotation (D-Glucose), Conformations of monosaccharides, the anomeric effect. Modified monosaccharides, Alditols, Cyclitols, Nomenclature of monosaccharides, Cyclic forms of the α and β-D-aldoses. 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	**10L**
Unit III	**Chiron approach Chemistry** Introduction, The concept of chiral templates and chirons wherein the carbon skeleton is the chiral precursor, Utilization of the basic concepts in synthesis of (S) Propanediol, (R) and (S) – Epichlorohydrin, L (+)-Alanine, (-) Multistratin, (-) Pentenomycin and (-) Shikimic acid.	**10L**

References

1. For Longifolene – (All Nine syntheses from Advanced Organic Chemistry Carey, Sundberg; Part B).
2. For Hirsutellone B (Angew. Chem. Int. Ed. 2009, 48, 6870 –6874)
3. For Ribisins A and B (J. Org. Chem. 2019, 84, 15165−15172)
4. For Vannusals (J. Am. Chem. Soc. 2010, 132, 20, 7138-7152)
5. Designing of organic synthesis – S. Warren (Wiley)
6. Some modern methods of organic synthesis – W. Carruthers (Cambridge)
7. Organic chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press)
8. Organic synthesis – Michael B. Smith
9. Essentials of Carbohydrate Chemistry and Biology: Thisbe K. Lindhorst, WILEY-VCH, 2000, Chapter 3.
10. Monosaccharide's: Their Chemistry and their Roles in Natural Products: Peter M. Collins,
11. Robert J. Ferrier: John Wiley & Sons, 1995.
12. Carbohydrate in Chemistry and Biology: Part 1 Chemistry of Saccharides Vol.1.WILEY-VCH, 2000.
13. The Organic Chemistry of Sugars; By: Daniel E. Levy Peter Fugedi
14. Publication: Taylor & Francis, Published on 2006
15. Handbook of Chemical Glycosylation by Alexei V. Demchenko, Wiley VCH, 2008
16. P.T. Anastas and J.C.Warner, Green Chemistry, theory and practice.Chiron Approach in organic synthesis – S. Hanessianh

Course outcomes:

1. To study the natural products synthestic methodologies
2. Must understand all the reagents used for synthesis
3. Should be know the drug discovery and development
4. Understanding of QSAR and SAR and applications. Information of drugs and its activity
5. Carbohydrates structures and its classification with reactions of sugars and its writing
6. Understanding of chiron approach and its applicatons

CHO-652 MJ Advanced Synthetic Organic Chemistry [4 credits, 60 Lectures]

Aim and Objectives of the course:

1. Coupling reactions with all catalytic cycles with mechanism of Pd,Ni,Ru,Ir,Fe, and Cu
2. Name reactions for C-C, C-O,C-N bond formation
3. Reaction for olefin synthesis
4. Should study multicomponent reactions with various reagents
5. All ring formation reactions for advance synthesis
6. Basics of metathesis reactions and its catalytic cycles
7. Study of B and Si reagents for various applications

Unit I	**Transition metal complexes in organic synthesis** Pd, Ni, Co, Fe (Metal mediated C-C and C-X bond formation reactions: Suzuki, Heck, Sonogashira, Stille, Fukuyama, Kumada, Hiyama, Negishi, Buchwald-Hartwig, Noyori, Reppe, Oxo process	**18L**
Unit II	**C=C formation reactions** Wittig, Horner-Wordworth-Emmons, Corey-Winter, Corey-fuchs, Ramberg-Backlund, Takai reaction, Julia-Lythgoe and Peterson olefination reactions, Titanium-carbene mediated olefination: Tebbe, Petasis and Nysted reagent, formation of alkene from alkyne.	**15L**
Unit III	**Multi-component reactions:** Ugi, Passerini, Biginelli and Mannich reaction	**4L**
Unit IV	**Ring formation reactions** Pausan-Khand, Nazerov reaction	**2L**
Unit V	**Click chemistry** Criterion for click reaction, Sharpless azides cycloadditions.	**2L**
Unit VI	**Metathesis** Schrock and Grubbs catalyst, Olefin cross coupling (OCM), ring closing (RCM) and ring opening (ROM) metathesis, application in polymerization and synthesis of small organicmolecules	**8L**
Unit VII	**Use of Boron and Silicon reagents in organic synthesis**, **and Other reactions**	**9L**
Unit VIII	**Other important reactions** Baylis Hilman, Mitsunobu reaction	**2L**

References:

1. C–N bond forming cross-coupling reactions: an overview: by JitenderBariwalab and Erik Van der Eycken*Chem. Soc. Rev.,* 2013, **42**, 9283
2. Iron Catalysis in Organic Synthesis Chem. Rev. 2015, 115, 3170–3387.
3. Recent advances in homogeneous nickel catalysis Nature 2014, Vol 509, Page 299-309.
4. Ruthenium-Catalyzed Reactions for Organic Synthesis *Chem. Rev.* **1998**, *98,* 2599-2660.
5. Organic Synthesis Involving Iridium-Catalyzed Oxidation Chem. Rev. 2011, 111, 1825–1845.
6. Aerobic Copper-Catalyzed Organic Reactions Chem. Rev. 2013, 113, 6234−6458.
7. Transition Metals for Organic Synthesis Volume 1 *Edited by M. Beller and C. Bolm*WILEY-VCH Verlag GmbH & Co. KGaA ISBN: 3-527-30613-7
8. Multicomponent Reactions Edited by Jieping Zhu, HuguesBienayme WILEY-VCH Verlag GmbH & Co. KGaA
9. Organic chemistry – J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press),
10. Some modern methods of organic synthesis – W. Carruthers (Cambridge)
11. Organic synthesis – Michael B. Smith
12. Advanced organic chemistry, Part B – F. A Carey and R. J. Sundberg, 5th edition (2007).
13. Strategic Applications of named reactions in organic synthesis-Laszlo Kurti and Barbara Czako
14. Name Reactions Jie Jack Li (Fourth Expanded Edition), Page No: 1-582.
15. Organic Synthesis Using Transition Metals, by Roderick Bates, Second Edition, A John Wiley & Sons, Ltd., Publication.

Learning Outcomes:

1. Basics reaction mechanism like oxidative addition, reductive elimination. Beta hydride elimination, transmetalation, ligand insertion and migration
2. Able to write the all catalytic cycles with stereochemistry
3. Better understanding of olefin synthesis with prediction of major and monor product
4. Must understand multicomponent and click reaction with mechanism
5. Must able to write and predict the product of metathesis reactions
6. Study of boron and silicon reagents in reaction like reduction oxidation protection Deprotection.
7. Must understand the regioselectivity, stereoselectivity, stereospeficity, chemo selectivity of reagents

CHO-653 MJP : Convergent Organic Synthesis [2 credit: 30L]

Note: Any **3 sets** should be conducted from the following convergent and divergent synthesis sets.

Students should acquire **pre-experiment** (Reading MSDS, purification of reactants and reagents, mechanism, stoichiometry etc) and **post-experiment skills** (work-up, isolation and purification of products, physical constants characterization using any spectroscopic methods etc.). Students must able to learn multicomponent reaction and convergent synthesis.

SET-I

A) Convergent Synthesis 1 (Three Stage Synthesis)

Stage I: Anisole to 4-nitro anisole to 4-amino anisole (2 steps)

Stage II: Toluene to 4-nitro toluene to 3-acyl nitro toluene (2 steps)

Stage III: Synthesis of N-(1-(2-methyl-5-nitrophenyl) ethyl) aniline from 4-amino anisole, 3-acyl nitro toluene and SBH (One pot synthesis: MCR)

B) Convergent Synthesis 2(Three Stage Synthesis)

Stage I: 4-Nitro toluene to 4-amino toluene (Reduction by using Sn/HCl)

Stage II: Phenol into 2-hydroxy benzaldehyde (Reimer-Tiemann reaction)

Stage III: Synthesis of amidoalkyl-2-naphthols from β-Naphthol,4-amino toluene and of 2-hydroxy benzaldehyde (One pot synthesis: MCR)

C). Convergent Synthesis-3 (Three Stage Synthesis)

Stage I: Salicylic acid to 5-Chloro-2-hydroxybenzoic acid

Stage II: o- Anisidine to 2-methoxy-4-nitroaniline

Stage III: Synthesis of 5-chloro-2-hydroxy-N-(2-methoxy-4-nitrophenyl) benzamide from 5-Chloro-2-hydroxybenzoic acid, -methoxy-4-nitroaniline (One pot synthesis: MCR)

D) Convergent Synthesis- 4 (Three Stage Synthesis)

Stage I: Benzene to actophenone (F.C acylation)

Stage II: 4-Nitrochlorobenzene into 4-amino chlorobenzene (Reduction by using hydrazine)

Stage III: Quinoline synthesis by using acetophenone, 4-amino chloro benzene and styrene (One pot synthesis: [3 + 2 + 1] cycloaddition reaction)

References

Practical organic chemistry by Mann and Saunders

Text book of practical organic chemistry –by Vogel

The synthesis, identification of organic compounds –Ralph L. Shriner, Christine K.F. Hermann, Terence C. Morrill and David Y. Curtin

Important Notes for Practical Courses

All experiments should be carried out on micro-scale and by considering stoichiometric quantities of reactants and reagents with the proper understanding of the mechanism.

Students must read MSDS and should handle chemicals and reactions accordingly.

The necessary reactions should be carried out in fume hood and appropriate safety measures should be taken during the laboratory experiments and projects.

All reactions should be **monitored using alumina coated TLC plates**.

Certified journals should be presented at the time of final examination.

Students opting for the projects are encouraged to participate in AVISHKAR, national and international conferences and other project competitions.

Teachers are encouraged to give the project ideas based on the societal needs.

CHO-654 MJP : Divergent Organic Synthesis [2 credit: 60L]

Note: Any **3 sets** should be conducted from the following convergent and synthesis sets. Students should acquire **pre-experiment** (Reading MSDS, purification of reactants and reagents, mechanism, stoichiometry etc) and **post-experiment skills** (work-up, isolation and purification of products, physical constants characterization using any spectroscopic methods etc.)

SET I-Divergent Synthesis 1 (5 Single Stage Synthesis from Acetyl acetone):

1) Acetyl acetone to Pyrimidine
2)Acetyl acetone to 2,4-dimethyl-1H-benzo[b][1,4]diazepine
3) Acetyl acetone to Pyrazole
4)Acetyl acetone with 1mmol benzaldehyde to 3-benzylidenepentane-2,4-dione
5) Acetyl acetone with 3 mmol benzaldehyde into 3-benzylidene-6-phenylhex-5-ene-2,4dione

SET II-Divergent Synthesis (5 Single Stage Synthesis from β-Naphthol)

1)β-Naphthol to Synthetic dye (By diazonium coupling)
2)β-Naphthol to 6-Bromo-2-naphthol (Bromination reaction)
3)β-Naphthol to β-Naphthyl methyl ether (Methylation reaction)
4)β-Naphthol to temperature dependent sulfonation (Sulfonation reaction)
5)β-Naphthol to (□) Binol then Resolution of Binol (Resolution technique)

SET III-Divergent Synthesis-3 (5 Single Stage Synthesis from Salysaldehyde)

1)Salicylaldehyde to Salicylaldehyde phenylhydrazone
2)Salicylaldehyde with melanonitrile to 2-iminochromene by intramolecular cyclization.
3)Salicylaldehyde to 2-hydroxy-3,5-dinitrobenzaldehyde
4)Salicylaldehyde to o-Formylphenoxy acetic acid
5)Salicylaldehyde to catechol

SET-IV. Divergent Synthesis-4 (5 Single Stage Synthesis from Acetophenone)

1)Acetophenone to Ethyl benzene by Wolf Kishner reduction
2)Acetophenone to m-Nitro acetophenone by nitration
3)Acetophenone to Chalcone using aromatic aldehyde
4)Acetophenone into Schiff base using aromatic amine
5)Acetophenone to Benzoic acid and Iodoform

References

Practical organic chemistry by Mann and Saunders
Text book of practical organic chemistry –by Vogel
The synthesis, identification of organic compounds –Ralph L. Shriner, Christine K.F. Hermann, Terence C. Morrill and David Y. Curtin

Important Notes for Practical Courses

All experiments should be carried out on micro-scale and by considering stoichiometric quantities of reactants and reagents with the proper understanding of the mechanism.

Post graduate departments should arrange at least **one study visit to relevant industry/national research laboratory/premier academic institute**.

Students must read MSDS and should handle chemicals and reactions accordingly.

The necessary reactions should be carried out in fume hood and appropriate safety measures should be taken during the laboratory experiments and projects.

All reactions should be **monitored using alumina coated TLC plates**.

Certified journals should be presented at the time of final examination.

Students opting for the projects are encouraged to participate in AVISHKAR, national and international conferences and other project competitions.

Teachers are encouraged to give the project ideas based on the societal needs.

CHO 655 MJP Green Chemistry and Isolation of natural product

Note: Students should be able to collect reasonable quantities of color pigments/oil/natural product to do the characterization (Physical Constant, Elemental analysis functional group test etc) and should also form the appropriate derivative. They are encouraged to use these pigments for developing food grade natural colors, soap perfume and medicinal drugs from lesser known plant source.

A) Green Experiment (any six)

1. Green approach for preparation of benzopinacolone from bezopinacol using photoreduction
2. Solvent free aldol condensation between 3,4-dimethoxybenzaldehyde and 1-indanone.
3. (4+2) cycloaddition by green method
4. Green oxidation reaction: adipic acid synthesis
5. Biodiesel synthesis (methyl ester) by green approach
6. Benzil to benzilic acid synthesis
7. 7-hydroxycoumarin synthesis by using k-10 clay
8. Ecofriendly nitration of phenol
9. 1,1-bis-napthol synthesis by green route
10. Aldol condensation by solvent free green approach
11. Azalactone synthesis from hippuric acid
12. Thioamide synthesis (Willgerodt-Kindler reaction)

B) Isolation of natural product

Unit II: Isolation of pigments from the natural products (Any 2)

1. Orange Marigold
2. Rose
3. Sunflower
4. Hibiscus

Any colored flowers/fruits available in the local area **(only one is allowed)**

Unit III: Isolation of essential oils from the natural products (Any 2)

1. Ginger
2. Lemongrass
3. Garlic
4. Ajwain/ajowan/Trachyspermum ammi
5. Vekhand (achourus calamus) root

Unit IV: Isolation of medicinally important component from the natural products (Any 2)

1. Nimbin from Neem leave
2. Amyrin from Apati/Apta bark
3. Eugenol from Tulsi leaves

4. D-Galacturonic Acid from Jeshtamadh
5. Piper from Betel leaf

1. Sr.No.	2. The student should understand
1	3. Reactions of green route
2	4. Should be able to setup microscale reactions
3	5. Should be able to learn natural product extraction techniques
4	6. Should be able to do the isolation of pure component after purification
5	7. Must be able to do the microscale workup with different conditions
6	8. Physical characterisation(mp/bp) and chemical characterisation
7	9. Spectral characterization and elucidation of structure

CHO- 656 (A)Introduction to Chemical Biology-I [2 credits, 30L]

Unit I	**Overview of Biochemical Concepts** Central dogma of cell biology, prokaryotes-eukaryotes and subcellular components,Overview of cell metabolism, Interdisciplinary approach, Biomolecules as potential drugtargets	**4L**
Unit II	**Chemistry of Biomembranes** Structure, Functions and Composition, Fluid Mosaic Model by Singer and Nicholson, Properties of membrane, Transport of Ions (Na^+, K^+, H^+, Ca^{2+}, Cl^-) and Molecules (Glucose, Amino acids, Proteins), transport across the membrane, Uniport, Symport, Antiport, Active and Passive facilitated transport, Exocytosis and Endocytosis (Pinocytosis, phagocytosis, receptor mediated endocytosis), Drug transport, Amphipathic nature and Significance of liposomes	**8L**

Unit III	**Carbohydrates** Classification, Structure and Properties, Derived sugars and their significance, Glycoproteins, glycolipids	**4L**
Unit IV	**Lipids** Classification, Structure and Properties of lipids, Saponification number, Iodine number, Acid number, Rancidity of lipids, Lipoproteins	**5L**
Unit V	**Amino Acids and Proteins** Introduction, Classification of amino acids, Physico chemical properties, Optical properties, Peptide bond, Primary, Secondary, Tertiary and Quaternary structure of proteins, Protein -Ligand interactions, Denaturation ofproteins, Oligopeptide synthesis, Concept of proteomics	**9L**

References:

1. Principals of biochemistry, Albert Lehninger (CBS Publisher and Distributers Pvt. Delhi.
2. Harper's Biochemistry by R.K. Murray, D. I. Granner, P. A. Mayes, (Prentice HallInternational Inc.)
3. Biochemistry by U. Satynarayana
4. Biochemistry by J. L. Jain
5. Biophysical Techniques by Upadhyaya Nath

Course Outcomes:

1. Should able to understand primary metabolic reactions
2. Should be able to understand metabolic products
3. Should know fundamentals of biochemistry
4. Should be able to understand classification of biomolecules

CHO-656 (B) Asymmetric Synthesis of Organic Compounds

[2 credits, 30 L]

Aim and Objectives of the course:

1. Assymetric synthesis reactions and concept of optical purity, ee, de % ee, chiral

auxiliary, chiral reagents and chiral pool strategies study

2. Study of Cram's model, Felkin-Anh model, Houk model, racemic modifications and tacticity

Chiral reactions- Aldol condensation, epoxidation, hydroxylation, reduction andcatalysis.

Unit III	**Introduction of Asymmetric Synthesis:** Classification of Asymmetric reactions, Optical purity, ee and de, calculation of % ee and optical purity, Stereoselective Synthesis, Categories and Strategies in Asymmetric Synthesis: Chiral substrate controlled, Chiral auxiliary controlled, Chiral reagent controlled, Chiral catalystcontrolled Asymmetric Synthesis.	**06L**
Unit IV	**Chiral pool and Chiral auxiliaries:** Chiral pool strategies in asymmetric synthesis, Chiral auxiliary- Evan's chiral Auxiliary, RAMP, SAMP, synthesis and Uses of Chiral Auxiliaries in asymmetricsynthesis	**06**
Unit V	**Determination of configuration** Diastereoselectivity: Cram's Model, Felkin Anh Model, dipolar model and Cram's rigid model; Houk models, Racemic modification: Methods of preparation and Resolution of modification; Stereochemistry of a polymerchain – Types and examples of Tacticity.	**06L**
Unit VI	**Chiral Reactions** a. **Aldol reactions and related reactions** : Aldol reactions and related reactions- Diastereoselective Aldol reaction, Aldol reaction of chiral enolate & achiral aldehydes, achiral enolate & chiral aldehydes, Heathcock aldol reaction, Double diastereoselective Aldol reaction, Chiral auxiliary-controlled Asymmetric Aldol reactions, Mukaiyama aldol reactions, Proline - catalyzed asymmetric Aldol reactions. **Asymmetric Hydrogenation and Reduction**- catalytic hydrogenation using Rh, Ru metals, Use of Use of chiral BINOL, BINAP, Noyori asymmetric hydrogenation, CBS reduction. b. **Asymmetric Epoxidation-** Sharpless Epoxidation, Jacobsen Epoxidation, Shi epoxidation,	**12L**

	c. Asymmetric dihydroxylation – phthalazine-basedligands DHQ and DHQD in-hydroxylation, Aminohydroxylation **d. Asymmetric Organocatalysis**- Enantioselective Organocatalysis Involving Iminium, Enamine. Proline and Macmillan Imidazolidinone catalyzed reactions, Organocascade Catalysis. asymmetric organocatalytic epoxidation	

References

1. Catalytic Asymmetric Synthesis, 3rd ed,Ed: I. Ojima, John Wiley & Sons, New Jersey, 2010.
2. Catalysis in Asymmetric Synthesis by Vittorio Caprio and Jonathan M. J. Williams
3.Angew. Chem. Int. Edn. 2008, 47, 4638–4660.
12.. Principles and Applications of Asymmetric Synthesis by Guo-Qiang Lin, Yue-MingLi, Albert S. C. Chan, A John Wiley & Sons, Inc., Publication.

Learning Outcomes:

1. To gain knowledge of asymmetric synthesis and chiral reactions with mechanisms
2. Understanding mechanism by using Crams model, Felkin-Anh model, Houlk model, racemic modifications and tacticity
3. Detailed mechanism in reduction, hydroxylation, epoxidation reactions. And applications of oranocatalysts

656 (C): Methods in Determining Reaction Mechanism (2-Credits, 30 L)

Unit I	Methods for determining Reaction Mechanisms	**4L**
Unit II	Linear Free Energy Relationships	**6L**
Unit III	Hammet equation Hammet plots, Hammet equation, substituent constants, reaction constants, use of Hammet plots, calculation of k and K, Deviations from straight line plots, Taft equation, solvent effects	**10L**
Unit IV	Study of DFT study and Energy profile diagram for organic reactions	**4L**
Unit V	Software in Chemistry: Introduction to software, its functions, and applications in organic chemistry (toxicity) software. Mnova chemdraw, ISIS/Draw, Origin, mavinsketch, studio discovery, visualization, Autodock 4.2	**6L**

References

1. Organic Chemistry – R. P. Morrison and R. N. Boyd
2. Organic Chemistry – I. L. Finar, volume II.
3. Mechanism and Structure in Organic Chemistry E. S. Gould (Holt, Rinehart and 9. Winston)
4. Advanced Organic Chemistry –J. March, 4th edition
5. Advanced Organic Chemistry- Part A: Structure and Mechanism- F. A. Carey and R. J.
6. Sundberg, 5th Edition, Springer 2007)
7. A guidebook to mechanism in Organic Chemistry- Peter Sykes
8. The Hammett Equation by C. D. Johnson
9. Organic Chemistry-J. Clayden, N. Greeves, S. Warren, P. Wothers, Oxford University Press
10. Textbook of polymer science 3rd edition by F. W. Billmeyer (1994).
11. Polymer Science by V.R. Gowarikar, N. B. Vishvanathan, New Age International Ltd. Publisher (1998)

Course Outcomes:

1. Reactions rate and its kinetics
2. Factors affect the rates of organic reaction and calculation of K and k
3. Implementation of Taft equation
4. Energy profiling of the reactions
5. Problems solving on Hammet equation
6. Energy profile diagram and progress of reaction
7. Recall the basic concepts and history of polymers. List the types of polymers based on their properties and type.

CHO-657	**Research Project (RP)**	**90L**