UNIVERSITY OF LUCKNOW
MASTERS OF PHARMACEUTICAL CHEMISTRY PROGRAMME
REGULATION 2020

1. Applicability

These regulations shall apply to the Masters in Pharmaceutical Chemistry programme from the session 2020-21.

2. Minimum eligibility for admission

A three/four years Bachelor's degree or equivalent with chemistry as one of the subject in final year awarded by University or Institute established as per law and recognized as equivalent by university with minimum 45% marks for general and OBC (SC/ST 40%) or equivalent grade shall constitute the minimum requirement for admission to the Masters in Pharmaceutical Chemistry Programme

3. Programme Objectives

i. To enable the students to understand the basic concepts of bio-inorganic, bio-organic, physical chemistry, analytical chemistry, drug formulation, drug design and development.
ii. To develop the ability to present pharmaceutical chemistry research by means of an oral presentation, a scientific poster or a written report.
iii. To be able to use and apply professional softwares relevant to chemistry.
iv. To equip the students with the knowledge to develop Pharmaceutically important molecules, new drug delivery systems etc.
v. To learn the application of analytical tools for determination of organic molecules and to generate validation protocol for all pharmaceutical operations starting from drug research to development to formulation.
vi. To learn the Mechanism of Action of various class of drugs.
vii. To learn the brief overview of the use of various drugs in treatment of various diseases.

4. Programme Outcomes

PO-1. Demonstrate, solve and an understanding of major concepts in all disciplines of Chemistry independently and in group as well as draw logical conclusions through Project and Seminar Presentation.
PO-2. Encourage students to make critical thinking and the scientific knowledge gained would help them to design, carry out, record and analyze the results of Chemistry as well pharmaceutical experiments.
PO-3. Equip students to face the employment challenges and instil confidence to turn into entrepreneur and also step into research career.
PO-4. Generation of new scientific insights or to the innovation of new applications of chemical research
PO-5. Present scientific and technical information resulting from laboratory as well as Industrial/pharmaceutical experimentation in both written and oral formats, would make them perfect.
PO-6. Learns modern methods of chemical systems in a laboratory setting make them perfect for any scientific laboratory and industry.
PO-7. The students will become well versed in the mechanisms and also with the mode of action of drugs.
PO-8. The present course content will build confidence in students and the students will improve their competencies on par with their counterparts in premier institutions across the nation.

5. Programme Specific Outcomes

PSO-1. Students will be able to understand the basic concepts of bio-inorganic, bio-organic, physical chemistry, analytical chemistry, drug formulation, drug design and development, and green chemistry
PSO-2. Students will develop the ability to present pharmaceutical chemistry research by means of an oral presentation, a scientific poster or a written report.
PSO-3. Students will be able to use and apply professional softwareôs relevant to chemistry.

PSO-4. Students will be able to demonstrate knowledge to develop Pharmaceutically important molecules, new drug delivery systems etc.
PSO-5. Students will demonstrate an ability to analyze and interpret data of analytical experiments in production, quality control & assurance of pharmaceutical synthesis and formulation.
PSO-6. Students will be able to apply analytical tools for determination of organic molecules.
PSO-7. Students will be able to generate validation protocol for all pharmaceutical operations starting from drug research to development to formulation.
PSO-8. Learn Role of drugs to inhibit the particular enzymes and treatment of disease
PSO-9. Learn Mode of action of different drugs.

6. Course Structure

The course structure of the Masters in Pharmaceutical Chemistry programme shall be as under.

Course No.	Name of the Couse	Credit	Remark
	Semester I		
PHCHCC-101	Physical Chemistry	**04**	**Core Course**
PHCHCC-102	Organometallic & Nuclear Chemistry	**04**	**Core Course**
PHCHCC-103	Organic Chemistry	**04**	**Core Course**
PHCHCC-104A PHCHCC-104B	Inorganic Chemistry Practical Organic Chemistry Practical	**08**	**Core Course**
PHCHVC-101	Separation Techniques	**04**	Value Added (Credited)
	Semester Total	**24**	
	Semester II		
PHCHCC-201	Pharmacology and Drug Design	**04**	**Core Course**
PHCHCC-202	Pharmacognosy	**04**	**Core Course**
PHCHCC-203	Chemistry of Natural Products and Biomolecules	**04**	**Core Course**
PHCHCC-204	Project and Seminar Presentation	**04**	**Core Course**
PHCHCC-205A PHCHCC-205B	Inorganic Chemistry Practical Organic Chemistry Practical	**08**	**Core Course**
PHCHVNC-201	Science and Technology of Cosmetics	**00**	Value Added (Non Credited)
	Semester Total	**24**	
	Semester III		
PHCHCC-301	Project and Seminar	**04**	**Core Course/** MOOC
PHCHCC-302	Pharmaceutical Chemistry Practical	**04**	**Core Course**
PHCHEL-302	Spectroscopic Methods in Pharmaceutical Chemistry	**04**	**Elective Course**
PHCHEL-301A	Medicinal Chemistry-I	**04**	**Elective Course**
PHCHEL-301B	Medicinal Chemistry-II		
PHCHIN-301	Summer Training	**04**	Summer Training
PHCHIER-301	Concepts of Chemistry	**04**	Interdepartmental Course
	Semester Total	**24**	
	Semester IV		
PHCHCC-401	Advance Organic Chemistry Practical	**04**	**Core Course**
PHCHEL-401	Biochemistry and Bacteriology	**04**	**Elective Course**

Course No.	Name of the Couse	Credit	Remark
PHCHEL-401A	Chemistry of Analgesics and Antipyretics	**04**	**Elective Course**
PHCHEL-401B	Bioethanol as Biofuel		
PHCHMT-401	Dissertation and Master Thesis	**08**	**Master Thesis**
PHCHIRA-401	Analytical Chemistry	**04**	Intradepartmental Course
	Semester Total	**24**	
	GRAND TOTAL	**96**	

PHCH - Subject; PHCHCC - Core Course; PHCHVC – Value added (credited); PHCHVNC – Value added (non-credited); PHCHEL – Elective; PHCHIER – Interdepartmental course; PHCHIRA – Intradepartmental course

7. Course Outlines

PROGRAMME STRUCTURE

The Master of Science in Pharmaceutical Chemistry is a Two Year Full Time Course consisting of Four Semesters.

Semester I
Semester II
Semester III
Semester IV

Sem	Core Course			Elective Course			Open elective Cours			Value Added		Total Credits
	No. o Paper	Credits (L+T/P	Total Credits	No. of Papers	Credits (L+T/P	Tot Cre	No. Pape	Credits (L+T/I	Total Credit	No. of Papers	Credits	
I	4	12+8	20	0	0+0	0	0	0+0	0	1	4	24
II	5	16+8	24	0	0+0	0	0	0+0	0	1	0	24
III	3	4+4+4	12	2	4+4	8	1	4+0	4	0	0	24
IV	2	4+8	12	3	4+4+4	12	0	0+0	0	0	0	24
Total Credits			68			20			4		4	96

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Semester-I

Paper Code	Title of the paper	Credits	Int. Ass.	End Sem. Exam.	Marks
PHCHCC-101	Physical Chemistry	4			
PHCHCC-102	Organometallic & Nuclear Chemistry	4			
PHCHCC-103	Organic Chemistry	4			
PHCHCC-104A **PHCHCC-104B**	Inorganic Chemistry Practical Organic Chemistry Practical	8			
PHCHVC-101	Separation Techniques	4			
	Total	24			

PHCH - Subject; PHCHCC - Core Course; PHCHVC – Value added (credited); PHCHVNC – Value added (non-credited); PHCHEL – Elective; PHCHIER – Interdepartmental course; PHCHIRA – Intradepartmental course

M.Sc. Pharmaceutical Chemistry Semester I Syllabus
Paper Code PHCHCC-101: Physical Chemistry
Core Course

Credits 04 **Hours 60**

Course Objective:

To provide students coming in the first year of Masters program in Pharmaceutical Chemistry an understanding of the biological processes inside living organisms, enzyme catalysis, theories of unimolecular reactions, kinetics of enzyme reactions.

Course Outcome:

Student will learn-

CO-1. To know and understand that how living organism acquires and transforms energy in order to perform biological work

CO-2. To understand how enzyme catalysis increases reaction rates without altering the chemical equilibrium.

CO-3. To became familiar with Langmuir theory, BET theory and their uses, Zeta potential. Electrokinetic phenomenon, Donnan equilibrium, Primary and Secondary salt effects

CO-4. To know the latest techniques which are nowadays used in determining the fast reactions.

Unit I

Bioenergetics: coupled reactions, ATP and its role in bioenergetics, high energy bond, free energy and entropy change in ATP hydrolysis, thermodynamic aspects of metabolism and respiration.
Acid-base catalysis: specific and general catalysis, Skrabal diagram, Bronsted catalysis law, prototropic and protolytic mechanism with examples, acidity function.

Unit II

Michaelis-Menten mechanism, effect of pH and temperature on enzyme catalysed reaction, Lineweaver Burk and Eadie equation and plots. Inbition of enzyme action, competitive inhibition and non competitive inhibition. Muscle contraction and energy generation in mechanochemical system.

Unit III

Adsorption and various types of adsorption isotherms. The Langmuir theory, kinetic and statistical derivation, multilayer adsorption-BET theory, Use of Langmuir and BET isotherms for surface area determination. Adsorption of liquids by solids, positive and negative adsorption, Gibbs adsorption equation., flash desorption

Unit IV

Theories of unimolecular reactions. Reactions in solution: factors determining reaction in solutions, effect of dielectric constant and ionic strength, cage effect, Bronsted-Bjerrum equation, primary and secondary kinetic salt effect, influence of solvent on reaction rates, significance of volume of activation,

Unit V

Kinetics of Fast reactions: relaxation, flow and shock methods, flash photolysis, NMR and ESR methods of studying fast reactions.
Colloids: Zeta potential, Electrokinetic phenomena, Sedimentation potential and
Streaming potential, Donnan membrane equilibrium.

Books Recommended:

1. P.W. Atkins, Physical Chemistry, Oxford University Press, New York.
2. S. Glasston, Physical Chemistry, Nostrand
3. Advance Physical Chemistry (Vol-1,2,3,4), K.L. Kapoor,Mac Millan, India
4. Puri Sharma Pathania, Advance Physical Chemistry.
5. J.O.M. Bockris and A.K.N. Reddy, Modern Electrochemistry, Vol.2, Plenum Press,New York
6. Statistical Thermodynamics, Second Edition, New Age International Limited Publisher, India by M.C. Gupta
7. Introductory Quantum chemistry by A.K Chandra, Second Edition,Tata Mc Graw-Hill publishing company Limited, India
8. Quantum chemistry Through problems and solution by R.K Prasad ,New age International Pvt Lmtd, Publishers
9. Molecular quantum Mechanics By P.W.Atkins Oxford University Press, Oxford New York
10. Physical Chemistry By Ira N. Levine

M.Sc. Pharmaceutical Chemistry Semester I Syllabus
Core Course
Paper Code PHCHCC-102: Organometallic and Nuclear Chemistry

Credits 04 **Hours 60**

Course Objective:

The course reviews the general principles of homogeneous catalysts, electron transfer agents, design and synthesis of organmetallic compounds, role of various metal ions as catalytic and structural centers in biological systems.

Course Outcome:

In this semester students learn

CO-1. the reaction mechanism and vibrational properties associated with inorganic coordination complexes which now-a-days are gaining importance as
Homogenous catalysts
Electron transfer agents
Sensors to detect ions as well as molecules such as nitroaromatic compounds a noxious compound utilized as an ingredient in explosives
Sensitizers in new-generation solar cells

CO-2. about the design of different highly reactive but potent organometallic compounds. This information can be a stepping stone to such students who are willing to excel themselves in industries in particular dealing with pharma sector.

CO-3. To recognize the importance of inorganic molecules in supporting organic biological systems.

CO-4. about how metal ions function as catalytic and structural centers in biological systems.

CO-5. about the metal ion transport and storage within cells and how any malfunction can result in various diseases.
CO-6. To gain insight into cutting edge developments that utilizes metal ions for medical purposes.
CO-7. To develop an appreciation for the structure and function of metal ions in the biological systems and how chemists aim to mimic them.
CO-8. to recognize the metal used for diagnosis and chemotherapy.

Unit I

Reactions of Organometallic Compounds Substitution reactions-nucleophilic ligand substitution, nucleophilic and electrophilic attack on coordinated ligands. Addition and elimination reactions-1,2 additions to double bonds, carbonylation and decarbonylation, oxidative addition and reductive elimination, insertion (migration) and elimination reactions. Rearrangement reactions, redistribution reactions, fluxional isomerism.

Unit II

Catalysis by Organometallic Compounds . Homogeneous and heterogeneous organometallic catalysis-alkene hydrogenation using Wilkinson catalyst, Tolman catalytic loops. the Fischer-Tropsch reaction(synthesis of gasoline). Hydroformylation of olefins using cobalt or rhodium catalyst. Carbonylation reactions-Monsanto acetic acid process

Unit III

Bioinorganic Compounds Essential and trace elements in biological systems, structure and functions of biological membranes, mechanism of ion transport across membranes, sodium pump, ionophores, valinomycin and crown ether complexes of Na^+ and K^+, ATP and ADP. Role of calcium in muscle contraction, blood clotting mechanism and biological calcification. Oxygen carriers and oxygen transport proteins-haemoglobins, myoglobins and haemocyanin, haemerythrins and haemevanadins, cooperativity in haemoglobin. Iron storage and transport in biological systems-ferritin and transferrin.

Unit IV

Redox metalloenzymes-cytochromes, peroxidases and superoxide dismutase and catalases. Nonredox metalloenzymes-CarboxypeptidaseA-structure and functions. Nitrogen Fixation-nitrogenase, vitamin B12 and the vitamin B12 coenzymes. Metal-Nuclei acid interaction
Metals in medicine-therapeutic applications of cis-platin, radio-isotopes and MRI agents. Toxic effects of metals (Cd, Hg, Cr and Pb).

Unit V

Analytical applications of radioisotopes-radiometric titrations, kinetics of exchange reactions, measurement of physical constants including diffusion constants, Radioanalysis, Neutron Activation Analysis, Prompt Gama Neutron Activation Analysis and Neutron Absorptiometry.
Applications of radio isotopes in industry, medicine, radiopharmacology, radiation safety precaution, nuclear waste disposal.

Recommended Books:

1. Introduction to Molecular Spectroscopy, G. M. Barrow, McGraw Hill.
2. Basic Principles of Spectroscopy, R. Chang, McGraw Hill.
3. Theory and Applications of UV Spectroscopy, H. H. Jaffe and M. Orchin, IBH- Oxford.
4. Introduction to Magnetic Resonance, A. Carrington and A..D. Maclachalan, Harper & Row.
5. Physical Methods for Chemistry, R. S. Drago, Saunders Company.
6. Infrared and Raman Spectra: Inorganic and Coordination Compounds, K. Nakamoto, Wiley.
7. Organometallic Chemistry: A Unified Approach by R. C. Mehrotra and A. K. Singh

M.Sc. Pharmaceutical Chemistry Semester I Syllabus
Core Course
Paper Code PHCHCC-103: Organic Chemistry

Credits 04 **Hours 60**

Course Objective:
This course will help the students learn about the various oxidation reduction and pericyclic reactions, principles of stereochemistry. Students will also learn about chiral molecules and drugs and their role in treatment of ailments.

Course Outcome:
CO-1. This helps students to understand the outcome of the reaction and the product formed on the basis of the thermodynamic as well Kinetic properties.
CO-2. Hammet equation explain the possible product that might be formed by changing the reaction parameters.
CO-3. The most modern and recant reactions help students to gain insight into modern synthetic chemistry.
CO-4. Various oxidation reduction and pericyclic reaction helps the students to learn basics of organic chemistry.
CO-5. Stereochemistry makes students aware of various terms involved, nomenclature and 3D structure of various compounds. The students also learn about the change in stereochemistry/ Conformation and condition involved when a particular substrate undergoes different types of reaction.
CO-6. Importance of chiral drugs would make the student aware of its role and its utility in curing a particular disease.

Unit I
Physical Organic Chemistry. Energy profiles. Kinetic versus thermodynamic control of product formation, Hammond postulate, kinetic isotope effects with examples, Linear free energy relationship Hammet equation, Taft equation.
Modern Synthetic Methods: Baylis-Hillman reaction, Henry reaction, Nef reaction, Kulinkovich reaction, Ritter reaction, Sakurai reaction, Ugi reaction. Brook rearrangement. Tebbe olefination. Metal mediated C-C and C-X coupling reactions: Heck, Suzuki, Negishi and Sonogashira, Nozaki-Hiyama,

Unit II
Oxidation: Metal based and non-metal based oxidations of (a) alcohols to carbonyls (chromium, manganese, aluminium, and silver based reagents) (b) phenols (Fremyôs salt, silver carbonate) (c) alkenes to epoxides (peroxides/peracids based), Sharpless asymmetric epoxidation.(d) alkenes to diols (Manganese, Osmium based), Sharpless asymmetric dihydroxylation, Prevost reaction. (e) alkenes to carbonyls with bond cleavage (manganese, osmium, ruthenium and lead based, ozonolysis) (f) alkenes to alcohols/carbonyls without bond cleavage (hydroboration-oxidation, Wacker oxidation) (g) ketones to ester/lactones (Baeyer-Villiger).

Unit III
Reduction-(a) Catalytic hydrogenation (Heterogeneous: Pd /Pt /Rh /Ni etc; Homogeneous: Wilkinson). Noyori asymmetric hydrogenation. (b) Metal based reductions using Li/Na/Ca in liquid ammonia, Sodium, Magnesium and Zinc (Birch, Pinacol formation, McMurry, Acyloin formation, dehalogenation and deoxygenations) (c) Hydride transfer reagents (i) $NaBH_4$ triacetoxyborohydride; LiAlH4 and DIBAL-H, MeerweinPondorff-Verley reduction) (ii) Stereo/enantioselective reductions (Chiral Boranes, Corey-Bakshi-Shibata).

Unit IV
Pericyclic Reactions: Main features of pericyclic reactions; Woodward-Hoffman rules, correlation diagram and FMO approaches; Electrocyclic reactions ï conrotatory and disrotatory motions for 4n and 4n+2 systems. Cycloadditions ï antarafacial and suprafacial additions, [2+2] and [4+2]

reactions (hз and ϕ), 1,3-dipolar cycloadditions and chelotropic reactions; Sigmatropic [i,j] shifts of C-H and C-C bonds; Claisen, thio-Claisen, Cope and aza-Cope rearrangements.
Stereochemistry of Organic Compounds:
Center of chirality: molecules with C, N, S based chiral centers. Axial, planar and helical chirality with examples, stereochemistry and absolute configuration of allenes, biphenyls and binaphthyls, , spiranes, exo-cyclic . Topicity and prostereoisomerism, topicity of ligands.

Unit V

Conformational Analysis of cyclohexane and its derivatives, decalins. Fused and bridged bicyclic systems. Conformation and reactivity of elimination (dehalogenation, dehydrohalogenation, semipinacolic deamination and pyrolytic elimination-Saytzeff and Hofmann eliminations). Chemical consequence of conformational equilibrium - Curtin Hammett principle.
Chiral drug synthesis Introduction to Chiral drugs, importance of stereochemistry in drug action, concepts of eutomer, distomer and eudysmic ratio, stereospecific and stereoselective synthesis, Synthesis of Chiral drugs like Ibuprofen, Propranolol, ramipril, levofloxacin.

Recommended Books:

1. Stereochemistry of organic compounds, Nasipuri, New Age International (P) Limited.
2. Organic Chemistry J. Clayden, N. Greeves, S. Warren and P. Wothers (Oxford Press.)
3. Advanced organic chemistry Part, A. F. A. Carey and R. J. Sundberg, 5th Ed. Springer (2007)
4. Advanced organic chemistry by J. March, 6th Ed. Wiley india Pvt. Ltd.
5. Mechanism and structure in Organic Chemistry ï E. S. Gould (Holt, Rinehart and Winston), Wiley india Pvt. Ltd.
6. Textbook of Pericyclic Reaction, Concept and Application, K.C. Majumdar and P. Biswas, Scientiffi International Pvt. Ltd.
7. Photochemistry and Pericyclic Reactions, Jagdamba Singh and Jaya Singh, New Age International (P) Limited.
8. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi.
9. Medicinal Chemistry, Ashutosh Kar, New Age International (P) Limited.

M.Sc. Pharmaceutical Chemistry Semester I Syllabus
Core Course
Paper Code PHCHCC-104B: Inorganic Chemistry Practical
Paper Code PHCHCC-104A Organic Chemistry Practical

Credits: 08

Course Objective:

To provide students coming in the first year of Masters program an understanding of the qualitative and quantitative chemical analysis, calculation of limiting reagent. Students will also get versed with the principles and applications of various methods of titration and the procedure of calculating purity of organic molecules.

Course Outcome:

CO-1. After completion of degree, students will gain the theoretical as well as practical knowledge of handling chemicals.

CO-2. Students will gain an understanding of:
a. the distinction between qualitative and quantitative chemical analysis.
b. how to calculate a limiting reagent, yield, and percent yield.

CO-3. students should be able to explain and perform the theoretical principles and important applications of classical analytical methods within titration (acid/base titrations, complexometric titration, redox titration) and various techniques of gravimetric and volumetric analysis.

CO-4. students should be able to check the purity of organic molecules by the use of TLC and how to calculate their Rf values.

CO-5. Also, students will be able to understand how to maintain a detailed scientific notebook.

INORGANIC CHEMISTRY PRACTICAL

1. Redox titrations
   (a) Dichromatometry
   (b) Iodometry
2. Gravimetric method
   (a) Ag as AgCl
   (b) Cu as CuSCN
3. Complexometric titrations of
   (a) Magnesium using EDTA
   (b) Zinc using EDTA
   (c) Neutralization reactions

ORGANIC CHEMISTRY PRACTICAL

Separation, purification, characterization and identification by making suitable derivatives of the three component Organic mixture (three solids or two solids and one liquid or two liquids and one solid) involving all the functional groups. Use TLC for checking the purity of the separated compounds and their derivatives and report their Rf values.

Recommended Books:

1. Vogel, A.I. A Textbook of Quantitative Inorganic Analysis, ELBS.
2. Marr, G. and Rockett, R.W. Practical Inorganic Chemistry, Van Nostrand Reinhold. 1972.
3. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009).
4. Sethi, Arun.,Systematic Lab Experiments in Organic Chemistry, New Age International Publisher.
5. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012).
6. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000).
7. Ahluwalia, V.K. & Dhingra, S. Comprehensive Practical Organic Chemistry: Qualitative Analysis, University Press (2000).

M.Sc. Pharmaceutical Chemistry Semester I Syllabus
Value Added (Credited)
PHCHVC-101 Separation Techniques

Credits 04 **Hours 60**

Course Objective:

To provide students coming in the first year of Masters program new insight into the separation and filtration technique which in turn pave the pathway for the purification and isolation of targeted compounds after rational synthesis.

Course Outcome:

CO-1. Students will learn the methods of separating a mixture or solution of chemical substances to obtain the pure constituents.
CO-2. Students will learn the tradition methods of purification such as crystallization, extraction and distillation.
CO-3. Students will know the Celite filtration, a useful technique used to remove fine solids such as metal salt from the reaction mixture.
CO-4. Students will learn the centrifugation techniques useful in the microanalysis and is based on density difference.
CO-5. They also learn the chromatographic techniques as they give accurate and complete separation and purification of the compounds.
CO-6. The students will also learn the modern techniques of chromatography such as flash chromatography, LPLC, HPLC and GC-MS etc.

Unit – I

1. Distillation
2. Crystallization
3. Membrane Processes
4. Filtration

Unit – II

1. Evaporation
2. Extraction
3. Celite Filtration
4. Gel Filtration

Unit – III

Demister (Vapour)
Adsorption & Stripping
Centrifugation

Unit – IV

1. TLC
2. Sephadex Chromatography
3. Flash Chromatography
4. LPLC
5. HPLC
6. Paper Chromatography

Unit – V

1. Counter current chromatography (CCC & DCCC)
2. Ion exchange chromatography
3. GC ï MS (Gas Chromatography)
4. Column chromatography (Silica gel)
5. Molecular Sieve chromatography or size exclusion chromatography

Recommended Books:

1. Lloyd R. Snyder LC Resoures, Inc walnut Greek, California
2. Colin F. Poole, Department of Chemistry, Wayne State University Detroit MI 48202, USA 2003 Elsevier.
3. J. D. Seader, and Ernest J. Henley, Separation Process Principles, Wiley, 2nd edition (2013).