M. Sc. INDUSTRIAL CHEMISTRY PROGRAMME

PROGRAMME STRUCTURE AND SYLLABUS

MAHATMA GANDHI UNIVERSITY

PREFACE

"*The Future Depends on What You Do Today*." – **Mahatma Gandhi**

The foundation of today's world is built upon the ideas and discoveries of great scientists, and its future is dependent on the innovations and inventions of young minds. One of the most important roles of higher education institutions is to equip today's young minds to meet tomorrow's challenges. Although the academic world in the state is highly teaching and research oriented, a healthy interface between academia and industry is lacking. That is why Kerala remains as an industrially backward state. Postgraduate (PG) programme in Chemistry with specialization in Industrial Chemistry will definitely improve the association between academia and industry, and ensure greater exposure and employability for the students.

In 2020, Mahatma Gandhi University approved M.Sc. Industrial Chemistry programme as a new generation innovative programme which satisfies the educational policies of the Government. Pertaining to this, an Expert Committee was constituted by the University to design the structure and syllabus of the programme. In line with the existing regulations of the University and to meet the academic requirements and career aspirations of chemistry students, the committee conducted brainstorming sessions to accomplish the task.

The programme comprises of 19 theory courses including 13 core and 6 elective courses. Emerging trends and recent developments in chemical sciences were also included in these courses. To impart laboratory skills among students to synthesize, separate and characterize chemical compounds using established reactions, protocols, and modern instrumentation, the committee judiciously identified and systematically framed 7 practical courses. Furthermore, to inculcate research culture and provide industrial exposure, research-oriented project work and industrial internship programme are included.

Syllabus design for a postgraduate programme is creative, but strenuous task. It is realized by the concerted and earnest efforts at different levels. I express my deepest gratitude to all the members of expert committee for their dedicated efforts for framing the syllabus, members of Board of Studies of Industrial Chemistry for meticulously revising the syllabus, and the honourable Vice Chancellor, the Members of Syndicate, the Academic Council, the Registrar and the Academic AIX Section of the University for their guidance and support.

Dr. Seno Jose
Chairperson, Board of Studies

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Table 1: Members of Expert Committee

Sl. No.	Name and Designation	Position
1	Dr. Seno Jose Associate Professor & Head Department of Chemistry Government College Kottayam	Chairperson
2	Dr. Geetha P. Associate Professor & Head Department of Chemistry D B Pampa College, Parumala, Pathanamthitta	Member
3	Dr. Suma Bino Thomas Associate Professor & Head Department of Chemistry Baselius College, Kottayam	Member
4	Shri. Manukumar N. Assistant Professor Department of Chemistry Government College Kottayam	Member
5	Smt. Smitha V.K., Assistant Professor Department of Chemistry Government College Kottayam	Member
6	Dr. Abi Santhosh Aprem Associate Vice President (R&D) HLL Lifecare Ltd, Thiruvananthapuram	Member

Table 2: Members of Board of Studies of Industrial Chemistry (UG&PG)

Sl. No.	Name and Designation	Position
1	Dr. Seno Jose Associate Professor & Head Department of Chemistry Government College Kottayam	Chairperson
2	Shri. Manukumar N. Assistant Professor Department of Chemistry Government College Kottayam	Member
3	Shri. Satheesh Babu T. Assistant Professor Department of Chemistry MES College, Nedumkandam, Idukki	Member
4	Dr. Sheela Gopal M. Associate Professor Department of Chemistry TMJM Government College, Manimalakunnu	Member
5	Dr. Ramya Jayan S. Assistant Professor Department of Chemistry D B Pampa College, Parumala, Pathanamthitta	Member
6	Dr. Anila B.N. Assistant Professor Department of Chemistry Government College Kottayam	Member
7	Dr. Sindhu K.S. Assistant Professor Department of Chemistry Morning Star Home Science College, Angamaly	Member
8	Dr. Tresa Sunitha George Assistant Professor Department of Chemistry St. Paul's College, Kalamassery, Ernakulam	Member
9	Dr. Meera Gopal Associate Professor Department of Chemistry Maharaja's College, Ernakulam	Member
10	Dr. Sharika T. Assistant Professor Department of Chemistry St. Xavier's College, Vaikom, Kottayam	Member
11	Dr. Abi Santhosh Aprem Associate Vice President (R&D) HLL Lifecare Ltd Thiruvananthapuram	Member

M. Sc. INDUSTRIAL CHEMISTRY DEGREE PROGRAM

(Academic Year 2020-21 onwards, as per the regulations of Mahatma Gandhi University-PGCSS 2019)

1. PROGRAMME OBJECTIVES

- To provide strong foundation in the discipline of Chemical Sciences and to introduce the emerging trends and recent developments in this discipline.
- To impart the basic experimental and technical skills to effectively employ in various fields of chemistry.
- To motivate critical thinking and analytical skills to solve complex scientific problems.
- To enable the students to apply appropriate qualitative and quantitative techniques to characterize and evaluate chemical compounds.
- To develop necessary laboratory skills to synthesize, separate and characterize chemical compounds using established reactions, protocols, and modern instrumentation.
- To inculcate research culture among students by providing exposure in renowned research institutions.
- To provide the students the necessary industrial exposure and training to familiarize important industrial instrumentation and processes.
- To strengthen institute-industry interactions through collaborations.

2. PROGRAMME OUTCOMES

On successful completion of this Programme, students will have the ability to:

- understand basic and advanced concepts in chemical sciences.
- effectively apply the experimental and technical skills in various fields of chemistry.
- think critically and analytically to solve scientific problems.
- employ laboratory skills to synthesize and characterize chemical compounds.
- undertake independent research problems.
- work effectively and safely in industries.

3. ADMISSION

- The admission to the programmes shall be as per the rules and regulations of the University.
- Graduation in Chemistry (Model 1, 2 or 3) with not less than CCPA of 5.00 out of 10.00 in Core Group (Core courses + Vocational courses + Complementary courses + Open Course).
- Relaxation in Marks in the qualifying examination:

  1. For SC/ST category, a pass in the qualifying examination is the minimum requirement for admission.

  2. For OEC category CCPA of 4.5 in the qualifying examination is required.

- The eligibility criteria for admission shall be as announced by the University from time to time.
- Separate rank lists shall be drawn up for seats under reservation quota as per the existing rules. All the reservation policies of the Government must strictly be followed in Government Colleges.
- The total number of seats for the programme may be up to 20. All seats are open to students who passed BSc Chemistry (Model-1/Model-2/Model-3) programmes.
- A weightage (maximum up to 10%) may be given for students who graduated in B.Sc. Chemistry (Model -II) Industrial Chemistry programme, during index marks calculation.
- The programme shall be conducted in line with the academic and examination calendar prepared of the University.

4. MEDIUM OF INSTRUCTION

English

5. FACULTY UNDER WHICH THE DEGREE IS AWARDED

Science

6. ASSESSMENT

The weightage for internal & external evaluation of theory/practical/project/viva-voce is 5 & 15 and the maximum Weighted Grade Point (WGP) is 25 & 75 respectively, (ratio 1:3)

6.1. Pattern of Questions

Sl. No.	Type of Questions	Weight	Number of questions to be answered
1	Short Answer type questions	1	8 out of 10
2	Short essay/ problem solving type questions	2	6 out of 8
3	Long Essay type questions	5	2 out of 4

6.2. Direct Grading System

Direct Grading System based on a 7–point scale is used to evaluate the performance (External and Internal Examination of students)

For all courses (theory & practical)/semester/overall programme Letter grades and GPA/SGPA/CGPA are given on the following scale:

Sl. No.	Range	Grade	Indicator
1	4.50 to 5.00	A^+	Outstanding
2	4.00 to 4.49	A	Excellent
3	3.50 to 3.99	B^+	Very good
4	3.00 to 3.49	B	Good (Average)
5	2.50 to 2.99	C^+	Fair
6	2.00 to 2.49	C	Marginal
7	up to 1.99	D	Deficient (Fail)

Minimum **C grade** is required for pass in a course.

Evaluation first stage - Both internal and external (to be done by the teacher)

Sl. No.	Grade	Grade Points
1	A^+	5
2	A	4
3	B	3
4	C	2
5	D	1
6	E	0

6.3. Weightage Distribution for External and Internal Examination

6.3.1. Theory-External

Maximum weight & Maximum Weighted Grade Point (WGP) for external evaluation is **30** and**150** respectively.

6.3.2. Theory-Internal (Components and Weightage)

Sl. No.	Components	Weightage
1	Assignment	1
2	Seminar	2
3	Best Two Test papers	1 each (2)
	Total	**5**

6.3.3. Practical-External (Components and Weightage)

Sl. No.	Components	Weightage
1	Written / Lab test	10
2	Record	2
3	Viva	3
	Total	**15**

6.3.4. Practical-Internal (Components and Weightage)

Sl. No.	Components	Weightage
1	Written / Lab test	3
2	Lab involvement	1
3	Viva	1
	Total	**5**

6.3.5. Project- External (Components and Weightage)

Sl. No.	Components	Weightage
1	Relevance of the topic	2
2	Content and presentation	8
3	Viva	5
	Total	**15**

6.3.6. Project- Internal (Components and Weightage)

Sl. No.	Components	Weightage
1	Relevance of the topic	1
2	Content and presentation	3
3	Viva	1
	Total	**5**

6.3.7. Industrial Internship Programme - External (Components and Weightage)

Sl. No.	Components	Weightage
1	Relevance of the topic	2
2	Content and presentation	8
3	Viva	5
	Total	**15**

6.3.8. Industrial Internship Programme - Internal (Components and Weightage)

Sl. No.	Components	Weightage
1	Relevance of the topic	1
2	Content and presentation	3
3	Viva	1
	Total	**5**

6.3.9. Comprehensive viva-voce -External (components and weightage)

Sl. No.	Components	Weightage
1	Course viva (all courses from first semester to fourth semester)	15
	Total	**15**

6.3.10. Comprehensive viva – Internal (Components and Weightage)

Sl. No.	Components	Weightage
1	Course viva (all courses from first semester to fourth semester)	5
	Total	**5**

7. PROGRAMME DESIGN AND STRUCTURE

7.1. Programme Design

7.1.1. Distribution of Courses and Credits

The Credit and Semester system is followed in this program. Total credits for the programme are eighty (80). The programme includes two types of courses: Core Chemistry Courses and Elective Courses. The elective courses are included in semesters III and IV. There are two Elective Course Groups (Group A and Group B). Each group comprises of three elective courses. Comprehensive viva-voce is included in semester IV. No course shall have more than four (4) credits. There shall be an Industrial Internship Programme (IIP) and Research Oriented Project (ROP) to be undertaken by all students. The programme will also include assignments, seminars, practical, industrial visits etc. The program has four semesters with 18 weeks in each semester. There are a total of 450 calendar hours (including theory, practical and ROP) in each semester which is in compliance with the minimum 390 hours stipulated by the UGC. The design and the structure of the programme are displayed in tables 1 and 2, respectively.

Table 1: Programme design

Semester	Hours	Credits
Semester I	450	16
Semester II	450	23
Semester III	450	16
Semester IV	450	25
Total	1800	80
Theory (Core + Elective) Practical Industrial Internship Programme (IIP) Research Oriented Project (ROP) Comprehensive Viva-Voce		54 18 3 3 2

Table 2: Programme Structure

SEM	Course Code	Course Title	Hours	Credits
SEMESTER I	CH060101	Inorganic Chemistry - I	72	4
	CH060102	Theoretical Chemistry - I	54	3
	CH060103	Organic Chemistry - I	72	4
	CH060104	Industrial Processes & Reactor Analysis	54	3
	CH060105	Industrial Chemistry Practical - I	72	2
	CH060205	Inorganic Chemistry Practical	36	Evaluated at the end of Semester II
	CH060206	Physical Chemistry Practical	36	
	CH060207	Organic Chemistry Practical	54	
Total – Semester I			**450**	**16**
SEMESTER II	CH060201	Inorganic Chemistry - II	72	4
	CH060202	Physical Chemistry - I	72	4
	CH060203	Organic Chemistry - II	54	3
	CH060204	Analytical Methods & Material Characterization	54	3
	CH060205	Inorganic Chemistry Practical	72	3
	CH060206	Physical Chemistry Practical	72	3
	CH060207	Organic Chemistry Practical	54	3
Total – Semester II			**450**	**23**
SEMESTER III	CH060301	Theoretical Chemistry - II	72	4
	CH060302	Physical Chemistry - II	54	3
	CH060303	Petrochemicals, Dyes & Perfumes	54	3
		Elective Course – I	54	3
	CH060304	Industrial Internship Programme (IIP)		3
	CH060405	Physical Chemistry Practical - II	54	Evaluated at the end of semester IV
	CH060406	Industrial Chemistry Practical - II	54	
	CH060407	Industrial Chemistry Practical – III	54	
	CH060408	Research Oriented Project (ROP)	54	
Total – Semester III (Theory & Practical + IIP)			**450**	**16**
SEMESTER IV	CH060401	Drug Chemistry & Pharmaceutical Technology	54	3
	CH060402	Industrial Polymers & Manufacturing	72	4
		Elective Course II	54	3
		Elective Course III	54	3
	CH060405	Physical Chemistry Practical - II	54	3
	CH060406	Industrial Chemistry Practical - II	54	2
	CH060407	Industrial Chemistry Practical - III	54	2
	CH060408	Research Oriented Project (ROP)	54	3
	CH060409	Comprehensive Viva-Voce		2
Total – Semester IV (Theory & Practical + ROP + Viva)			**450**	**25**
Total			**1800**	**80**

7.1.2. Elective Courses

Group A Courses

Course Code	Course Title	Hours	Credits
CH900301	Elective Course I: Chemistry of Advanced Materials	54	3
CH900402	Elective Course II: Advanced Physical Chemistry	54	3
CH900403	Elective Course III: Advanced Synthetic Organic Chemistry	54	3

Group B Courses

Course Code	Course Title	Hours	Credits
CH910301	Elective Course I: Industrial Oils and Fat Products	54	3
CH910402	Elective Course II: Industrial Enzyme Technology	54	3
CH910403	Elective Course III: Smart Materials, Soft Materials and Green Chemistry	54	3

7.1.3. Industrial Internship Programme (IIP)

All the students shall undertake an IIP in a reputed industry in the country. The main objective of the programme is to provide the students an industrial exposure to understand and familiarize the actual working environment in industries. The IIP would provide students an exposure to important industrial instrumentation and processes, and instil them the good qualities of integrity, responsibility and self-confidence. It would also enable students to undertake safety practices and regulations followed in an industry and to inculcate the spirit of teamwork. All ethical values and good working practices must be followed by the students. The duration of the IIP may be one month. Since no rigid time frame is provided for the IIP in the regular teaching hours, students have the flexibility to realize the programme in a single stretch during the semester break. The evaluation may be conducted towards the end of fourth semester, on the basis of the project report submitted by the student and its successful presentation. A maximum of three (3) credits are allotted for the IIP.

7.1.4. Research oriented project (ROP)

A research-oriented project (ROP) shall be carried out in a reputed research institution or industry in the country. The ROP shall be carried out under the supervision of a scientist or researcher/faculty member of the host institution. A teacher in the parent institution may act as a co-supervisor. The ROP carried out in a renowned research institution would provide a research culture to the student and enhance his/her analytical skills, critical thinking and problem-solving ability. The student would get an opportunity to undertake hands-on-training on sophisticated analytical instruments. Furthermore, association with researchers and scientists would develop the skills of information processing, interpretation of the experimental and empirical data, and academic writing. The duration of the ROP shall be two months (which includes 54 regular hours of semesters 3 and 4), and may be realized during the fourth semester of the programme. There shall be an internal assessment and an external assessment for the ROP. The external evaluation shall be based on the project report submitted by the student and its successful presentation and defence. A maximum of 3 credits are allotted for the ROP. The research findings emanating from the ROP may be published in peer reviewed journals.

8. BOARD OF STUDIES (BoS)

A BoS may be constituted for MSc Industrial Chemistry and BSc Model (II & III) programmes. The Board shall design and introduce new courses, modify or re-design existing courses and replace any existing courses with new/modified courses to facilitate better exposure and training for the students.

SEMESTER I

Course	Details				
Course Code	**CH060101**				
Course Title	**INORGANIC CHEMISTRY - I**				
Degree	M. Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I				
Type	Core Course - Theory				
Credits	4	Hrs/Week	4	Total Hours	72

Module	Course Description	Hrs
1.0	**Introduction**	**3**
1.1	Classification of ligands (sigma and pi). Classification of complexes based on coordination numbers and possible geometries.	3
2.0	**Isomerism in Coordination Compounds**	**6**
2.1	Isomerism: - Geometrical and optical isomerism in octahedral complexes, resolution of optically active complexes, stereo selectivity and conformation of chelate rings,	3
2.2	Linkage isomerism-electronic and steric factors affecting linkage isomerism. Prussian blue and related structures. Spinels.	3
3.0	**Theories for Metal-Ligand bonding in complexes**	**18**
3.1	Crystal field Splitting of d orbitals in octahedral, tetrahedral, square planar, square pyramidal and triagonal bipyramidal fields. Factors influencing the magnitude of crystal field splitting - Calculation of crystal field stabilization energies, Dq values, Jahn Teller (JT) effect, theoretical failure of crystal field theory,	9
3.2	Evidence of covalency in the metal-ligand bond, nephelauxetic effect, ligand field theory, and molecular orbital theory - M.O energy level diagrams for octahedral and tetrahedral complexes without and with π-bonding experimental evidences for pi-bonding.	9
4.0	**Electronic spectra of transition metal complexes**	**9**
4.1	Russell-Saunders states, Microstates, Terms of d^n configurations Ground state term. Splitting of terms in weak and strong octahedral and tetrahedral fields. *d-d* transition - selection rules for electronic transition, effect of spin orbit coupling and vibronic coupling.	5
4.2	Orgel diagrams, Spectra of 3d metal complexes, determination of *Dq* and Racah parameters, Tanabe-Sugano diagrams. Charge transfer spectra.	4

5.0	**Magnetic properties of transition metal complexes**	**9**
5.1	Classification of substances according to magnetic properties. magnetic susceptibility, Guoy's and faraday's methods for the determination of magnetic susceptibility. Temperature dependence of magnetism- curie's law, curies-weiss law. Calculation of magnetic moment from magnetic susceptibility spin only formula.	5
5.2	Crystal field theory and its application to explain magnetic properties of coordination compounds: - Spin only magnetic moment spin-orbit coupling, quenching of orbital angular moment- spin cross over.	4
6.0	**Stability of complexes and reaction mechanism**	**18**
6.1	Thermodynamic and Kinetic stability and stability constant: - relation between stability constant, factors affecting the stability of complexes. Determination of stability constant. Thermodynamic aspects of complex formation- Irving William order of stability. Chelate effect	3
6.2	Substitution reactions in square planar complexes, trans effect-theory, factors affecting trans effect, mechanism, Application. Substitution in tetrahedral complexes.	5
6.3	Substitution reaction in octahedral complexes: dissociative, associative and interchange mechanisms, isomerization, racemization. Replacement reactions involving multidentate ligands.	5
6.4	Electron transfer reactions - inner sphere mechanism and outer sphere mechanism. Marcus equation. Mixed outer and inner sphere reactions. Two electron transfers	5
7.0	**Lanthanides and Actinides**	**9**
7.1	General characteristics of lanthanides-Electronic configuration, Term symbols for lanthanide ions, Oxidation state, Lanthanide contraction. Coordination complexes of the lanthanoids- hydrated salt, beta diketones. Electronic spectra and magnetic properties of lanthanide complexes. Lanthanide complexes as shift reagents, adiabatic demagnetization.	6
7.2	General characteristics of actinides- Electronic configuration, Oxidation state, difference between *4f* and *5f* orbitals. Uranium and thorium complexes. Electronic and magnetic properties of the actinides.	3

RECOMMENDED TEXT BOOKS

1. J.E. Huheey, E.A. Keiter, R.A. Keiter, ***Inorganic Chemistry Principles of Structure and Reactivity***, 4thEdn. Pearson Education India (2006).
2. F. Albert Cotton, Geoffrey Wilkinson, Carlos A. Murillo, Manfred Bochmann ***Advanced Inorganic Chemistry, An Indian Adaptation***, Wiley (2021)
3. M. Weller, T. Overton, J. Rourke and F. Armstrong, ***Inorganic Chemistry,*** 6th Edition, Oxford University Press, South Asia Edition (2015).
4. Simon Cotton, ***Lanthanide and Actinide Chemistry***, John Wiley and Sons (2006).

SUGGESTED READING AND REFERENCES

1. D. Banerjea. ***Coordination Chemistry, 3rd Ed***, Tata McGraw – Hill, New Delhi. (2009).
2. F. Basolo, R.G. Pearson, ***Mechanisms of Inorganic Reaction***, John Wiley & Sons, (2006).
3. C. E. Housecroft, A. G. Sharpe, ***Inorganic Chemistry***, Pearson (2012).
4. B.E. Douglas, D.H. McDaniel, J.J. Alexander, ***Concepts and Models of Inorganic Chemistry,*** 3rd Edn., Wiley-India (2007).
5. Sutton, D. ***Electronic Spectra of Transition Metal Complexes***, McGraw-Hill: New York (1968)
6. Mabbs, F.E. and Machin, D.J. ***Magnetism and Transition Metal Complexes*** Chapman and Hall: U.K (1973).
7. R. G. Wilkins, ***Kinetics and Mechanisms of Reactions of Transition Metal Complexes***, Wiley VCH (2002).

Course	Details				
Course Code	**CH060102**				
Course Title	**THEORETICAL CHEMISTRY - I**				
Degree	M. Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I				
Type	Core Course- Theory				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**The Evolution and Formulation of Quantum Mechanics**	**18**
1.1	The origin of Quantum Mechanics: The Blackbody Spectrum, Planck's distribution law, The Photoelectric effect, The Compton effect, The hydrogen atom spectra.	4
1.2	The standing waves, One dimensional wave equation, Wave packets, de Broglie's matter waves, The Davisson-Germer experiment, The wave-particle duality	3
1.3	The Schrödinger wave equation, Heisenberg's uncertainty principle: derivation, the position-momentum and energy-time relations, consequences of the uncertainty principle, relation to experiment and the problem of measurement, Bohr's principle of complementarity, The Copenhagen interpretation	5
1.4	Formulations of quantum mechanics: Well-behaved wavefunction, Normalization and Orthogonality, Operators, Hermitian properties, Commutation of operators, Eigenfunctions, Eigenvalues, Expectation values, Postulates of quantum mechanics. The statistical interpretation of wavefunctions	6
2.0	**Application of Schrödinger's Equations to Exactly Solvable Model Problems**	**27**
2.1	The Particle in a Box Model: one-dimensional box, two-dimensional box and three-dimensional box models, separation of variables, concept of degeneracy, concept of nodes	5
2.2	The Harmonic Oscillator Model: Classical simple harmonic oscillator, One-dimensional quantum harmonic oscillator, Properties of solutions: Energy states, Wavefunctions – Hermite's polynomials, Quantum tunneling, Bohr's correspondence principle	6
2.3	Non-planar rigid rotor and their solutions: - Legendre and associated Legendre equations, Legendre polynomials. Spherical harmonics	4
2.4	Hydrogenic Species: Solution of the Schrodinger equation and the determination of energy levels: The separation of the Wave Equation, The r-equation, the θ- equation and the ϕ-equation, The energy levels, Radial probability distribution functions, Atomic orbitals.	8

2.5	Angular momentum: The angular momentum operators, Orbital and Spin motion of electrons, The angular momentum of composite systems	4
3.0	**Approximation Methods in Quantum Mechanics**	**9**
3.1	Perturbation theory: First order perturbation theory for a non-degenerate level – Illustration: Particle in a one-dimensional box with slanted bottom /The Perturbed Harmonic Oscillator.	5
3.2.	The Variation Method: The variation integrals and its properties, Illustration using a trial function for particle in a one dimensional-box and using a trial function e^{-ar} for the hydrogen atom.	4

RECOMMENDED TEXT BOOKS

1. Linus Pauling, E.B. Wilson, ***Introduction to Quantum Mechanics: With Applications to Chemistry***, International Student Edition, (1935).
2. Peter Atkins, Ronald Friedman, ***Molecular Quantum Mechanics,*** 5th ed. Oxford University Press, (2005).
3. Donald A. McQuarrie, ***Quantum Chemistry***, Viva Student Edition, (2013).
4. Ira N. Levine, ***Quantum Chemistry,*** 7th Edition, Pearson (2016).
5. R.K. Prasad, ***Quantum Chemistry***, New age international Publishers, 4th Revised Edition, (2021).
6. A.K. Chandra, ***Introductory Quantum Chemistry***, 4th Edition, (2002).

SUGGESTED READING AND REFERENCE BOOKS

1. John Polkinghorne, ***Quantum Theory: A very Short Introduction***, Oxford University Press, (2002).
2. J.P. McEvoy, Oscar Zarate, ***Quantum Theory: A graphic Guide***, (2013).
3. Jim Baggott, ***The Quantum Story: A history in 40 Moments***, Oxford University Press, (2011).
4. ***Thirty Years that Shook the Physics***, George Gamow, Dover Publications, (1996).
5. Peter Atkins, Julio de Paula, Ronald Friedman, ***Physical Chemistry: Quanta, Matter, Change***, 2nd Edition, (2012).
6. T. Engel, ***Quantum Chemistry and Spectroscopy***, 4th Edition, Pearson Education, (2019).
7. David Bohm, ***Quantum Theory***, Dover Publications, (2017).
8. Albert Messiah, ***Quantum Mechanics,*** Dover Publications, (2018).
9. J.P. Lowe, K Peterson, ***Quantum Chemistry***, 3rd Edition, Academic Press, (2006).
10. ***Quantum Mechanics***, Leonard I. Schiff, 3rd Edition, (1968).
11. D. J. Griffiths, ***Introduction to Quantum Mechanics,*** Pearson Education, (2005).
12. L.E. Ballentine, ***The Statistical Interpretation of Quantum Mechanics***, Review of Modern Physics, Volume 42, Number 4, (1970).

Course	Details				
Course Code	**CH060103**				
Course Title	**ORGANIC CHEMISTRY - I**				
Degree	M. Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I				
Type	Core Course- Theory				
Credits	4	Hrs/Week	4	Total Hours	72

Module	Course Description	Hrs
1.0	**Structure and Bonding in Organic molecules**	**18**
1.1	Review of basic concepts in organic chemistry: Atomic and molecular orbits, concepts of bonding, anti-bonding and nonbonding molecular orbital, hybridization – sp, sp^2 & sp^3.	2
1.2	Formation, structure and stability of carbocations, carbanions, free radicals, carbenes, nitrenes and aryne, Benzyne intermediates.	5
1.3	Aromaticity: - Hückel rule and modern theory of aromaticity, criteria for aromaticity and antiaromaticity, MO description of aromaticity and antiaromaticity, Homoaromaticity. Aromaticity of annuelens and heteroannulenes, fused ring systems, fulvenes, fulvalenes, azulenes, pentalenes and heptalenes. Stability of benzylic cations and radicals. Effect of delocalized electrons on pKa.	8
1.4	Hydrogen bonding: Inter- and intra-molecular hydrogen bonding. Range of the energy of hydrogen bonding. Effect of hydrogen bond on conformation	3
2.0	**Physical Organic Chemistry**	**9**
2.1	Energy profiles. Kinetic versus thermodynamic control of product formation, Hammond postulate, Bell-Evans-Polanyi principle, Curtin-Hammet principles. Kinetic isotope effects with examples. Linear free energy relationships-Hammet equation, Taft equation. Neighbouring group participation	5
2.2	Acid and base Catalysis. Detection of intermediates. Ester formation and hydrolysis reactions of esters-AAC2, AAC1, AAL1, BAC2and BAL1 mechanisms.	4
3.0	**Stereochemistry of Organic Compounds**	**18**
3.1	Concept of chirality, chirality and symmetry elements, optical isomerism and optical activity, measurement of optical activity. Chirotopicity and stereogenecity.	3
3.2	Axial chirality in allenes, spiranes, alkylidinecycloalkanes, oximes, adamantanes, biphenyls. Chirality in heteroatom systems.	2

3.3	Stereochemistry of molecules with more than one chiral centre, cyclic compound, bicyclic compound, chirality without chiral centre.	3
3.4	Fisher projection saw horse projection, wedge formula. Absolute configuration. R and S notation in cyclic and acyclic compounds E-Z notation, erythro and threo nomenclature.	3
3.5	Meso compounds, enantiomeric excess and diastereomeric excess and their determination, diastereoisomers and its properties. Racemic modification, racemization and its resolution.	4
3.6	Topicity and prostereoisomerism, topicity of ligands and faces as well as their nomenclature, NMR distinction of enantiotopic- diastereotopic ligands	3
4.0	**Conformational Analysis**	**18**
4.1	Factors affecting conformational stability of molecules, conformational analysis of substituted ethanes, Conformation of acyclic compounds, Conformations of cyclic system other than cyclohexane, conformation of cyclohexane and substituted cyclohexanes.	6
4.2	Conformation and reactivity of elimination (dehalogenation, dehydrohalogenation, semi pinacolic deamination and pyrolytic elimination - Saytzeff and Hofmann eliminations), substitution, reduction of cyclohexanones and oxidation of cyclohexanols**.** formation and cleavage of epoxides. Factors governing the reactivity of axial and equatorial substituents in cyclohexanes.	12
5.0	**Asymmetric Synthesis**	**9**
5.1	Stereoselectivity and stereospecificity, stereoselective reactions and asymmetric synthesis. Diastereoselective synthesis- Cram's rule, Felkin – Anh model, Prelog's rule. Enantioselective synthesis.	4
5.2	Chiral pool, Chiral auxiliaries, Chiral reagent, asymmetric catalysis- reduction of ketones, hydrogenation of alkenes, asymmetric epoxidation, asymmetric dihydroxylation. Asymmetric formation of carbon- carbon bonds, Asymmetric aldol reaction, Zimmermann – Traxler model	5

RECOMMENDED TEXT BOOKS

Structure and Bonding in Organic molecules

1. R. R. Carey and R. J. Sundburg, ***Advanced Organic Chemistry, Part A: Structure and Mechanisms***, Springer, 5th Edition (2007).
2. J. Clayden, N. Greeves, S. Warren and P. Wothers, ***Organic Chemistry***, 2nd Edition, Oxford University Press (2012).

Physical Organic Chemistry

1. E. V. Anslyn and D. A. Dougherty, ***Modern Physical Organic Chemistry***, University Science Books (2005).
2. N. S. Isaacs, ***Physical Organic Chemistry***, ELBS, Longman, UK (1987).

Stereochemistry of Organic Compounds

1. E. L. Eliel, S. H. Wilen and L. N. Mander, ***Stereochemistry of Carbon Compounds***, John Wiley (1997).
2. Subrata Sen Gupta, ***Basic Stereochemistry of Organic Molecules,*** Oxford university press (2014).
3. D. Nasipuri, ***Stereochemistry of Organic Applications***, 3rd Edition, New Age Pub. (2010).

Conformational Analysis

1. E. L. Eliel, S. H. Wilen and L. N. Mander, ***Stereochemistry of Carbon Compounds***, John Wiley (1997).
2. P.S.Kalsi: **Stereochemistry, Conformation and Mechanism**, 7th Edition, New Age Publishers (2008).
3. D. Nasipuri, **Stereochemistry of Organic Applications**, 3rd Edition., New Age Pub., 2010.
4. Subrata Sen Gupta, ***Basic Stereochemistry of Organic Molecules,*** Oxford university press, (2014).

Asymmetric Synthesis

1. G. L. David Krupadanam, ***Fundamentals of Asymmetric Synthesis***, Orient Blackswan Private Limited (2013).
2. J. Clayden, N. Greeves, S. Warren and P. Wothers, ***Organic Chemistry***, 2nd Edition, Oxford University Press (2012).

SUGGESTED READING AND REFERENCES

1. M. B. Smith, J. March, ***March's Advanced Organic Chemistry***, John Wiley & Sons, 6th Edition (2007).
2. T. H. Lowry and K. S. Richardson, ***Mechanism and Theory in Organic Chemistry***, 3rd Edition, Addison-Wesley (1998).
3. Maya Shankar Singh, ***Advanced Organic Chemistry: Reactions and Mechanisms***, Pearson (2013).
4. Peter Sykes, ***A Guide book to Mechanism in Organic Chemistry***, 6th Edition, Pearson (2006).
5. C. K. Ingold, ***Structure and Mechanism in Organic chemistry***, 2nd Edition, CBS Publishers (1994).
6. Okuyama and Maskill, ***Organic Chemistry: A Mechanistic Approach***, Oxford University Press (2013).
7. Von P. J. Garratt, ***Aromaticity,*** John Wiley & Sons Incorporated (1986).
8. D. G. Morris, ***Stereochemistry***, RSC (2001).
9. A. J. Kirby, ***Stereoelectronic effects***, Oxford Chemistry Primers (2011).

Course	Details				
Course Code	**CH060104**				
Course Title	**INDUSTRIALPROCESS AND CHEMICAL REACTORS**				
Degree	M. Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I				
Type	Core Course- Theory				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Chemical Reactor**	**18**
1.1	Introduction to reactors in the chemical industry. Mole Balances and reactors- general mole balance equation, mole balance equation of batch reactor, continuous flow reactors, tubular reactor, packed bead reactor.	6
1.2	Conversion and reactor sizing: - batch reactor design equations, design equation for flow reactors, tubular flow reactor, application for continuous flow reactors.	5
1.3	Rate law and stoichiometry: power model and rate laws, order, rate constant, Arrhenius equation. Stoichiometry- batch systems, constant volume batch system,	4
1.4	Collection and Analysis of rate data: Differential method, Graphical method, polynomial method, integral method.	3
2.0	**Unit Operations**	**18**
2.1	Introduction, Fundamentals of heat transfer, heat exchange equipments, shell and tube heat exchangers. Conduction, steady state conduction Finned tube (extended surface) heat exchanger, plate heat exchanger, spiral heat exchanger, scraped heat exchanger and air-cooled heat exchanger.	**6**
2.2	Evaporation: types of evaporators, jacketed, horizontal and vertical evaporators, forced circulation evaporations. Distillation: steam distillation, vacuum distillation, fractional distillation. Tray and packed column. Absorption: Absorption equipments, liquid distribution techniques. Crystallization: Theory and mechanism of growth of crystals super saturation (Mier's theory), classification of crystallizers, Swenson walkers, krystal, oslo, continuous vacuum crystallizers.	**12**

3.0	**Unit process**	**9**
3.1	Nitration: Nitrating agents, kinetics and mechanism of nitration of aromatic compounds, nitration of paraffinic hydrocarbons, typical industrial manufacturing process. Sulfonation: Sulfonating agents, kinetics and mechanism, desulfonation. Batch and continuous processes, manufacturing processes for detergents. Alkylation and acylation: Alkylation and acylation at Carbon, Oxygen and Nitrogen, Friedel- Craft reaction, Industrial processes	
4.0	**Biochemical reaction system**	**9**
4.1	Enzyme reactions- Enzyme substrate complex, mechanism, Michaelis-Menten Kinetics, batch reactor calculation for enzyme reaction, Competitive and noncompetitive inhibition. Bioreactor- cell growth, rate, effet of temperature. nutrients for microorganism, toxic effects on culture. Industrial preparation of alcohol from molasses, preparation of vinegar, glycerol.	

RECOMMENDED BOOKS

1. H. Scott Fogler, ***Elements of Chemical Reaction Engineering***, Prentice Hall (2016).
2. R. E. Hayes and J. P Mmbaga, ***Introduction to Chemical Reactor Analysis***, CRC press (2012).
3. George T. Austin, ***Shreve's Chemical Process Industries***, McGraw Hill Education (2017).
4. McCabe and Smith and Harriott, ***Unit operation in chemical Engineering***, McGraw Hill (2014).
5. P. H. Groggins, ***Unit Processes in Organic Synthesis***, McGraw Hill Education (2001).

SUGGESTED READING AND REFERENCES

1. F. A. Henglein, ***Chemical Technology***, Pergamon (1968).
2. J R Backhurst, J H Harker, J. M. Coulson J. F. Richardson, ***Coulson and Richardson's Chemical Engineering***, Vol I, II and III, Butterworth-Heinemann (2002)
3. W. I. Badger and J. T. Bandchero, ***Introduction to Chemical Engineering***, MGH (1955).
4. O. A. Hougen, R. M. Watson and R. A. Ragetz, ***Chemical Process Principles, Part 1 and Part 2***, CBS Publisher (2018).
5. Frank Rumford, Chemical Engineer Operations, Constable & Co. (1951).
6. R.B. Bird, E.W. Stewuart, E.N. Lightfort, ***Transport Phenomenon, John Wiley and Sons*** (1960).
7. James A. Ken, ***Riegel's Hand Book of Industrial Chemistry***, Springer (2003).
8. A. H. Patel, ***Industrial Microbiology***, Laxmi Publications (2011) .
9. B.K. Dutta, ***Heat Transfer: Principles and Applications***, PHI (2001).
10. D.Q. Kern, ***Process Heat Transfer***, Tata Mc Graw-Hill (1950).

SEMESTER II

Course	Details				
Course Code	**CH060201**				
Course Title	**INORGANIC CHEMISTRY II**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/II				
Type	Core Course- Theory				
Credits	4	Hrs/Week	4	Total Hours	72

Module	Course Description	Hrs
1.0	**Chemistry of Main Group Elements**	**18**
1.1	Boron hydrides: - structure, bonding, preparation and properties. Styx numbers, closo, nido, arachno boranes. Polyhedral borane and their anion. Polyhedral structures-Wade's rule, carboranes, metallaboranes and metallacarboranes. Boron-nitrogen compounds: Borazine, and boron nitride.	6
1.2	Graphite-intercalation compound. Silicates and alumina silicates-discrete, ribbon, layer and frame work Structure- Zeolite. Silicones-Synthesis. Isopoly acids of vanadium, molybdenum and tungsten. Heteropoly acids of Mo and W.	6
1.3	Synthesis, Structure, bonding and uses of Sulphur-nitrogen compounds: Tetrasulphur tetranitride, disulphur dinitride and polythiazyl SxNy compounds. S-N cations and anions.	3
1.3	Molecular sulphides: P_4S_3, P_4S_7, P_4S_9 and P_4S_{10}. Phophorous-nitrogencompounds: Phosphazines. Inter halogen compounds	3
2.0	**Organometallic Compounds-Synthesis, Structure and Bonding.**	**18**
2.1	Hapto-nomenclature of organometallic compounds and 18 electron rules, exception to 18- electron rule.	1
2.1	Metal carbonyls: bonding in metal carbonyls, synergism, preparation, properties, structure and bonding of simple mono and binuclear metal carbonyls, metal nitrosyls, and dinitrogen complexes. IR and NMR spectral studies of bridging and non-bridging CO-ligands.	6
2.2	Cluster compounds -LNCCS and HNCCS. Inorganic metal clusters-binuclear clusters, Isoelectronic and isolobal analogy, Wade-Mingos rules. Di nuclear compounds of Re, Cu and Cr, metal-metal multiple bonding in $(Re_2X_8)^{2-}$, trinuclear clusters,	4
2.3	Synthesis and structure of complexes with cyclic pi donors: - metallocenes and cyclic arene complexes. Synthesis and properties of ferrocene.	3
2.4	Synthesis, structure and bonding of metal carbenes, metal carbynes, metal alkene, Alkyne and Allyl Complexes.	4

3.0	**Organometallic Reactions and Catalysis**	**9**
3.1	Oxidative addition, S_N2, radical and ionic mechanisms. Oxidative coupling. Reductive elimination. Migratory Insertion. Insertion of alkenes, elimination, Abstraction.	3
3.2	Homogeneous catalysis: - Hydrogenation by Wilkinson`s catalyst, Hydroformylation, Wacker process, Monsanto acetic acid process, Polymerisation by metallocene catalysts. Cativa process and olefin metathesis	4
3.3	Heterogeneous catalysis: - Ziegler-Natta polymerizations, Fischer-Tropsch process.	2
4.0	**Bioinorganic Compounds**	**18**
4.1	Essential and trace elements in biological systems. Biological roles of some metal ions. Role of iron in living systems. Oxygen carriers and oxygen transport proteins: - Structure and functions of hemoglobin and myoglobin, oxygen transport mechanism, cooperativity, Bohr Effect. Structure and functions of hemerythrin and hemocyanin.	5
4.2	Cytochromes, Cytochrome P_{450}. Iron sulfur proteins. Nitrogen fixation, iron storage and transport, sodium pump, ionophores, valinomycin.	4
4.3	Chemistry of Photosynthesis: Light reactions: Reaction center, photosystem, ZScheme, Photosystem I and II, structure and function of Mn cluster. vitamin B_{12} and the vitamin B_{12} coenzymes.	4
4.4	Enzymes, Structure and functions of carbonic anhydrase, carboxypeptidase - A and superoxide dismutase. Copper protein Role of calcium in muscle contraction, blood clotting mechanism and biological calcification.	5
5.0	**Nuclear and Radiation Chemistry**	**9**
5.1	Nuclear Reactions- Q value and reaction threshold, reaction cross section, cross section and reaction rate, neutron capture cross section-variation of neutron capture cross section with energy (1/V law).	2
5.2	Nuclear fission and fusion reactions- fission fragments and mass distribution, fission yields, fission energy, fission cross section and threshold fission neutrons, nuclear fusion reactions and their applications.	2
5.3	Principles of counting technique: G.M. counter, proportional, ionization and scintillation counters, cloud chamber.	2
5.4	Radio analysis, Neutron Activation Analysis, Prompt Gama Neutron Activation Analysis and Neutron Absorptiometry.	2
5.5	Analytical applications of radioisotopes-radiometric titrations, kinetics of exchange reactions, measurement of physical constants including diffusion constants, Measurement of radiation doses. Relevance of radiation chemistry in biology, Radiation polymerization.	1

RECOMMENDED TEXT BOOKS

Chemistry of Main Group Elements:

1. N. N. Greenwood, A. Earnshaw. ***Chemistry of Elements***, Butterworth-Heinemann (1997).
2. K.F. Purcell, J C. Kotz, ***Inorganic Chemistry***, Cengage (2010).
3. Mark Weller, Tina Overton, Jonathan Rourke, ***Inorganic Chemistry***: 7th International Edition, Oxford University Press (2018).
4. Nils Wiberg, A. F. Holleman, Egon Wiberg, ***Inorganic Chemistry***, Academic Press (2001).

Organometallic Compounds-Synthesis, Structure and Bonding

1. Robert H. Crabtree, ***The Organometallic Chemistry of the Transition Metals***. 3rd Edition, Wiley–Blackwell (2014).
2. Gary O. Spessard and Gary L. Miessler, ***Organometallic Chemistry***, Oxford University Press (2015).
3. J.E. Huheey, E.A. Keiter, R.A. Keiter, ***Inorganic Chemistry Principles of Structure and Reactivity***, 4thEdn. Pearson Education India (2006).

Bioinorganic Compounds

1. J.E. Huheey, E.A. Keiter, R.A. Keiter, ***Inorganic Chemistry Principles of Structure and Reactivity***, 4thEdn. Pearson Education India (2006).
2. R.W. Hay, ***Bio Inorganic Chemistry***, John Wiley & Sons (1984).

Nuclear and Radiation Chemistry

1. H. J. Arnikar, ***Essentials of Nuclear Chemistry***, Wiley Eastern, 1982.
2. S.N. Goshal, *Nuclear Physics*, S. Chand and Company, 2006.

SUGGESTED READING AND REFERENCES

1. G.L.Miessler, D.A.Tarr, ***Inorganic Chemistry***, Pearson (2010).
2. F. Albert Cotton, Geoffrey Wilkinson, Carlos A. Murillo, Manfred Bochmann ***Advanced Inorganic Chemistry, An Indian Adaptation***, Wiley (2021)
3. P. Powell, **Principles of *Organometallic Chemistry***, 2nd Edition, Chapman and Hall (1988).
4. B.D. Guptha, A.J. Elias, ***Basic Organometallic Chemistry***, Universities Press (2010).
5. Friedlander and J.W.Kennedy, ***Introduction to Radiochemistry***, John Wiley and Sons (1981).
6. S. Glastone, ***Source Book on Atomic Energy***, 3rd Edition, Affiliated East-West Press Pvt. Ltd. (1967).
7. R. Sarkar, ***General inorganic Chemistry***, Part I & Part II, New Central Book Agency (2005).

Course	Details				
Course Code	**CH060202**				
Course Title	**PHYSICAL CHEMISTRY I**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/II				
Type	Core Course- Theory				
Credits	4	Hrs/Week	4	Total Hours	72

Module	Course Description	Hrs
1.0	**Molecular Spectroscopy**	**27**
1.1	Basics of Spectroscopic Techniques: - Brief review of Electromagnetic spectrum: nature of radiation, Radiation-matter interaction. Factors affecting the width and Intensity of Spectral lines	2
1.2	Microwave spectroscopy: -Rotation spectra of diatomic and poly atomic molecules, isotope effect, non-rigid rotator, symmetric asymmetric top molecules, Stark effect.	4
1.3	Infrared spectroscopy: Simple harmonic oscillator, Anharmonic oscillator, Morse potential energy diagram, vibrational spectra of poly atomic molecules, normal modes of vibrations overtones combination and difference bands, Fermi resonance, finger print region and group vibrations, hot bands, Effect of rotation on the spectra of polyatomic molecules. Working principle of an infrared spectrometer.	4
1.4	Raman spectroscopy: - scattering of light, polarizability and classical theory of Raman spectrum, quantum theory of Raman spectrum, Pure rotational Raman spectra, Vibrational Raman spectra, polarization of light and Raman effect. Instrumentation and structural determination.	3
1.5	Electronic spectroscopy: electronic spectra of diatomic molecules selection rule, Franck-Condon principle, electronic spectra of polyatomic molecules, Jablonski diagram, fluorescence quenching, Förster-resonance energy transfer (FRET). Dexter energy transfer, Marcus theory.	4
1.6	NMR spectroscopy: Principles of NMR spectroscopy- spin, spin quantum numbers, magnetogyric ratio, population of energy levels, Larmor precession. relaxation methods, Proton NMR- Nuclear shielding, Chemical shift- Spin-Spin coupling and splitting of NMR signals. AX, AX_2, AX_3, AMX and AB NMR pattern. Effect of Relative magnitudes of J. Karplus relationship. - Nuclear Overhauser, ^{13}C chemical shift and structure correlation	5
1.7	EPR spectroscopy: - electron spin in molecules, interaction with magnetic field, g factor, factors affecting g values, fine structure and hyperfine structure, Kramers' degeneracy.	3

1.8	Mossbauer spectroscopy: Principle, Doppler effect, recording of spectrum, Chemical shift, Factors affecting chemical shift, application to metal complexes, MB spectra of Fe (II) and Fe (III) cyanides.	2
2.0	**Solid State Chemistry**	**9**
2.1	Miller indices, point groups (derivation not expected), translational symmetry, glide planes and screw axes, space groups, simple cases like triclinic and monoclinic systems, interplanar spacing and method of determining lattice types, reciprocal lattices,	4
2.2	Bragg's law and applications, methods of characterizing crystal structure, rotating crystal method, powder X-ray diffraction method, determination of structure of sodium chloride by powder method, comparison of the structures of NaCl and KCl, brief outline of single crystal X-ray diffraction.	5
3.0	**Thermodynamics of ideal systems**	**27**
3.1	Entropy, dependence of entropy on variables of a system (S, T and V; S, T and P). Thermodynamic equations of state. Irreversible processes - Clausius inequality.	5
3.2	Free energy, Maxwell relations and significance, temperature dependence of free energy - Gibbs Helmholtz equation, applications of Gibbs Helmholtz equation.	4
3.3	Partial molar quantities, chemical potential and Gibbs-Duhem equations, determination of partial molar volume and enthalpy.,	5
3.4	Concept of activity, method for determining activity and activity coefficient. Concept of Fugacity, determination of fugacity. Determination of fugacity of a real gas, variation of fugacity with temperature and pressure. Duhem-Margules equation and its applications. Excess functions- excess free energy, excess entropy, excess enthalpy, and excess volume	5
3.5	Third law of thermodynamics, Nernst heat theorem, determination of absolute entropies using third law, entropy changes in chemical reactions.	3
3.6	Three component systems-graphical representation. Solid-liquid equilibria, ternary solutions with common ions, hydrate formation, compound formation. Liquid-liquid.	5
4.0	**Catalysis**	**9**
4.1	Homogeneous catalysis: – mechanism, Arrhenius intermediates and van't Hoff intermediates. Acid base catalysis, enzyme catalysis-Michaelis-Menten Mechanism. Heterogenous catalysis –adsorption and catalysis- unimolecular surface reactions – bimolecular surface reaction –Langmuir-Hinshelwood mechanism and Eley-Rideal mechanism.	9

RECOMMEND TEXT BOOKS

1. C.N. Banwell, E.M. McCash, ***Fundamentals of Molecular Spectroscopy***, 4th Edn., Tata McGraw Hill (1994).
2. William Kemp, ***NMR in chemistry - A Multinuclear Introduction***, McMillan (1986).
3. H. Gunther, ***NMR Spectroscopy***, Wiley (1995).
4. Thomas Engel, Philip Reid, Warren Hehre, ***Physical chemistry, 3rd edition***, Pearson (2013).
5. N. Sathyanarayana, ***Introduction to Magnetic Resonance Spectroscopy*** *ESR, NMR, NQR*, IK International, 2009.
6. Peter Atkins, Julio de Paula, Ronald Friedman, ***Physical Chemistry: Quanta, Matter, Change***, 2nd Edition, (2012).
7. J. Rajaram, J.C. Kuriakose, ***Thermodynamics***, S Chand and Co., 1999.
8. J.N. Gurtu, A Gurthu, ***Advanced Physical Chemistry***, Pragati Prakashan
9. 5. Richard I. Masel, ***Chemical Kinetics and Catalysis***, Wiley Interscience, 2001.
10. L.V. Azaroff, ***Introduction to Solids***, McGraw Hill, NY, 1960.
11. A.R. West, ***Basic Solid State Chemistry*** *2nd edn.*, John Wiley & Sons, 1999.

SUGGESTED READING AND REFERENCES

1. J. M. Hollas, ***Modern spectroscopy***, Wiley (2014).
2. C. Harris, M. D. Bertolucci, ***Symmetry and Spectroscopy: An Introduction to Vibrational and Electronic Spectroscopy,*** Dover Books (1989).
3. H. Friebolin, ***Basic One- and Two-Dimensional NMR-Spectroscopy***, Wiley ()1993.
4. S. K. Dogra, H. S. Randhawa, ***Atomic and Molecular Spectroscopy***, Pearson (2014).
5. Peter Atkins, Julio de Paula, ***Atkins' Physical Chemistry***, 10th Edition, Oxford University Press (2015).
6. Peter Atkins, ***Four Laws That Drive the Universe***, Oxford University Press (2007).
7. A. McQuarrie, J. D. Simon, ***Physical Chemistry: A Molecular Approach***, University Science Books (1997).
8. Yunus A. Cengel, Michael A. Boles, Thermodynamics: An Engineering Approach, 8th Edition, Mc Graw Hill Education (2016).
9. Charles Kittel, ***Introduction to Solid State Physics,*** 7th Edition, John Wiley & Sons, (2004).
10. Mark Ladd***, Crystal Structures: Lattices & Solids in Stereo view***, Horwood (1999).
11. Richard Tilley, ***Crystals & Crystal Structures***, John Wiley & Sons (2006).
12. C. Giacovazzo ***Fundamentals of Crystallography,*** 2nd Edition, Oxford Uty Press (2002).
13. Werner Massa, ***Crystal Structure Determination,*** 2nd Edition, Springer (2004).
14. N.B. Hanna, ***Solid state Chemistry***, Prentice Hall.

Course	Details				
Course Code	**CH060203**				
Course Title	**ORGANIC CHEMISTRY II**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/II				
Type	Core Course- Theory				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Aliphatic and Aromatic Substitutions**	**5**
1.1	Nucleophilic Aliphatic Substitution: Mechanism and Stereochemistry of S_N2 and $S_N1$reactions. SN*i* and neighboring group mechanism.	2
1.2	Electrophilic Aromatic Substitution: Arenium ion mechanism, substituent effect on reactivity in mono and disubstituted benzene rings, *ortho/para* ratio, *Ipso* substitution. Nucleophilic Aromatic substitution: Addition-elimination (SNAr) mechanism. Elimination addition (benzyne) mechanism,	3
2.0	**Addition and Elimination Reactions**	**5**
2.1	Mechanistic and stereo chemical aspects of addition to C=C involving electrophiles, nucleophiles and free radicals. Effect of substituent on rate of addition, orientation of addition,	2
2.2	Mechanistic and stereochemical aspects of E1, E1cB and E2 eliminations. The effect of substrate structure, base, leaving group and reaction medium on elimination reactions. Saytzev *vs* Hofmann elimination, α-elimination, pyrolytic *syn* elimination (E*i*) and conjugate eliminations.	3
3.0	**Chemistry of Carbonyl Compounds**	**8**
3.1	Name reactions under carbanion chemistry: -Mechanism of Claisen, Dieckmann, Knoevenagel, Stobbe, Darzen and acyloin condensations. Chemistry of enolate and enamines- aldol and Michael reactions, Perkin, and benzoin condensation. Reformatosky, Wittig, Cannizaro, Mannich and Prins reactions, Robinson annulation. Addition to carbon-nitrogen multiple bonds: Ritter reaction and Thorpe condensation.	8
4.0	**Pericyclic Reactions**	**9**
4.1	Pericyclic Reactions: Classification- electrocyclic, sigmatropic, cycloaddition, chelotropic reactions. Woodward Hoffmann rules, Frontier Orbital and Orbital symmetry correlation approaches. examples highlighting pericyclic reactions in organic synthesis such as Claisen, Cope, Diels-Alder and Ene reactions (with stereo chemical aspects), dipolar cycloadditions and their utility in organic synthesis.	9

5.0	**Photochemistry of Organic Compounds**	**6**
5.1	Photoreactions of carbonyl compounds: Norrish reactions of ketones. Patterno Buchi reaction. Barton, Di-π-methane and photo Fries rearrangements. Photochemistry of nitro and azo groups.	6
6.0	**Chemistry of natural products**	**9**
6.1	Chemical classification of Natural products, classification of alkaloids based on ring structure, isolation and general methods of structure elucidation based on degradative reactions. Structure of atropine and quinine	3
6.2	Terpenoids - Isolation and classification of terpenoids, classification of steroids. Woodward synthesis of cholesterol, conversion of cholesterol to testosterone.	3
6.3	Total synthesis of Longifolene, Reserpine, Introduction to flavonoids and anthocyanins (Structures only)	3
7.0	**Applications of Electronic, Vibrational, NMR and Mass Spectroscopy in Organic Chemistry**	**12**
7.1	UV-Visible spectroscopy*:* Factors affecting the position and intensity of electronic absorption bands. Empirical rules for calculating **λmax** of dienes, enones and benzene derivatives. Infrared Spectroscopy*:* organic functional group identification through IR spectroscopy. NMR: Application of NMR in organic identification. Introduction to two-dimensional NMR. Mass Spectroscopy: Basic principles, ionization techniques, isotope abundance, molecular ion, fragmentation processes of organic molecules. ESI-MS and MALDI-MS.	8
7.2	Nitrogen rule and Rule of Thirteen. Structural determination of organic compounds using spectroscopic techniques (Problem solving approach)	4

RECOMMEND TEXT BOOKS

1. F. A. Cary and R. I. Sundberg, ***Advanced Organic Chemistry, Part A and B***, 5th Edition, Springer (2009).
2. Peter Sykes, ***A Guide book to Mechanism in Organic Chemistry***, 6th Edition, Pearson (2006).
3. J. Clayden, N. Greeves, S. Warren and P. Wothers, ***Organic Chemistry***, 2nd Edition, Oxford University Press (2012).
4. L. Kuerti and B. Czako, ***Strategic Applications of named Reactions in Organic Synthesis***, Elsevier Academic Press (2005).
5. T. H. Lowry and K. S. Richardson, ***Mechanism and Theory in Organic Chemistry,*** 3rd Edition, Addison-Wesley (1998).
6. S. Sankararaman, ***Pericyclic Reactions-A Textbook: Reactions, Applications and Theory***, Wiley VCH (2005).

7. J. Sing and J. Sing, ***Photochemistry and Pericyclic Reactions***, 3rd Edition, New Age International (2012).
8. William Kemp, ***NMR in chemistry - A Multinuclear Introduction***, McMillan (1986).
9. Jag Mohan, ***Organic Spectroscopy: Principles and Applications***, 2nd Edition, Narosa

SUGGESTED READING AND REFERENCES

1. Michael B Smith, ***Organic Synthesis***, 3rd Edition (2011).
2. M. B. Smith and J. March, ***March's Advanced Organic Chemistry***, 6/e, John Wiley & Sons
3. M. B. Smith, J. March, ***March's Advanced Organic Chemistry***, John Wiley & Sons, 6th Edition (2007).
4. Ian Fleming, **Molecular Orbitals and Organic Chemical Reactions**, Wiley (2010).
5. G. M. Loudon, ***Organic Chemistry***, 4th Edition, Oxford University Press (2008).
6. M. B. Smith ***Organic Chemistry an Acid Base Approach***, CRC Press, 2010.
7. T. Okuyama and H. Maskill, ***Organic Chemistry a Mechanistic Approach***, Oxford University Press (2014).
8. Ian Fleming, ***Selected Organic Synthesis***, John Wiley and Sons (1982).
9. E. Corey and I.M. Chang, ***Logic of Chemical Synthesis***, John Wiley, New York (1989).
10. N. R. Krishnaswamy, ***Chemistry of Natural Products: A Laboratory Hand Book***, 2nd Edition, Universities Press (2012).
11. Scott Gronert, Joseph B. Lambert, Herbert F. Shurvell, David Lightner, Robert Graham Cooks, ***Organic Structural Spectroscopy***, 2nd Edition, Pearson (2014).
12. Robert M. Silverstein, Francis X. Webster, David J. Kiemle, David L. Bryce, ***Spectrometric Identification of Organic Compounds,*** 8th Edition**,** John Wiley (2014).
13. Donald L Pavia, ***Introduction to Spectroscopy,*** 4th Edition, Cengage (2014)
14. Ian Fleming, ***Spectroscopic Methods in Organic Chemistry,*** 7th Edition, Springer (2020).
15. P S Kalsi, ***Spectroscopy of organic compounds,*** New Age International (2007).

Course	Details				
Course Code	**CH060204**				
Course Title	**ANALYTICAL METHODS AND MATERIALS CHARACTERIZATION**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/II				
Type	Core Course- Theory				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Surfaces and Thin Films characterization**	**18**
1.1	Surface morphology characterization techniques: - Scanning electron microscope and Transmission electron microscope. Near field microscopes (Scanning tunneling microscope, atomic force microscope)	7
1.2	Surface electronic properties characterization techniques: - Electron emission from surfaces by incident electron or photon, X-ray photoelectron spectroscopy (XPS), UV-Visible photoelectron spectroscopy (UPS), Auger electron spectroscopy (AES), High-Resolution Electron-Energy-Loss Spectroscopy (HREELS), Near edge X-ray absorption fine structure (NEXAFS)	7
1.3	Surface structure characterization techniques: Low energy electron diffraction (LEED), Reflection high energy electron diffraction (RHEED)	4
2.0	**Electro Analytical Methods**	**9**
2.1	Fundamentals of Electrochemical techniques. Voltametry-cyclic voltametry, ion selective electrodes, anodic stripping voltametry. Application of cyclic voltammetry in inorganic and organic chemistry	3
2.2	Polarography- Apparatus, Theory and working of apparatus, factors affecting limiting current- residual current, migration current, diffusion current, adsorption current, polarogram, half wave potential, limiting current density, The dropping mercury electrode, advantages and limitations of DME, applications of polarography.	4
2.3	Amperometric titrations: general principles of amperometry, Apparatus and calculation. application of amperometry in the qualitative analysis of anions and cations in solution, merits and demerits of amperometric titrations	2
3.0	**Optical Methods**	**14**
3.1	Atomic absorption spectroscopy (AAS), principle of AAS, absorption of radiant energy by atoms, classification of atomic spectroscopic methods, measurement of atomic absorption, instrumentation.	3

3.2	Atomic emission spectroscopy (AES), excitation sources (flame, AC and DC arc), spark, inductively coupled plasma, glue discharge, laser microprobes, instrumentation, and qualitative and quantitative analysis. advantages and disadvantages of AES, origin of spectra, principle and instrumentation.	4
3.3	Flame emission spectroscopy (FES), flames and flame temperature, spectra of metals in flame, instrumentation.	3
3.4	Fluorescence and phosphorescence spectrophotometry – Theory, instrumentation and application.	2
3.5	CD spectroscopy: CD of polypeptides and nucleic acids, Induced CD, magnetic circular dichroism	2
4.0	**Thermal and Radiochemical Methods**	**4**
4.1	Thermogravimetry (TG), Differential Thermal Analysis (DTA) and Differential Scanning Calorimetry (DSC) and their instrumentation.	4
5.0	**Chromatography**	**9**
5.1	Chromatography: - column, thin layer chromatography. HPLC-outline study of instrument modules. Important applications of chromatographic techniques. Gel Permeation Chromatography.	5
5.2	Gas chromatography, Instrumentation and application. Detectors employed in chromatography separations.	4

SUGGESTED READING AND REFERENCES

1. Roland Wiesendanger, ***Scanning Probe Microscopy and Spectroscopy: Methods and Applications***, Camebridge University Press (1994).
2. Hans Lüth, ***Solid surfaces interface and thin films***, 7th Edition, Springer (2014).
3. RS Drago, ***Physical Methods in Chemistry***, 2nd edition, Saunders (1992).
4. D. H. Williams and I. Fleming, ***Spectroscopic Methods in Organic Chemistry***, 4th edition (1988).
5. R.M. Silverstein, G.C. Bassler and T.C. Morrill, ***Spectrometric Identification of Organic Compounds***, John Wiley & Sons, New York, 5th edition (1991).
6. E. A. V. Ebsworth, D. W. H. Rankin, & S. Cradock, ***Structural Methods in Inorganic Chemistry***, CRC Press, 2nd edition (1991).
7. K. Nakanishi, N. Berova, R. W. Woody, ***Circular Dichroism: Principles and Applications***, VCH Publishers (1994).
8. J. Lackowicz, ***Principles of Fluorescence Spectroscopy***, Plenum Press(1983)
9. A. J. Baird and L. R. Faulkner, ***Electrochemical Methods - Fundamentals and Applications***, Wiley (1980).
10. C.L. Wilson, D.W. Wilson, ***Comprehensive Analytical Chemistry***, Elsevier (1982).
11. G.D. Christian, J.E. O'Reilly**,** ***Instrumental Analysis***, Allyn & Bacon (1986).
12. H.A. Laitinen, W.E. Harris, ***Chemical Analysis***, McGraw Hill (1975).
13. V.K. Ahluwalia, ***Green Chemistry: Environmentally Benign Reactions***, CRC (2008).
14. F.W. Fifield, D. Kealey, ***Principles and Practice of Analytical Chemistry***, Blackwell Science (2000).

Course	Details				
Course Code	**CH060105**				
Course Title	**Industrial Chemistry Practical I – Advanced analysis of Industrial Materials**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I				
Type	Practical Course				
Credits	2	Hrs/Week	4	Total Hours	72

Module	Course Description	Hrs
	(At least 8 experiments are to be carried out from section 1, 2, 3, 4, 5, 6, 7)	
1.0	**Part I - Cement analysis**	
	1. Estimation of SiO_2 in cement 2. Estimation of of Calcium in cement 3. Determination of Iron in cement 4. Estimation of Magnesium in cement 5. Estimation of Aluminium in cement	
2.0	**Part II - Drug Analysis**	
	1. Determination of Vitamin B complex content of commercial tablets 2. Determination of Vitamin C content of commercial tablets. 3. Determination of Chloramphenicol in the given capsule. 4. Determination of Tetracycline in the given capsule. **5.** Determination of Diazepam (UV-Visible Spectrophotometer)	
3.0	**Part III - Water analysis**	
	1. Total solids, total dissolved solids, total suspended solids in water sample 2. Determination of nitrate from water sample 3. Determine the dissolved oxygen content from water sample 4. Determination of acidity, alkanity, carbonates and bicarbonates 5. Calculate the concentration of inorganic phosphorous in water sample 6. Flame photometer: estimate the dissolved Na and K 7. Hardness of water from various samples of water 8. Estimate the organic matter present in the soil 9. Estimate the biologically oxygen demand from the given water sample	

	10. Estimate the chemical oxygen demand from the given water sample 11. Estimate the heavy metals in water sample.	
4.0	**Part IV - Analysis of fuel**	
	1. Determination of carbon residue of coal 2. Determination of ash point of coal sample 3. Determination of smoke point of kerocene 4. Determination of viscosity and fluidity of given oil sample 5. Determination of flash point and fire point of a fuel [petrol, digel, kerocene, 2-Toil] by (a) clevelands open cup apparatus (b) Abel's closed cup apparatus (c) Pensky- Martin claved cup apparatus	
5.0	**Part V - Ore analysis**	
	1. Determination of the amount of Fe^{2+} and total iron in the iron ore solution by $K_2Cr_2O_7$. 2. Determination of the amount of copper in a solution of copper ore or brass	
6.0	**Part VI - Analysis of Soil**	
	1. Determination of phosphate content of the given soil extract, fertilizer solution or phosphate rock solution **2.** Determination of total nitrogen content of soil, manure or a fertilizer	
7.0	**Soap Analysis**	
	1. Moisture 2. Iodine value of total fatty acids derived from soaps 3. TFM value of toilet soaps 4. Estimation of Glycerine content of toilet soaps and transparent soaps	

REFERENCES

1. R. K. Trivedi, P. K. Goel, ***Chemical and biological methods for water pollution studies***.
2. ***Water and waste water analysis*** – APHA publications.
3. Dara S. S., ***A text book on experiment and calculations Engg. Chemistry***, S. Chand and Company Ltd. (1997).
4. Mann & Saunders, ***Practical organic chemistry***.
5. ***Vogel's Textbook of Practical Organic Chemistry***, (2003).
6. Shriner, ***The systematic identification of organic compounds*** (2004).
7. G. N. David Krupadanam, Analytical chemistry (2001).
8. Ashutoshkar, ***Advanced practical medicinal chemistry***.

9. Ashutoshkar, ***Pharmaceutical drug analysis***.
10. P D Sethi, ***Quantitative analysis of drugs in pharmaceutical formulations***.
11. A H Beekett, J B Stenlake, ***Practical pharmaceutical chemistry Part-1 and Part-2***.
12. R M Silverstein, F X Webste, ***Spectroscopic identification of organic compounds***.
13. Shahidi, ***Bailey's Industrial Oil and Fat Products***, 6th edition, John Wiley & Sons (2005).
14. M. Ash, I. Ash, ***Formulary of Detergents and other Cleaning Agents***, Chemical Publishing (1999).
15. H. Butler, ***Poucher's Perfumes, Cosmetics and Soaps***, 10th edition, Springer (2000).
16. J. Sherma and G. Zwig, ***TLC and LC analysis of pesticides of international importance***, Vol. VI & VII, Academic Press.
17. H. Wagner, S. Bladt, E.M. Zgainsti, ***Plant Drug Analysis***, Springer, Tokyo (1984).
18. Agarwal, Joul, A text book of metallurgical Analysis.
19. Welcher, Standard Methods of Chemical Analysis Vol. I to III.
20. W.W. Scott, N.H. Furman, Scotts standard methods of analysis.
21. Encyclopedia of Industrial Chemical Analysis – (All Volumes) – J. Wiley Inter Science.

Course	Details				
Course Code	**CH060205**				
Course Title	**INORGANIC CHEMISTRY PRACTICAL**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I&II				
Type	Practical Course				
Credits	3	Hrs/Week	2+4	Total Hours	36+72

Module	Course Description	Hrs
1.0	**Separation and identification of two less familiar metal ions**	**36**
1.1	Separation and identification of two less familiar metal ions such as Tl, W, Se, Mo, Ce, Th, Ti, Zr, V and Li. (Anions which need elimination not to be given. Minimum six mixtures to be given.)	
2.0	**Colorimetric and Gravimetric Estimation of Metal Ions**	**72**
2.1	Colorimetric estimation of Fe, Cu, Ni, Mn, Cr, NH^{4+}, nitrate and phosphate ions. (Minimum two experiments)	
2.2	Estimation involving quantitative separation of suitable binary mixtures of ions in solution (Cu^{2+}, Nl^{2+}, Zn^{2+}, Fe^{3+}, Ca^{2+}, Mg^{2+}, Ba^{2+}) by volumetric colorimetric or gravimetric methods.	
3.0	**Preparation and Characterization of complexes**	
3.1	Preparation and characterization of complexes (IR, UV- Visible, TG, DSC and Columetry Methods)- - any five preparation a. Tris(thiourea)copper(I) complex b. Potassium tris(oxalato) aluminate (III). c. Hexammine cobalt (III) chloride. d. Tetrammine copper (II) sulphate. e. Schiff base complexes of various divalent metal ions. f. penta amminechlorocobalt(III)chloride g. hexaquachromium (III) chloride h. chloropentamminecobalt(lll) chloride i. nitro- and nitrito-pentamminecobalt (III) chloride j. cis and trans potassium dioxalato diaquachromate(III)	

REFERENCES

1. A.I. Vogel, G.Svehla, ***Vogel's Qualitative Inorganic Analysis***, 7th edition, Longma (1996).
2. A.I. Vogel, ***A Text Book of Quantitative Inorganic Analysis***, Longma (1966).
3. I.M. Koltoff, E.B. Sandell, ***Text Book of Quantitative Inorganic Analysis***, 3rd edition, McMillian (1968).
4. V.V. Ramanujam, ***Inorganic Semimicro Qualitative Analysis***, The National Pub. Co., (1974).
5. Gregory S. Girolami, Thomas B. Rauchfuss and Robert J. Angelici, ***Synthesis and Technique in Inorganic Chemistry: A Laboratory Manual, University Science Books***. ***Synthetic methods of organometallic and inorganic chemistry*** ed. by Wolfgang A. Herrmann, Georg Thieme Verlag, New York, (1997).
6. Elias, A. J., ***A Collection of Interesting General Chemistry Experiments***, Universities Press Pvt. Ltd., (2002).
7. Roesky, H. W.; Muckel, K., ***Chemical Curiosities: spectacular experiments and inspired quotes***, VCH (1996).

Course	Details				
Course Code	**CH060206**				
Course Title	**PHYSICAL CHEMISTRY PRACTICAL-I**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I & II				
Type	Practical Course				
Credits	3	Hrs/Week	3	Total Hours	36+72

Module	Course Description	Hrs
	(At least 12 experiments are to be carried out from section 1, 2, 3, 4, 5, & 6)	
1.0	**Adsorption**	
	1. To study the adsorption of oxalic acid on charcoal and test the validity of Langmuir's and Freundlich's adsorption isotherm. 2. To determine the surface area of the given powdered catalyst sample by means of BET adsorption isotherm. 3. Study the adsorption of acetic acid on charcoal and prove the validity of Freundlich's adsorption isotherm and Langmuir's adsorption isotherm. 4. Surface Adsorption Kinetics of Dyes on activated carbon using UV-Visible spectroscopy/calorimetry	
2.0	**Surfactants**	
	1. Determination of HLB number of a surfactant by saponification method 2. Determination of critical micellar concentration of surfactants	
3.0	**pH- Metry**	
	1. Determination of pKa values of dibasic acid using pH Meter 2. Determine the degree of hydrolysis and the hydrolysis constant of aniline hydrochloride by pH 3. Determination of the acid and base dissociation constant of an amino acid (glycine/histidine/cysteine) and hence the isoelectric point of the acid 4. Determination of stability constant and donor acceptor ratio of Cupric-Glycine complex by pH titration method	
4.0	**Phase Diagrams**	
	1. Construction of phase diagram of compounds with congruent melting point: diphenyl amine-benzophenone system. 2. Determination of phase diagram of a simple eutectic system (e.g., Biphenyl, Naphthalene- Diphenyl amine) (b) Determination of the composition of a binary solid mixture.	

	3. Construction of phase diagrams of three component systems with one pair of partially miscible liquids. 4. Effect of (KCl/succinic acid) on miscibility temperature.	
5.0	**Polarimetry**	
	1. Kinetics of the inversion of sucrose in presence of HCl. 2. Determination of the concentration of a sugar solution. 3. Determination of the concentration of HCl. 4. 4. Determination of the relative strength of acids.	
6.0	**Distribution law**	
	1. Distribution coefficient of iodine between an organic solvent and water. 2. Distribution coefficient of benzoic acid between benzene and water. 3. Determination of the equilibrium constant of the reaction KI + I2 ↔ KI3	

REFERENCES

1. ***Advanced Practical Physical Chemistry***, Goel Publications (1989).
2. J. B. Yadav, ***Experimental Physical Chemistry***, 2nd Edition W.G. Palmer, Cambridge University Press.
3. D.P Shoemaker, C.W. Garland, J.W. ***Nibler Experiments in Physical chemistry***, McGraw Hill.
4. V.D. Athawale and Parul Mathur, ***Experimental Physical Chemistry***, New Age International (P) Ltd.
5. A. Halpern and G. McBane, ***Experimental physical chemistry***.
6. F. Daniels, ***Experimental physical chemistry***.
7. G. P. Matthews, ***Experimental Physical Chemistry***.
8. James B. Foresman and Aeleen Frisch, ***Exploring Chemistry with Electronic Structure Methods: A Guide to Using Gaussian***, second edition.
9. Longman, A.M. James, ***Practical Physical Chemistry***.
10. B. Viswanathan & R.S. Raghavan, ***Practical Physical Chemistry***, Viva Books (2009).
11. A. Finlay, ***Practical Physical Chemistry***, Longman's Green & Co.
12. J.B. Firth, ***Practical Physical Chemistry***, Read Books. (2008).
13. S.W. Rajbhoj and T.K. Chondhekar, ***Systematic Experimental Physical Chemistry***, Anjali Publication.
14. Gaurav Jain, Roop K. Khar, ***Text book of Physical Pharmacy***.

Course	Details				
Course Code	**CH060207**				
Course Title	**ORGANIC CHEMISTRY PRACTICAL**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I &II				
Type	Practical Course				
Credits	3	Hrs/Week	3	Total Hours	54+54

Module	Course Description	Hrs
1.0	**PART I**	**18**
1.1	General methods of separation and purification of organic compounds such as: 1. Solvent extraction 2. Soxhlet extraction 3. Fractional crystallization 4. TLC and Paper Chromatography- Practical application of TLC, Preparation of TLC plates, Activation, Identification of different classes of compounds 5. Column Chromatography	
2.0	**Part II**	**36**
2.1	1. Separation of Organic binary mixtures by chemical/solvent separation methods 2. Separation of organic mixtures by TLC 3. Separation/ purification of organic mixtures by column chromatography	
2.2	Draw the structures and generate the IR and NMR spectra of the substrates and products in the following reactions: 1. Cycloaddition of diene and dienophile (Diels-Alder reaction) 2. Oxidation of primary alcohol to aldehyde and then to acid 3. Benzoin condensation 4. Esterification of simple carboxylic acids 5. Aldol condensation	
3.0	**Part III**	**54**
3.1	Extraction of Natural products and purification by column chromatography and TLC 1. Caffeine from Tea waste 2. Chlorophill 3. Steroids 4. Flavonoid (Soxhlet extraction) 5. citral from lemon grass (steam distillation).	

	6. Casein from milk.	
3.2	1. Estimation of equivalent weight of acids by Silver Salt method, 2. Estimation of nitrogen by Kjeldahl method 3. Estimation of reducing sugars, Estimation of amino group, phenolic group and esters. Colourimetrically 4. estimations: Vitamins (Ascorbic acid)	
3.3	**Organic preparations** (minimum five)	

REFERENCES

1. A.I. Vogel, ***A Textbook of Practical Organic Chemistry***, Longman (1974).
2. A.I. Vogel, ***Elementary Practical Organic Chemistry***, Longman (1958).
3. F.G. Mann, B.C Saunders, ***Practical Organic Chemistry***, 4th edition, Pearson Education India (2009).
4. R. Adams, J.R. Johnson, J.F. Wilcox, ***Laboratory Experiments in Organic Chemistry***, Macmillan (1979).
5. B. B. Dey, M V Sitaraman and T R Govindachari, ***Laboratory manual of Organic Chemistry***, Allied Publishers, New Delhi, (1996).
6. Mann and Saunders, ***Practical Organic Chemistry*** (1980).

SEMESTER III

Course	Details				
Course Code	**CH060301**				
Course Title	**THEORETICAL CHEMISTRY II**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/III				
Type	Core Course- Theory				
Credits	4	Hrs/Week	4	Total Hours	72

Module	Course Description	Hrs	
1.0	**Quantum Mechanics of Many -electron atoms**	**9**	
1.1	Symmetric and Anti symmetric Wavefunctions, Pauli's exclusion principle, The Helium atom, singlet and triplet states, Construction of anti-symmetric wavefunction. Hartree-Fock equations and Self-Consistent Field, Slater type orbitals, Slater determinants, Coulomb and Exchange Operators. Term symbols, Hund's rules.	9	
2.0	**Computational chemistry**	**18**	
2.1	Potential energy surface, Hartree- Fock molecular theory, properties of limiting Hartree-Fock models, theoretical models and theoretical model chemistry, beyond the Hartree- Fock, The Gaussian Basis Sets, Selection of a theoretical model, Graphical models.	6	
2.2	Semi-empirical methods: General introduction to semi-empirical methods. Introduction to Density Functional Theory (DFT) methods: Hohenberg Kohn theorems. Kohn-Sham orbitals. Exchange correlation functional. Local density approximation	6	
2.3	Computational Chemistry Calculations: Potential energy surface: stationary point, transition state or saddle point, geometry optimization. Comparison and applications of Ab initio, DFT, Semi-empirical and Molecular mechanics methods	6	
3.0	**Chemical bonding**	**15**	
3.1	The Born- Oppenheimer approximation; Valence Bond (VB) theory – VB theory of H_2 molecule. Quantum mechanical treatment of sp, sp^2 and sp^3 hybridization.	6	
3.2	Molecular Orbital (MO) theory – MO theory of H_2^+ ion, MO theory of H_2 molecule, MO treatment of homo nuclear diatomic molecules, hetero nuclear diatomic molecules and polyatomic molecules. Spectroscopic term symbols for diatomic molecules; Comparison of MO and VB theories.	6	

3.3	The Hückel Molecular Orbital theory of ethene, butadiene, benzene, allyl. Calculation of charge distributions, bond orders and free valency.	3	
4.0	**Molecular Symmetry and Group Theory**	**18**	
4.1	Symmetry elements, symmetry operations. Point groups and their symbols. Mathematical definition of group, Group multiplication tables. Matrices: matrix algebra, addition and multiplication of matrices, inverse of a matrix, square matrix, character of a square matrix, diagonal matrix, direct product and direct sum of square matrices, block factored matrices, solving linear equations by the method of matrices; Matrix representation of symmetry operations.	6	
4.2	Representation of groups by matrices, construction of representation using vectors and atomic orbitals, representation generated by cartesian coordinates positioned on the atoms of a molecule (H_2O and SO_2). Reducible and irreducible representations-construction of irreducible representation by standard reduction formula. Great Orthogonality Theorem (GOT). Properties of irreducible representations. Construction of irreducible representation using GOT-construction of character tables for C_{2v}, C_{2h}, C_{3v}, C_3 and C_{4v}. Direct product of representations.	12	
5.0	**Applications of Group Theory in Spectroscopy**	**12**	
5.1	Applications in vibrational spectra: transition moment integral, vanishing of integrals, symmetry aspects of molecular vibrations, selection rules for vibrational absorption. Determination of the symmetry of normal modes of H_2O, Trans-N_2F_2 and NH_3 using Cartesian coordinates and internal coordinates. Complementary character of IR and Raman spectra-determination of the number of active IR and Raman lines. Application in electronic spectra: selection rules for electronic transition, electronic transitions due to the carbonyl chromophore in formaldehyde.	12	

RECOMMENDED TEXT BOOKS

1. Donald A. McQuarrie, ***Quantum Chemistry***, Viva Student Edition, (2013).
2. R.K. Prasad, ***Quantum Chemistry***, New age international Publishers, 4th Revised Edition, (2021).
3. Ira N. Levine, ***Quantum Chemistry,*** 7th Edition, Pearson (2016).
4. T. Engel, ***Quantum Chemistry and Spectroscopy***, 4th Edition, Pearson Education, (2019).
5. Peter Atkins, Ronald Friedman, ***Molecular Quantum Mechanics,*** 5th ed. Oxford University Press, (2005).
6. F.A. Cotton, ***Chemical Applications of Group Theory,*** 3rd Edition Wiley Eastern (1990).
7. A.S. Kunju, G. Krishnan, ***Group Theory and its Applications in Chemistry***, PHI Learning (2010).
8. R. Ameta, ***Symmetry and Group Theory in Chemistry***, New Age International (2013).

SUGGESTED READING AND REFERENCES

1. Errol Lewars, ***Computational Chemistry: Introduction to theory and application of Molecular Quantum Mechanics***, Second edition, Springer (2003).
2. Attila Szabo and Neil S. Ostlund, ***Modern Quantum Chemistry: Introduction to Advanced Electronic Structure Theory***, Dover Books in Chemistry (1996).
3. F. Jensen, ***Introduction to computational chemistry***, 2nd Edition, Wiley, (2007).
4. Leach, ***Molecular Modelling: Principles and Applications***, 2nd Edition, Longman, (2001).
5. Christopher J. Cramer, ***Essentials of Computational Chemistry: Theories and Models***, 2nd Edition (2004).
6. F.L. Pilar, ***Elementary Quantum Chemistry***, McGraw-Hill ()1968.
7. J.P. Lowe, K Peterson, ***Quantum Chemistry***, 3rd Edition, Academic Press, (2006).
8. Horia Metiu, ***Physical Chemistry – Quantum Mechanics,*** Taylor & Francis (2006).
9. A.K. Chandra, ***Introductory Quantum Chemistry***, 4th Edition, (2002).
10. Linus Pauling, E.B. Wilson, ***Introduction to Quantum Mechanics: With Applications to Chemistry***, International Student Edition, (1935).
11. R.L. Flurry, Jr., ***Quantum Chemistry***, Prentice Hall (1983).
12. M.S. Pathania, ***Quantum Chemistry and Spectroscopy (Problems & Solutions),*** Vishal Publications (1984).
13. Jack Simons, ***An Introduction to Theoretical Chemistry***, Cambridge University Press, (2003).
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Group theory

1. H. H. Jaffe and M. Orchin, ***Symmetry in Chemistry***, John Wiley &Sons Inc. (1965).
2. L.H. Hall, ***Group Theory and Symmetry in Chemistry,*** McGraw Hill (1969).
3. R. McWeeny, ***Symmetry: An Introduction to Group Theory and its Applications***, Pergamon Press, London (1963).
4. P.H. Walton, ***Beginning Group Theory for Chemistry***, Oxford University Press Inc., NewYork (1998).
5. Mark Ladd, ***Symmetry & Group Theory in Chemistry***, Horwood (1998).
6. Arthur M Lesk, ***Introduction to Symmetry & Group theory for Chemists***, Kluwer Academic Publishers (2004).
7. K.Veera Reddy, ***Symmetry & Spectroscopy of Molecules 2nd Edn.***, New Age International (2009).
8. A.W. Joshi, ***Elements of Group Theory for Physicists***, New Age International Publishers (1997).
9. A Vincent, ***Molecular Symmetry and Group Theory: A Programmed Introduction to Chemical Applications,*** 2nd Edn., Wiley (2000).
10. V. Ramakrishnan, M.S. Gopinathan, ***Group Theory in Chemistry***, Vishal Publications, (1992).

Course	Details				
Course Code	**CH060302**				
Course Title	**PHYSICAL CHEMISTRY II**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/III				
Type	Core Course- Theory				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Fundamentals of Statistical Mechanics**	**27**
1.1	Fundamental concepts and Postulates of statistical mechanics: probability theory, permutation, characterizing distribution function, Phase space, ensembles, Liouville's theorem, Stirling's theorem.	4
1.2	Boltzmann distribution: microstates and configuration, Derivation of Boltzmann distribution and its Physical meaning.	5
1.3	Ensemble: Canonical ensemble, relating q to Q for an ideal gas, translation partition function, rotational partition function: diatomic and polyatomic, Vibrational partition function, equi-partition theorem, electronic partition function.	8
1.4	Statistical thermodynamics: energy and canonical partition function, degree of freedom, Heat capacity, Einstein solid, entropy, residual entropy, other thermodynamic function.	5
1.5	Maxwell- Boltzmann, Bose-Einstein, Fermi-Dirac statistics.	5
2.0	**Chemical Kinetics**	**9**
2.1	Collision theory-steric factor. Conventional transition state theory-Eyring equation. Thermodynamic formulation of the two theories. Absolute reaction rate theory (ARRT)-thermodynamic treatment, application of ARRT to simple bimolecular process.	2
2.2	Theory of unimolecular reactions-Lindemann- Hinshelwood, RRKM - steady state approximation, primary and secondary kinetic salt effect-Study of fast reactions by Stopped flow method	3
2.3	Photochemical Reaction kinetics: - study of kinetics of photo chemical H_2-Br_2 reaction, H_2-Cl_2 reaction, Thermal H_2-Br_2, acetaldehyde pyrolysis reaction. Oscillatory reactions- Belousov Zhabotinskii reaction, Lotka-Volterra mechanism. Brusselator, Oregonator.	4
3.0	**Fundamental concepts in Electrochemistry**	**18**
3.1	Theories of ions in solution- Drude and Nernst's electrostriction model and Born's model Mechanism of electrolytic conductance, relaxation and electrophoretic effects.	4

3.2	Debye – Huckel – Onsager equation and its validity in aqueous and non -aqueous solutions. Deviations from the Onsager equation, conductance ratio and Onsager equation. Dispersion of conductance at high frequencies (Debye–Falkenhagen effect). Conductance with high potential gradients (Wien effect). The Debye – Huckel Limiting law.	5
3.3	Electro kinetic phenomena: Electrical double layer-electrode kinetics of electrode processes, the Butler-Volmer equation-The relationship between current density and overvoltage, the Tafel equation.	5
3.4	Polarization - electrolytic polarization, dissolution and deposition potentials, concentration polarization; Overvoltage: hydrogen overvoltage and oxygen overvoltage.	4

RECOMMENDED TEXT BOOKS

1. Peter Atkins, Julio de Paula, ***Atkins' Physical Chemistry***, 10th Edition, Oxford University Press (2015).
2. Peter Atkins, Julio de Paula, Ronald Friedman, ***Physical Chemistry: Quanta, Matter, Change***, 2nd Edition, (2012).
3. Thomas Engel and Philip Reid, **Thermodynamics, Statistical Thermodynamics &Kinetics**, Pearson, 4th Edition (2018).
4. Rajaram and Kuriakose, ***Thermodynamics,*** East-West (1986).
5. Keith J. Laidler, ***Chemical Kinetics,*** 3rd Edition**,** Pearson Education (2008).
6. Thomas Engel, Philip Reid, Warren Hehre, Alex Angerhofer***, Quantum Chemistry and Spectroscopy + Thermodynamics, Statistical Thermodynamics, and Kinetics***, Pearson (2018)
7. Samuel Glasstone, ***Introduction to Electrochemistry***, East-West Press (2006)

SUGGESTED READING AND REFERENCES

1. Steinfeld, Francisco, Hase, ***Chemical Kinetics and Dynamics,*** 2nd edition, Prentice Hall International. Inc. (1989).
2. Santhosh K. Upadhyay, ***Chemical Kinetics and Reaction Dynamics,*** Springer (2006).
3. Richard I. Masel, ***Chemical Kinetics and Catalysis***, Wiley Interscience (2001).
4. S. Glasstone, ***Thermodynamics for chemists***, East-West (1973).
5. B.G. Kyle, ***Chemical and Process Thermodynamics,*** 2nd edition, Prentice Hall (1999).
6. V.S. Bagotsky, ***Fundamentals of Electrochemistry***, 2nd edition, John Wiley & Sons (2006).
7. B.K. Sharma, ***Electrochemistry,*** Krisna Prakashan (1985).
8. Praveen Tyagi, ***Electrochemistry***, Discovery Publishing House (2006).
9. R. Crow, Principles and Applications of ***Electrochemistry***, 4th Edn., S. Thornes (1994).
10. International, 1986. Gabor Harsanyi, ***Sensors in Biomedical Applications - Fundamentals, Technology and Applications***, CRC Press (2000).
11. Raluca-Ioana Stefan, ***Electrochemical Sensors in Bioanalysis***, CRC Press (2001).
12. A.J. Dekker, **Solid state physics**, MacMillan Publishers (2008).
13. Noam Eliaz, Eliezer Gileadi, ***Physical Electrochemistry: Fundamentals, Techniques, and Applications***, Wiley VCH (2008).

Course	Details				
Course Code	**CH060303**				
Course Title	**PETROCHEMICALS, DYES & PERFUMES**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/IV				
Type	Core Course- Theory				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Introduction to petrochemistry**	**2**
1.1	Introduction to petroleum refinery, Classification of Crude oil-Characterization, Composition, Physical properties of Crude oil.	
2.0	**Crude oil Properties**	**6**
2.1	Crude Assay ASTM TBP distillations evaluation of crude oil properties. API gravity various average boiling points and mid percent corves. Evaluation of properties of crude oil and its fractions. Design concept of crude oil distillation column design. Furnace design	
3.0	**Distillation of Crude Petroleum**	**6**
3.1	Preparation of petroleum for processing. Destruction of petroleum emulsion. Electric desalting plants. Fundamentals of preliminary distillation. Methods of petroleum distillation. Distillation of crude petroleum.	
4.0	**Purification of petroleum products**	**6**
4.1	Absorptive and adsorptive purification, sulphuric acid purification, Alkaline purification. Hydro refining. Purification in a DC electric field. New methods of purification. De mercaptanisation. Stabilisation.	
5.0	**Thermal and Catalytic cracking**	6
5.1	Coking and Thermal process, Delayed coking. Catalytic cracking, Cracking reactions, Zeolite catalysts. Cracking Feedstocks and reactors, Effect of process variables. FCC Cracking, Catalyst coking and regeneration, Design concepts, New Designs for Fluidized-Bed Catalytic Cracking Units.	
6.0	**Isomerization, Alkylation and Polymerization**	**4**
6.1	Isomerization process, Reactions, Effects of process variables. Alkylation process, Feedstock, reactions, products, catalysts and effect of process variables. Polymerization: Objectives, process, Reactions, catalysts and effect of process variables.	

7.0	**Petrochemicals**	**6**
7.1	Manufacturing processes of formaldehyde, acetic acid, acetic anhydride acrylonitrile, BTX production, nitrobenzene, ethylene oxide.	
8.0	**Perfumes, Cosmetics and Dyes**	**18**
8.1	Compounds used for different perfumes, Essential oils, Preparation of phenyl ethanol, Yara-Yara, β-ionone, musk ketone, musk ambrette, musk xylene, phenyl acetic acid and its' esters, benzyl acetate, synthetic musk, jasmine.	6
8.2	**Cosmetics Industries: -** formulation of cold cream, vanishing cream, cleansing cream, all-purpose cream, protective cream, antiperspirants, deodorant, face powder - Hair structure, Shampoos, Conditioner, Shaving and after shaving products, Dentrifice and Mouthwash, Lipstick, Nail lacquer	8
8.3	**Dyes: -** Introduction, Classification of Dyes, Witt's Theory, Synthesis of Fast Red A, Naphthol Blue Black 6B, Naphthol Green B, Alizarin pyronene- G.	4

SUGGESTED READING AND REFERENCES

1. W. L. Nelson, ***Petroleum Refining Engineering,*** Mc Graw- Hill (1969)
2. R.N. Watkins, Petroleum Refinery distillation, Gulf Publishing Co. (1979).
3. Robert A Mayers, Hand book of petroleum refining process (1986).
4. B.B. Rao, ***Modern Petroleum Refining Process***, 6th edition, Oxford and IBH (2018).
5. Mark J. Kaiser J.H. Gary, G.E. Handwerk, ***Petroleum Refining: Technology and Economics***, 5th edition (2007).
6. James G Speight, ***The chemistry and technology of petroleum***, CRC Press (2014).
7. B. K. Sharma, ***Industrial Chemistry***, Goel Publication, Goa (2014).
8. N. K. Sinha, ***Petroleum Refining and petrochemicals***, Umesh Publications (2003).
9. S. Maiti, ***Introduction to Petrochemicals***, Oxford & IBH (2002).
10. M M Uppal, ***A Text Book of Engineering Chemistry***, Khanna Publishers1986).
11. Kochu Baby, S. Manjuram, ***Modern Petroleum Chemistry-An overview***, Kannatheri Publication, Kochi (2003).
12. George T. Austin, ***Shreve's Chemical Process Industries***, McGraw Hill (2017).
13. Charles E. Dryden, ***Outlines of Chemical Technology***, Affiliated East-West Press (1973).
14. G.N. Pandey, ***A Textbook of Chemical Technology Volumes 1 and 2***, Sangam Books (2018).
15. G. R. Chatwal, ***Synthetic Dyes***, Himalaya Publishing House (2009).
16. M. Ash and I. Ash, ***Formulary of Cosmetic Preparations***, Chemical Publishing Co Inc. (1977).
17. M. Ash and I. Ash, ***Formulary of Paints and Other Coatings***, Chemical Publishing Co Inc. (2000).
18. F.V. Wells, Marcel Billot, ***Perfumery Technology***, Longman Higher Education (1981).

SEMESTER - IV

Course	Details				
Course Code	**CH060401**				
Course Title	**DRUG CHEMISTRY AND PHARMACEUTICAL TECHNOLOGY**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/IV				
Type	Core Course- Theory				
Credits	3	Hrs/Week	4	Total Hours	54

Module	Course Description	Hrs
1.0	**Drug chemistry**	**18**
1.1	Drug targets: drug act at proteins, Introduction to receptors, receptor type, functions and ligand binding interactions; Ion channel receptors; kinase-linked receptors; G-Protein coupled receptors.	4
1.2	Absorption, distribution, metabolism, excretion. Drug administration, Drug dosing, formulation, delivery.	4
1.3	Chemistry of pencillins: - Mechanistic studies of beta- lactamate, antibiotics. Anti-cancer- drug acting on nucleic acid, intercalating agents, camptothecins, alkylating agents. Acting on enzymes, acting on structural protein, inhibitiors of signalling pathways.	5
1.4	Drug discovery- Finding a lead compound, isolation, purification, structure determination. Structure activity relationships, drug optimization	5
2.0	**Computer in Medicinal Chemistry**	**18**
2.1	Structure activity relationship (QSAR): graphs and equations, physico chemical properties, Hansch equation, craig plot, Topliss scheme. Planning a QSAR study, Three dimensional QSAR.	9
2.2	Three dimensional structures, SMILES, ADME molecular properties, energy minimization, molecular properties, Conformational analysis, structure comparisons, identifying the active conformation,3D pharmacophore identification. Docking procedure, Protein mapping. De novo design, Database handling.	9
3.0	**Dispensing**	**9**
3.1	Principles of dispensing medicaments: - Hard gelatin capsules, material and formulation, Filling equipments, finishing and evaluation.	3
3.2	Soft gelatin capsules, manufacturing process, Incompatibilities and its overcoming. Preparation of pills, tablets, capsules, injectables, coating of tablets.	3
3.3	Newer Drug Delivery systems-site specific drug delivery systems in cancer chemotherapy to brain and CNS, to kidney and urinary tract.	3

4.0	**Pharmaceutical Analysis**	**9**
4.1	Titrimetric Methods in Pharmaceutical analysis: non-aqueous, argentometric titrations, complexometric titrations, redox titrations, iodometric titrations, diazotisation titrations and Karl Fischer titrations.	4
4.2	Applications of AAS, UV-Visible spectroscopy, IR-spectroscopy, NMR spectroscopy, Mass Spectrometry, TLC, GC and HPLC in pharmaceutical Analysis (theory and instrumentation not expected). Capillary Electrophoresis-Instrumentation and applications in pharmaceutical analysis.	5

RECOMMENDED TEXT BOOKS

1. Graham L. Patrick, ***An Introduction to Medicinal Chemistry***; 2nd edition, Oxford University Press (2013).
2. Richard B. Silverman, ***The Organic Chemistry of Drug Design and Drug Action***, Second Edition, Elsevier (2004).
3. C.V.S. Subrahmanyam, Thimma Setty, Sarasija Suresh, ***Pharmaceutical Engineering Principles & Practices***, Vallabh Prakashan (2009)
4. H.C. Ansel, Loyd V Allen, and Nicholas G. Popovich, ***Ansel's Pharmaceutical Dosage Forms and Drug Delivery Systems,*** 8th Edition, Wolters Kluwer India Pvt. Ltd. (2018).

SUGGESTED READING AND REFERENCES

1. Eberhard Voit, ***A First Course in Systems Biology***, Garland Science (2017).
2. Edda Klipp, Wolfram Liebermeister, Christoph Wierling, Axel Kowald, ***Systems Biology: A Textbook***, Wiley-VCH, 2nd Edition (2016).
3. Mark Newman, ***Networks: An Introduction***, Oxford University Press (2010).
4. D. J. Abraham, ***Burger's Medicinal Chemistry and Drug Discovery***, Wiley (2003).
5. S.S. Pandeya, J.r. Dimmock, ***An introduction to drug design***, New Age International Publishers, New Delhi (1997).
6. Alex Gringauz, ***Introduction to Medicinal Chemistry: How Drugs Act and Why,*** Wiley – VCH (1996).
7. L. L. Brunton, R.H.Dandan, B. C. Knollmann, ***Goodman & Gilman's: The Pharmacological Basis of Therapeutics***, 13th Edition, McGraw Hill (2018).
8. David L. Nelson; Michael M. Cox, ***Lehninger Principles of Biochemistry***, Eighth Edition, WH Freeman (2020).
9. Shayne Cox Gad (Ed.) ***Handbook of Pharmaceutical Manufacturing Formulations Vol. I to VI***, CRC Press (2019).
10. David B. Troy (Ed.), ***Remington: The Science and Practice of Pharmacy***, 21st Edition, Lippincott Williams and Wilkins (2005).
11. S.S. Kadam, K.R. Mahadik, K.G. Bothra, ***Principles of Medicinal Chemistry Vol.1,*** 18th Edition, NiraliPrkashan (2010).
12. Ashutosh Kar, ***Medicinal Chemistry***, 7th Edition, New Age International, (2018).
13. David A. Williams (Ed.), ***Foye's Principles of Medicinal Chemistry***, 17th Edition Lippincott Williams and Wilkins (2012).

Course	Details				
Course Code	**CH060402**				
Course Title	**INDUSTRIAL POLYMERS AND MANUFACTURING**				
Degree	**M.Sc.**				
Branch (Specialization)	**Industrial Chemistry**				
Year/Semester	**2/III**				
Type	**Core Course**- Theory				
Credits	**4**	**Hrs/Week**	**4**	**Total Hours**	**72**

Modules	Course Description	Hrs
1.0	**Basic Concepts of Polymers**	**6**
1.1	General Polymer Background, Concept of functionality and reactivity, Degree of polymerization. Free radical, Ionic and Co- ordination polymerization. Bulk, Solution, Emulsion, Suspension and Interfacial polymerization.	
2.0	**Polymer Rheology and Morphology**	**9**
2.1	Viscoelasticity, Maxwell and Voigt Models; Non-Newtonian Behavior and Rheology; Rubber Elasticity. Unentangled Polymer Dynamics, Rouse and Zimm Models. Crystalline And Amorphous Polymer Phase.	
3.0	**Solution properties of polymers:**	**9**
3.1	Flory-Huggins Theory, enthalpy change and free energy change on mixing, Phase equilibria, Flory-Kringbaum Theory, Theta temperature, polymer-polymer mixing, kinetics of phase separation.	
4.0	**Morphology and order in crystalline polymers**	**6**
4.1	Configurations of polymer chains. Crystal structures of polymers. Morphology of crystalline polymers, crystalline melting point Tm. The glass transition temperature, Tg-Relationship between Tm and Tg, effects of molecular weight, chemical structure, chain topology, branching and cross linking.	
5.0	**Fillers**	**6**
5.1	Carbon black: Introduction manufacture and morphology, physical and chemical properties, effect of carbon black, properties of compounding, mixing and dispersion. characteristics and application of calcium carbonate, clay.	
6.0	**Functions and example of compounding ingredients**	**6**
6.1	Activators, Accelerators, Blowing agents, Softeners, pigments, Tactifers, Release agents, Reclaimed rubber, Tactics, Ground crumb, Mineral rubber, Retarders	

7.0	**Technology of Production of polymers**	**6**
7.1	Technology of Production of Polyethylene, Polypropylene (PP), Polyvinyl, Polystyrene, Phenol formaldehyde, Nylon-6,6 and Nylon-6	
8.0	**Polymer processing**	**6**
8.1	Compression moulding, casting, extrusion, Fiber-spinning, injection moulding , thermoforming	
9.0	**Physical and mechanical testing of Polymer**	**9**
9.1	Stess-strain measurement, stress cracking, hardness, tear strength or tear resistance, resilience's, flex cracking resistance, abrasion resistance, impact resistance.	
10.0	**Chemical testing**	**9**
10.1	Molecular mass determination- Number average and weight average, Gel permeation chromatography. Thermal analysis: - DSC, TGA, TMA, DTA. X-ray diffraction technique. SEM, TEM, IR, Electrical conductivity, thermal conductivity.	

RECOMMENDED BOOKS AND REFERENCES

1. Fred W. Billmeyer, ***Text book of Polymer Science***, 3rd edition, Wiley (1984).
2. J.M.G Cowie, Valeria Arrighi, ***Polymers: Chemistry and Physics of Modern Materials***, 3rd edition, CRC Press (2007).
3. H. R. Allcock and F. W. Lampe, ***Contemporary Polymer Chemistry***, 2nd Edition, Prentice Hall, Englewood Cliffs, New Jersy (1981).
4. V.R. Gowariker, N. V. Viswanathan and Jayadev Sreedhar, ***Polymer Science***, New Age International Limited, (1996).
5. G. S. Misra, ***Introductory Polymer Chemistry***, Wiley Eastern Limited (1993).
6. Prema Moy Ghosh, ***Polymer Science and Technology of Plastics and Rubbers***, Tata McGraw Hill (1990).
7. D. Campbell and J.R. White, ***Polymer Characterization***, Physical Techniques, Chaopman and Hall (1989).
8. F. Rodriguez, ***Principles of Polymer Science Systems***, McGraw Hill Book Co. (1970).
9. J A Brydson, ***Plastics Materials***, 7th Edition, Butterworth-Heinemann (1999).

ELECTIVE COURSES

Course	Details				
Course Code	**CH900301**				
Course Title	**Chemistry of Advanced Materials**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/III				
Type	Elective Course				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Introduction to Material Science**	**3**
1.1	Introduction, classification of materials, Functional Classification of Materials, Classification of Materials Based on Structure, Materials Design and Selection.	
2.0	**Atom and Ion Movements in Materials**	**3**
2.1	Applications of Diffusion, Stability of Atoms and Ions, Mechanisms for Diffusion, Activation Energy for Diffusion, Fick's First Law, Factors Affecting Diffusion.	
3.0	**Nanomaterials**	**9**
3.1	Definition of nano dimensional materials, Historical milestones, unique properties due to nano size, Classification of Nanomaterials. General methods of synthesis of nanomaterial Fullerenes, Graphene, Carbon nanotubes: Synthesis, Structure, Properties, Chemical Modification, Applications Quantum dots, Nanowires, Nanorods: Properties and Applications	9
4.0	**Specialty Polymers**	**6**
4.1	Aromatic liquid crystalline polyesters, Phenolics, Polyimide, Poly ether ether ketones- synthesis, processing and applications	3
4.2.	Electrically Active Polymers: Conjugated polymers, intrinsically conductive polymers, Polymers with piezoelectric, pyrroelectric and ferroelectric properties, polymers used as insulators, polymers used in telecommunications, power transmissions	3
5.0	**Ceramic materials**	**6**
5.1	Bonding in Ceramics, Structures of Crystalline Ceramics, Defects in Crystalline Ceramics, Synthesis and Processing of Crystalline Ceramics, Silica and Silicate Compounds, Glass-Ceramics, Ceramic sensors.	
6.0	**Superconducting materials**	**6**
6.1	Metallic and ceramic superconducting materials, Theories of superconductivity, Meissner effect, High temperature superconductors and crystal structure.	

7.0	**Composite Materials**	**12**
7.1	Dispersion-Strengthened Composites, Particulate Composites, Fiber-Reinforced Composites, Characteristics of Fiber-Reinforced Composites, Applications, Laminar Composite Materials and Applications. Nanocomposites: Theories of reinforcement-Filler-Matrix Interaction-Intercalation and Exfoliation. Bionanocomposites, Applications.	
8.0	**Electronic and magnetic Materials**	**9**
8.1	Band Structure of Solids, Semiconductors, General Overview of Integrated Circuit Processing, Deposition of Thin Films, Conductivity in Other Materials. OLED and organic solar cell working principle, Perovskites, Piezoelectric materials. Classification of Magnetic Materials, Magnetic Dipoles and Magnetic Moments, Magnetization, Permeability, and the Magnetic Field, Applications of Magnetic Materials Metallic and Ceramic Magnetic Materials	9

RECOMMENDED TEXT BOOKS

1. Donald R. Askeland and J. Wendelin***, The Science and Engineering of Materials,*** Seventh Edition, Wright Publisher, Global Engineering: Timothy L. Anderson (2014).
2. Tilley, R. J. D, ***Understanding solids: the science of materials***; 2nd edition, John Wiley & Sons Ltd (2013).
3. C.N.R. Rao, A. Muller, A.K. Cheetam (Eds), ***The Chemistry of Nanomaterials***, Vol.1, 2, Wiley –VCH, Weinheim (2004).
4. R.R. Luise, ***Applications of High Temperature Polymers***, CRC press, 1st edition, (1996).
5. C.P. Poole, Jr: F.J. Owens, ***Introduction to Nanotechnology***, Wiley Interscience, New Jersey (2003).
6. Kenneth J. Klabunde (Ed), ***Nanoscale materials in Chemistry***, Wiley, Interscience, New York (2001).
7. T. Pradeep, ***Nano: The Essentials in understanding nanoscience and nanotechnology,*** Tata McGraw Hill, New Delhi (2007).
8. H. Fujita (Ed.), ***Micromachines as tools in nanotechnology,*** Springer- Verlag, Berlin, (2003).
9. Robert William Dyson, ***Speciality Polymers,*** 2nd edition, Blackie Academic and Professional (1998).
10. ManasChanda, Salil K. Roy, ***Industrial Polymers, Specialty Polymers, and their Applications,*** CRC Press (2008).

SUGGESTED READING AND REFERENCES

1. William D Callister, JR; David G Rethwisch, ***Fundamentals of Materials Science and Engineering an integrated approach***, Wiley (2011).
2. S.V. Subramanyan and E.S. Rajagopal, ***High Temperature Superconductors***, Wiley Eastern (1989).
3. F.R. Jones, ***Handbook of Polymer Fiber Composites***, Longman Scientific and Tech. (1994).
4. K.K. Chowla, ***Composite Materials***, Springer-Verlag, (1987).
5. S. M. Sze, ***Physics of Semiconductor Devices*** John Willey, 2nd Ed., (1981).
6. R.C. Buchanan, Marcel Dekker: ***Ceramics Materials for Electronics***, Marcel Dekker Inc (1991).
7. M.W. Barsoum, ***Fundamentals of Ceramics***, McGraw Hill (1997).
8. W. David Kingery, H. K. Bowen, Donald R. Uhlmann, ***Introduction to Ceramics***, John Wiley & Sons (1999).
9. L.L. Hench and J.K. West: ***Principles of Electronic Ceramics***, Wiley (1990).
10. T. J. J. Müller and U. H. F. Bunz, ***Functional Organic Materials***, Wiley-VCH (2007).
11. S. Ogawa, ***Organic Electronics Materials and Devices***, Springer (2015).

Course	Details				
Course Code	**CH900402**				
Course Title	**ADVANCED PHYSICAL CHEMISTRY**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/IV				
Type	Elective Course				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Thermodynamics of Irreversible Processes**	**9**
1.1	Simple examples of irreversible processes, the phenomenological laws and Onsager reciprocal relations, verification, entropy production, application to the theory of diffusion, Thermo electric circuits, thermo-osmosis, electro-kinetic effects, the Glansdorf –Pregogine equation.	9
2.0	**Photochemistry**	**9**
2.1	Photophysical processes of electronically excited molecules- Franck – Condon principle– quantum mechanical treatment-Dissociation and pre dissociation of diatomic molecules	5
2.2	Energy transfer from electronically excited molecules- Stern – Volmer mechanism only- Photophysical pathways: fluorescence, phosphorescence, E-type and P- type delayed fluorescence.	4
3.0	**Solid state chemistry**	**9**
3.1	Kronig-Penney model, Free electron theory, Zone theory and MO theory of solids.	3
3.2	Energy bands-conductors and non-conductors, intrinsic and extrinsic semiconductors. Electrons and holes. Mobility of charge carriers. Hall Effect.	3
3.3	Optical properties-photoconductivity, photovoltaic effects, luminescence. Applications of optical properties	3
4.0	**Surface chemistry**	**9**
4.1	Adsorption: Adsorption in solids, measurement of adsorption. Langmuir adsorption isotherm, BET equation, derivation. determination of surface area of adsorbents, heat of adsorption and its determination.	4
4.2	Colloids: Zeta potential, electrokinetic phenomena, sedimentation potential and streaming potential, Donnan membrane equilibrium. Micelles, surface tension	5
5.0	**Fuel Cells and Conducting polymers**	**9**
5.1	Fuel Cells: Description, working principle, anodic, cathodic and cell reactions, fabrication of electrodes and other components, applications.	4

5.2	Proton Exchange Membrane Fuel Cells, alkaline fuel cells, phosphoric acid. Membranes for fuel cells: Nafion – Polymer blends and composite membranes.	3
5.3	Conducting polymers: - Poly sulphur nitride, polyacetylene, Poly para phenylene	2
6.0	**Fast reactions**	**3**
6.1	relaxation, flow and shock methods, flash photolysis, NMR and ESR methods of studying fast reactions. Experimental technique of studying molecular motion dynamics.	3
7.0	**Gaseous State**	**6**
7.1	Derivation of Maxwell's law of distribution of velocities, most probable velocity, derivation of average, RMS and most probable velocities, collision diameter, collision frequency in a single gas and in a mixture of two gases, mean free path. effusion, the rate of effusion, the law of corresponding states, transport properties of gases.	6

RECOMMEND TEXT BOOKS

1. J. Rajaram, J.C. Kuriakose, ***Thermodynamics***, S Chand and Co. (1999).
2. J.N. Gurtu, A Gurthu, ***Advanced Physical Chemistry***, Pragati Prakashan (2011).
3. K.K. Rohatgi-Mukherjee, ***Fundamentals of Photochemistry***, 2nd Edn., New Age International (1986).
4. M. Aulice Scibioh and B. Viswanathan, ***Fuel Cells – principles and applications***, University Press, India (2006).
5. L.V. Azaroff, ***Introduction to Solids***, McGraw Hill (1960).
6. A.R. West, ***Basic Solid State Chemistry***, 2nd edition, John Wiley & Sons (1999).

SUGGESTED READING AND REFERENCES

1. Peter Atkins, Julio de Paula, Ronald Friedman, ***Physical Chemistry: Quanta, Matter, Change***, 2nd Edition, (2012).
2. Peter Atkins, Julio de Paula, ***Atkins' Physical Chemistry***, 10th Edition, Oxford University Press (2015).
3. D.A. McQuarrie, J.D. Simon, ***Physical Chemistry: A Molecular Approach***, University Science Books, (2019).
4. A.W. Adamson, A.P. Gast, ***Physical Chemistry of Surfaces***, 6th Edition, John Wiley & Sons (1997).
5. D.O. Cowan, R. L. Drisko, ***Elements of Organic Photochemistry***, Plenum Press (1976).
6. H.H. Willard, J. A. Dean, L.L. Merritt, ***Instrumental Methods of Analysis***, Van Nostrand (1965).

Course	Details				
Course Code	**CH900403**				
Course Title	**ADVANCED SYNTHETIC ORGANIC CHEMISTRY**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/IV				
Type	Elective Course				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Oxidations**	**9**
1.1	Metal based and non-metal-based oxidations of alcohols: - chromium, manganese, silver, ruthenium, DMSO, and hypervalent iodine.	2
1.2	Peracids oxidation of alkenes and carbonyls: - Sharpless, Jacobsen, and Shi epoxidations	1
1.3	Alkenes to diols- manganese, osmium based. Alkenes to carbonyls with bond cleavage- manganese, ruthenium, and lead based, ozonolysis. Sharpless asymmetric dihydroxylation.	2
1.4	Alkenes to alcohols/carbonyls without bond cleavage: - hydroboration-oxidation, Wacker oxidation, and selenium based allylic oxidation. Oppenaur oxidation	2
1.5	Riley reaction, Baeyer-Villiger oxidation, Dess-Martin oxidation, TEMPO oxidation, Swern oxidation, IBX oxidation	2
2.0	**Reductions**	**9**
2.1	Reduction: Metal based reductions using Li/Na in liquid ammonia, sodium, zinc, titanium, Birch reduction. Catalytic hydrogenation: - Palladium, Platinum, Rhodium, Nickel, Wilkinson).	2
2.2	Hydride transfer reagents: - $LiAlH_4$, $NaBH_4$, L-selectride, K-selectride, DIBAL-H, Red-Al, Trialkylsilanes, and Trialkylstannane.	3
2.3	Enantioselective reductions: - Chiral Boranes, Corey-Bakshi-Shibata and Noyori asymmetric hydrogenation. Clemmensen reduction, Wolff-Kishner reduction, Bouveault-Blanc reduction, MPV reduction	4
3.0	**Synthetic Reagents**	**9**
3.1	Synthetic applications of NBS, LDA, BuLi, diborane, 9-BBN, ter-butoxycarbonylchloride, DCC, Gilman's reagent, Grignard reagent, tri-n-butyltinhydride, 1,3-dithiane, Pb $(OAc)_4$, ceric ammonium nitrate, DABCO, DMAP, DBU, Oxone, DDQ, DEAD, Baker's yeast, and Lindlar catalyst, phase transfer catalysts in organic synthesis.	9
4.0	**Chemistry of Heterocyclic Compounds**	**9**
4.1	Synthesis of heterocycles: 5-membered ring from 1,4-carbonyl compounds, Hantzsch pyridine synthesis. pyrazole from hydrazine, di carbonyl compounds, pyrimidines synthesis from 1,3-dicarbonyl	9

	compounds and amidines, isoxazoles, tetrazoles, triazoles made by cyclo additions, Fischer indole synthesis. quinolines and isoquinolines. Reactivity of pyridine, pyridine oxide, reactivity of 5-membered rings-addition, substitution, Diels-alder. Reactivity of 5-membered ring with two or more nitrogens, Reactivity of benzo fused heterocycles, Reactivity of 6-membered ring with two or more nitrogens.	
5.0	**Molecular Rearrangements and Transformations**	**6**
5.1	Molecular rearrangements through intermediary carbocations: Wagner -Merwin, Pinacol-pinacolone, Semi-pinacol, Dienone-phenol, Benzylic acid, Demyavov, Favorskii, Orton, Fries rearrangements.	4
5.2	Nitrene intermediate rearrangement: Hofmann, Curtius, Lossen, Schmidt, Beckmann. Carbenes: Wolff rearrangement.	2
6.0	**Modern Synthetic Methods**	**6**
6.1	Baylis-Hillman reaction, Henry reaction, Kulinkovich reaction, Ritter reaction, Sakurai reaction,	2
6.2	Metal mediated C-C and C-X coupling reactions: Heck, Stille, Suzuki, Negishi and Sonogashira, Nozaki-Hiyama, Buchwald-Hartwig, Pauson-Khand reaction,	2
6.3	Bergman cyclization, Nazarov cyclization, cation-olefin cyclization. Baldwin's rules. Pauson-Khand reaction, Volhardt reaction.	2
7.0	**Retro Synthetic Analysis and heterocyclics**	**6**
7.1	Retrosynthetic Analysis, synthons, functional group inter conversion, 1,2-disconnections, 1,3- disconnection, C-C disconnections, 1-5 related functional groups, natural reactivity and umpolung.	6

RECOMMEND TEXT BOOKS

1. W. Carruthers, ***Modern Methods of Organic Synthesis***, Cambridge Uni. Press (1996).
2. L. Kuerti and B. Czako, ***Strategic Applications of named Reactions in Organic Synthesis***, Elsevier Academic Press (2005).
3. F. A. Cary and R. I. Sundberg, ***Advanced Organic Chemistry, Part A and B***, 5th Edition, Springer (2009).
4. Michael B Smith, ***Organic Synthesis***, 3rd Edition (2011).
5. J. Clayden, N. Greeves, S. Warren and P. Wothers, ***Organic Chemistry***, 2nd Edition, Oxford University Press (2012).

SUGGESTED READING AND REFERENCES

1. S. Warren, ***Organic Synthesis: The disconnection Approach***, Wiley (2004).
2. R. Noyori, ***Asymmetric Catalysis in Organic Synthesis***, John Wiley (1994).
3. R. O. C. Norman and J. M. Coxon***, Principles of Organic Synthesis***, 3rd edition, CRC Press (1998).
4. J. J. Li, ***Name Reactions***, 4th edition, Springer (2009).
5. J. A. Joules, K. Mills, ***Heterocyclic Chemistry***, 4th Ed., Oxford University Press (2004).
6. T. L. Gilchrist, ***Heterocyclic Chemistry***, 3rd Edition, Pearson (1997).

Course	Details				
Course Code	**CH910301**				
Course Title	**INDUSTRIAL OILS AND FAT PRODUCTS**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/IV				
Type	Elective Course				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Extraction and Processing of Oils and Fats**	**18**
1.1	Mechanical pre-treatment and heat treatment of oil-bearing materials. Rendering of fats and cooking of oil seeds. Mechanical expression of oils. Solvent extraction theory and practice, type of extractors, solvent recovery, alternative solvents for extraction, super critical fluid extraction of oils and fats.	6
1.2	Refining, bleaching, deodorization, fractionation, winterization, stabilization, solidification, homogenization, emulsification and dewaxing.	6
1.3	Study of the sources, composition, characteristics and utilization of commercially important oils and fats- butter, tallow, coconut oil, palm oil, cocoa butter, olive oil, rice bran oil, sesame oil, soybean oil, sunflower oil, linseed oil, mustard oil, castor oil.	6
2.0	**Oils and Fats as Food Materials**	**9**
1.2	Cooking oil, salad oil, and salad dressings. Quality evaluation of cooking oils and salad oils. Margarine and Shortenings Essential fatty acids: ω-3 and ω-6 fatty acids and their dietary sources, significance to human nutrition and health. Fat-related diseases: atherosclerosis, arthritis. Nutritional significance of EFA, HDL, LDL and VLDL	9
3.0	**Hydrogenation of Oils**	**9**
3.1	Catalytic hydrogenation: chemistry of hydrogenation, hydrogenolysis, influence of various factors in hydrogenation, mechanism, kinetics and thermodynamics of hydrogenation reactions, hydrogenation catalysts-theory of catalysis Manufacture of catalyst for hydrogenation-Hydrogenation of vegetable and marine oils manufacture of vanaspati	9
4.0	**Analysis of Fats and Oils**	**9**
4.1	Test methods for physical properties: melting point, softening point, slipping point titre, congeal point, flow test, cloud test, consistency test. Test methods for chemical properties: Iodine value, thiocyanogen number, saponification value, acid value and free fatty acid, oxirane oxygen, hydroxyl and acetyl value, peroxide value, Reichert-Meissel value, Polenski value and Kirschner value, diene value.	9

5.0	**Waxes and Fatty alcohols**	**9**
5.1	Occurrence, classification, properties and composition of waxes. Synthetic waxes. Analysis and utilization of waxes. Naturally occurring fatty alcohols – production, uses and applications Alcohol ethers.	9

RECOMMENDED BOOKS AND REFERENCES

1. D. Swern, ***Bailey's Industrial Oil and Fat Products***, 4th edition, Wiley, (1982).
2. T.H. Applewhite, ***Bailey's Industrial Oil and Fat Products***, Vol. III, 4th edition (1985).
3. E.S. Pattison, ***Fatty acids and their Industrial Applications***, Marcel Dekker (1968)
4. A.J.C. Andersen, ***Refining for Oils and Fats for Edible Purposes***, Pergamon (1962).
5. F.D. Gunstone, ***An introduction to Chemistry and Biochemistry of Fatty acids and their Glycerides***, Chapman and Hall (1968).
6. T.P. Hilditch, P.N. Williams, ***The Chemical Constitution of Natural Fats***, 4th edition, Wiley (1964).
7. H.A. Boekenoogen, ***Analysis and Characterization of Oils, Fats and Fat Products*** Vol. I, Interscience (1964).
8. P. Tooley, ***Chemistry in Industry-Fats, Oils and Waxes***, John Murray (1971).
9. W.W. Christie, ***Lipid Analysis***, 3rdEdn., Oily Press (2003).
10. F. Rosengarten, ***The Book of Spices***, Jove (1981).
11. W. Parry, ***Hand Book of Spices***, Chemical Publishing (1969).
12. J.S. Pruthi, ***Spices and Condiments Chemistry, Microbiology and Technology***, Academic Press (1980).
13. E. Guenther, ***The Essential Oils***, Vol I-VI, Van Nostrand, 1972. 14. L.H. Meyer, Food Chemistry, Reinhold (1960).

Course	Details				
Course Code	**CH910402**				
Course Title	**INDUSTRIAL ENZYME TECHNOLOGY**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/III				
Type	Elective Course				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	**Enzymes and their action**	**9**
1.1	Introduction to enzymes. Transition state theory. Acid-Base catalysis. Covalent catalysis—Binding modes of catalysis (i) Proximity effect (ii) Transition state stabilization (iii) Strain and Distortion. Examples of some typical enzyme mechanisms for (1) Triose phosphate isomerase, (ii) α-chymotrypsin and serine protease (iii) Lysozyme (iv) Carboxy peptidase-A (v) Ribonuclease.	9
2.0	**Enzyme Models and Enzymatic transformations**	**18**
2.1	Introduction — Biomimetic chemical approach to biological systems-Enzyme models Advantage of enzyme models. Requirements necessary for the design of enzyme models. Host-Guest complexation chemistry. Examples of some host molecules-Crown ether cryptanes, cyclodextrins. Cyclodextrin based enzyme models-Valixarenes, ionophores, micelles and synzymes (synthetic enzymes) — chiral recognition and catalysis. Introduction to industrial enzymes. Enzymatic synthesis of α-amino acids and peptides. Transformations of lipases and esterases. Kinetic resolutions of catboxylic acids, esters and alcohols - Transesterification. Amine resolution-use of oxido-reductase. C-C bond formation using enzymes-asymmetric cyanohydrin formation and asymmetric aldol condensations	18
3.0	**Recombinant DNA and Fermentation technology**	**18**
3.1	Introduction to genetic engineering. Recombinant DNA technology-restriction endonuclease, cloning, linkers, adaptors. Application of recombinant DNA technology in production of pharmaceuticals, diagnosis of diseases, insect control, improved biological detergents, gene therapy-examples. Principles of finger printing technology- Site directed mutagenesis.	

	Fermentation technology: Introduction to fermentation. Industrial fermentation. Advantages and limitations of fermentation. Production of drugs and drug intermediates from fermentation examples. Chiral hydroxy acids, vitamins, amino acids, β-lactam antibiotics. Precursor fermentation and microbial oxidation and reductions	18
4.0	**Coenzymes**	**9**
4.1	Introduction. Co factors — cosubstrates — prosthetic groups. Classification — Vitamin derived coenzymes and metabolite coenzymes. Structure and biological functions of coenzyme A, thiamine pyrophosphate (TPP), pyridoxal phosphate (PLP), oxidized and reduced forms of I) nicotinamide adenosine dinucleotide / their phosphates (NAD), NADH, NADP+ NADPH) ii) Flavin adenine nucleotide FAD, FADH2 and iii) Flavin mononucleotide (FMN, FMNH2) lipoic acid, biotin, tetrahydrofolate and ubiquinone. Adenosine triphosphate (ATP) and adenosine diphosphate (ADP), S-adenosyl methionine (SAM) and uridine diphospho sugars (UDP-sugars) Mechanism of reactions catalyzed by the above coenzymes.	9

RECOMMENDED BOOKS AND REFERENCES

1. Laurence Moran, Robert Horton, Gray Scrimgeour, ***Principals of Biochemistry***, Pearson New International Edition (2013).
2. Herman Dugas and Christopher Penney, ***Bioorganic chemistry - A chemical approach to enzyme action***, Springer (1981)
3. D. Bala Subramanian, ***Concepts in biotechnology***, University Press (2004).
4. Melvin Berger, ***Enzymes in Action***, Ty Crowell Co. (1971).
5. Suckling Colin, ***Enzyme Chemistry: Impact and Applications***, 3rd edition, Springer India (2010).
6. Khan M. Y., Khan Farha, ***Principles of Enzyme Technology***, PHI Learning Pvt Ltd (2015).
7. Taylor, ***Enzyme Kinetics and Mechanisms***, Springer (2009).
8. Rajagopal, ***Recombinant Dna Tech & Genetic Engg***, McGraw Hill (2012).
9. Bernard R. Glick, Cheryl L. Patten, ***Molecular Biotechnology Principles and Applications of Recombinant DNA***, American Society for Microbiology (2017).
10. Keya Chaudhuri, ***Recombinant DNA Technology***, The Energy and Resources Institute, TERI (2012).
11. P. F. Stanbury, Allan Whitaker, Stephen J. Hall, ***Principles of Fermentation Technology***, Butterworth-Heinemann Ltd (1995)
12. Tim Bugg, ***Introduction to Enzyme and Coenzyme Chemistry***, Wiley (1997).
13. Karl August Folkers, ***Vitamins and Coenzymes***, Wiley Interscience (1964).

Course	Details				
Course Code	**CH910403**				
Course Title	**SMART MATERIALS, SOFT MATERIALS AND GREEN CHEMISTRY**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/III				
Type	Elective Course				
Credits	3	Hrs/Week	3	Total Hours	54

Module	Course Description	Hrs
1.0	Smart materials, Smart Biomaterials and Nanobiomaterials	**9**
1.1	Common smart materials and associated stimulus-response, Application areas of smart systems Ferroelectric materials: Piezoelectric materials- piezoelectric effect, Piezoceramics, Piezopolymers, Piezoelectric materials as sensors, Actuators and bimorphs.	3
1.2	Smart biomaterials: Stimuli responsive polymers (pH, temperature, light, magnetic and biomolecules) and their applications as biomaterials. Stimuli responsive hydrogels.	3
1.3	Nanobiomaterials: Interaction of bio-molecules and nano particle surfaces. Biocompatible nanomaterials, Nanogels and microgels: preparation methods, characterization and applications.	3
2.0	**Shape memory materials**	**9**
2.1	Shape memory alloys (SMAs), Shape memory polymers, Shape memory effect-Mechanism, programming and recovery-Shape memory alloys versus shape memory polymers-Thermodynamics of shape memory effect.	3
2.2	Techniques for activating shape memory effect: Thermal-electric-magnetic-light-water-pH	3
2.3	Biomedical applications: Requirements of a polymeric material in biomedical field, vascular stents-aneurysm-occlusion devices-drug delivery- orthodontics based SMPs-pressure bandages and sutures.	3
3.0	**Soft Materials and Gels**	**9**
3.1	Soft Materials: The concept and development of soft materials, Nature of supramolecular interactions for the soft materials; Noncovalent interactions, ion-ion interactions, Ion-dipole interactions, Dipole-	6

	dipole interactions, π-π stacking, Cation-π interactions, Solvophobic interactions; van der Waals interactions, Hydrogen bonding, Multiple hydrogen bonding motifs, Jorgensen model for H-bonding; Photoresponsive molecules and self-assembly, Micelles, Vesicles, Toroids, Colloids, Rods.	
3.2	Gels: Different class of gels- low molecular weight organo gels, hydrogels, basics, classifications, Structure and theory of formation, Swelling, Physical hydrogels, Ionic and hydrogen bonding in gels, Polyelectrolyte gels, Applications of hydrogels.	3
4.0	**Introduction to green chemistry**	**9**
4.1	Green chemistry-relevance and goals, Anastas' twelve principles of green chemistry - Tools of green chemistry: alternative starting materials, reagents, catalysts, solvents and processes with suitable examples.	9
5.0	**Microwave mediated organic synthesis**	**9**
5.1	Microwave activation, advantage of microwave exposure, specific effects of microwave, neat reactions, solid supports reactions, Functional group transformations, condensations reactions, oxidations, reductions reactions multi-component reactions.	9
6.0	**Alternative synthesis, reagents and reaction conditions**	**9**
6.1	Introduction, synthesis of ionic liquids, physical properties, applications in alkylation, hydroformylations, epoxidations, synthesis of ethers, Friedel-craft reactions, Diels-Alder reactions, Knoevengal condensations, Wittig reactions, Phase transfer catalyst, Synthesis applications. A photochemical alternative to Friedel-crafts reactions - Dimethyl carbonate as a methylating agent, the design and applications of green oxidants, super critical carbon dioxide for synthetic chemistry.	9

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1. D.J. Leo, ***Engineering Analysis of Smart Material Systems,*** Wiley (2007).
2. M. Addington, D.L. Schodek, ***Smart Materials and New Technologies in Architecture***, Elsevier (2005).
3. M.V. Gandhi, B. S. Thompson, ***Smart Materials and Structures***, Chapman & Hall (1992).
4. K. Otsuka, C.M. Wayman (Eds.), ***Shape Memory Materials***, Cambridge University Press (1998).
5. P. Ball, ***Made to Measure: Materials for the 21stCentury***, Princeton University Press (1997).
6. I. Galaev, B. Mattiasson (Eds.), ***Smart Polymers: Applications in Biotechnology and Biomedicine***, 2 nd ed., CRC Press (2008).

7. B. Ratner, A. Hoffman, F. Schoen, J Lemons, ***Biomaterials Science: An introduction to materials in Medicine***, 2nd edition, Academic Press (2004).
8. S. Dumitriu, ***Polymeric Biomaterials***, 2nd edition, Marcel Dekker (2002).
9. S. Ramakrishna, T. S. Sampath Kumar, ***Biomaterials: A nano approach***, CRC press (2010).
10. S. Li, A. Tiwari, M. Prabaharan and S. Aryal, ***Smart Polymer Materials for Biomedical Applications***, Nova Science Publishers Inc (2010).
11. N. Yui, R. J. Mrsny, K. Park (Eds.), ***Reflexive Polymers and Hydrogels: Understanding and Designing Fast Responsive Polymeric Systems***, CRC Press (2004).
12. Lendlein Andreas, Steffen Kelch, ***Shape-Memory Polymers*** Angew. Chem. Int. Ed., 41, 2034 – 2057 (2002).
13. C. Liu, H. Qin and P. T. Mather, ***Review of progress in shape-memory polymers***, J. Mater. Chem., 17, 1543–1558 (2007).
14. Wie Zhao, ***Shape memory polymers and their composites in biomedical applications*** (2018).
15. V. V. Tsukruk, S. Singamaneni, ***Scanning Probe Microscopy of Soft Matter: Fundamentals and Practices***, Wiley VCH Publishers (2011).
16. N. Takashi, ***Supramolecular Soft Matter***, 1st edition, John Wiley & Sons (2011).
17. V.K. Pillai, M. Parthasarathy, ***Functional Materials: A Chemist's Perspective***, Orient BlackSwan, Universities Press- IIM Series (2013).
18. S. K. Tripathy, Jayant Kumar, H.S. Nalwa, ***Handbook of Polyelectrolytes and Their Applications***, American Scientific Publishers (2003).
19. B. Rolando, ***Hydrogels Biological Properties and Applications***, 2nd edition, Springer (2009).
20. M. Tokita, K. Nishinari, ***Gels: Structures, Properties, and Functions: Fundamentals and Applications in Vol. 136 of Progress in Colloid and Polymer Science***, Springer (2009).

21. ***Methods in modern biophysics,*** Bengt Nolting, Springer-Verlag, Berlin, First Indian Reprint, 2004. (Pages 102-146 for Unit II and 147 – 163 for Unit V)
22. ***Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life,*** W. Kain and B. Schwederski, John-Wiley R Sons, New York.
23. ***Green Chemistry, environmentally benign reactions***, V. K. Ahluwalia. Ane Books India (Publisher). (2006).
24. ***Green Chemistry: A Textbook,*** V. K. Ahluwalia, Narosa Publishing House, 2013.
25. ***Green Chemistry, Designing Chemistry for the Environment***, edited by Paul T. Anastas & Tracy C. Williamson. Second Edition, (1998).
26. ***Green Chemistry, Frontiers in benign chemical synthesis and processes***, edited by Pau T. Anastas & Tracy C. Williamson. Oxford University Press, (1998).
27. ***Green Chemistry, Environment friendly alternatives***, edited by Rashmi Sanghi & M. M. Srivastava, Narora Publishing House, (2003).

Course	Details				
Code	**CH060405**				
Title	**PHYSICAL CHEMISTRY PRACTICAL II**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	1/I & II				
Type	Practical Course				
Credits	2	Hrs/Week	2	Total Hours	54+54

Module	Course Description	Hrs
	Minimum 12 Experiments.	
1.0	**Potentiometry**	
	1. To determine the dissociation constant of dibasic acid by potentiometric method. 2. Potentiometric titration of a mixture of KCl + KBr + KI to determine the composition of each component in the mixture. 3. Determination of single electrode potentials (Cu and Zn). 4. Determination of end point of a titration using Gran Plot. Determination of the concentration of a mixture of Cland Iions. 5. Determination of the formation constant of silver-ammonia complex and stoichiometry of the complex potentiometrically.	
2.0	**Conductometry**	
	1. Determination of critical micellar concentration by conductometry and calculation of free energy of micellization 2. Estimation of mixture of acids conductometrically 3. Precipitation titration and determination of solubility of sparingly soluble salts (Lead sulphate) by conductometry. 4. Verification of Onsager equation. 5. Determination of the degree of ionization of weak electrolytes. 6. Verification of Kouhlrasch's Law (Determination of eq. conductivity of a weak electrolyte at infinite dilution).	
3.0	**Chemical Kinetics**	
	1. Determination of the rate constant of the hydrolysis of ester by sodium hydroxide. 2. Determination of Arrhenius parameters. 3. Kinetics of reaction between $K_2S_2O_8$ and KI 4. Iodination of acetone in acid medium. 5. Determination of specific reaction rate of saponification of ethyl	

4.0	**Refractometry**	
	1. Identification of pure organic liquids and oils. 2. Determination of molar refractions of pure liquids. 3. Determination of concentration of solutions (KCl-water, glycerol-water). 4. Determination of molar refraction of solids. 5. Study of complex formation between potassium iodide and mercuric iodide system.	
5.0	**Viscosity**	
	1. Determination of viscosity of pure liquids. 2. Verification of Kendall's equation. 3. Determination of the composition of binary liquid mixtures (alcohol-water, benzene-nitrobenzene). 4. Determination of the molecular weight of a polymer (polystyrene in toluene)	
6.0	**Computational Chemistry Experiments**	
	Experiments illustrating the capabilities of modern open source/ free computational chemistry packages in computing. 1. Single point energy 2. Geometry optimization 3. Vibrational frequencies 4. Population analysis 5. Conformational analysis of ethane, transition state search 6. Molecular orbitals, ionisation energy, electron affinity 7. Dipole moment, free valence, bond order 8. Determination of inversion barrier of simple molecules like NH3 , H2O, H2O2 9. Determination of Z-matrices /Cartesian coordinates of furan, thiophene, pyrrole and benzene using structure drawing programs like Chem sketch and MacMolPlt.	

REFERENCES

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2. J. B. Yadav, ***Experimental Physical Chemistry***, 2nd Edition W.G. Palmer, Cambridge University Press.
3. D.P Shoemaker, C.W. Garland, J.W. ***Nibler Experiments in Physical chemistry***, McGraw Hill.
4. V.D. Athawale and Parul Mathur, ***Experimental Physical Chemistry***, New Age International (P) Ltd.
5. A. Halpern and G. McBane, ***Experimental physical chemistry***.
6. F. Daniels, ***Experimental physical chemistry***.
7. G. P. Matthews, ***Experimental Physical Chemistry***.
8. Longman, A.M. James, ***Practical Physical Chemistry***.
9. B. Viswanathan & R.S. Raghavan, ***Practical Physical Chemistry***, Viva Books (2009).
10. A. Finlay, ***Practical Physical Chemistry***, Longman's Green & Co.
11. J.B. Firth, ***Practical Physical Chemistry***, Read Books. (2008).
12. W. G. Palmer, ***Experimental Physical Chemistry***, Cambridge University Press (2009).
13. J.H. Jensen, ***Molecular Modelling Basics***, CRC Press (2010).

Course	Details				
Course Code	**CH060406**				
Course Title	**Industrial Chemistry Practical II – Advanced Synthesis and Characterization of Industrial Materials**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2 /III & IV				
Type	Practical Course				
Credits	2	Hrs/Week	3	Total Hours	54+54

Module	Course Description	Hrs
	(At least 6 experiments are to be carried out from Part 1, 2, 3)	**54**
1.0	**Identification Tests**	
	1. Identification of Polymers by Chemical analysis 2. Colour tests for identification of Alkaloids 3. Identification of Antibiotics with some Colour reactions	
2.0	**Perfumes and Dyes**	
	1. Synthesis of Raspberry Ketone from 4-Hydroxy Benzaldehyde 2. Synthesis of Methyl Salicylate from Salicylic acid 3. Synthesis of TCPO from 2,4,6, Trichloro phenol 4. Preparation of Florescent Dye Eosin 5. Synthesis of methyl Anthranilate (Grape Flavor) 6. Synthesis of Sudan- I 7. Synthesis of Yellow chrome 8. Synthesis of Prussian blue.	
3.0	**Polymer and Composite**	
	1. Emulsion Polymerization of Vinyl acetate 2. Suspension Polymerization of Vinyl acetate/ Methyl Methacrylate 3. Preparation of Polystyrene by an Anionic Polymerization Method 4. Synthesis of Nylone 6,6 5. Preparation of Urea formaldehyde resin 6. Preparation of Phenol formaldehyde resin – novolak and resol 7. Preparation of Epoxy resin from Bisphenol A and Epichlorohydrin 8. Super absorbent Polyelectrolyte based on a Crosslinked Acrylic acid copolymer. 9. Conducting polymer: - Chemical oxidation of 2,4-dimethyl Pyrrole using ferric chloride	

	10. Conducting polymer: - Electrochemical polymerization of aniline 11. Conducting polymer: - Chemical Oxidation of Aniline 12. Cellulose modification: Preparation of Cellulose acetate	
	(At least 6 experiments are to be carried out from Part 4, 5, 6, 7)	**54**
4.0	**Natural Product**	
	1. Isolation of curcumin from Curcuma longa. 2. Isolation of piperine from piper nigrum 3. Isolation of chitin and glucosamine 4. Isolation of Citric acid from Lemon. 5. Isolation of Naringin from Grapefruit peel 6. Extraction of Caffeine from tea 7. Isolation of DNA and RNA	
5.0	**Nano Chemistry**	
	1. Synthesis of Silver nano particle and analysis 2. Synthesis of Zinc sulfide nano particle and Characterization 3. Synthesis of Zinc oxide nano roads and Characterization 4. Synthesis of polymeric nanoparticles and characterization Synthesis of Graphene oxide from Graphite and characterization. 5. Synthesis of nano cellulose	
6.0	**Synthesis of medicinal Compounds**	
	1. Laboratory Synthesis of the drug Benzocaine 2. Laboratory Synthesis of the drug sulfanilamide 3. Laboratory Synthesis of the drug barbutaric acid 4. Laboratory Synthesis of the drug Phenytoin	
7.0	**Green Synthesis**	
	1. Aldol Condensation Reaction 2. Friedel-Crafts Alkylation Reaction 3. Substitution (SN2) Reaction	

REFERENCES

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2. K.N Jayaveera, S. Subramanyam, K. Yogananda reddy, ***Practical Medicinal Chemistry***, S. Chand (2014).
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4. Charles Dickso, **Experiments in Pharmaceutical Chemistry**, Second Edition, CRC Press (2014).
5. Stanley R. Sandler, Wolf karo, Jo-Anne Bonesteel, Eli M Eli, Pearce, ***Polymer Synthesis and Characterization a Laboratory Manual***, Academic Press (1998).

6. Gerrard Eddy Jai Poinern, ***A Laboratory Course in Nanoscience and Nanotechnology***, CRC press (2020).
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8. Ashutoshkar, ***Pharmaceutical drug analysis***, New Age International Private Limited (2012).
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11. R. K. Bansal***, Laboratory Manual of Organic Chemistry***, New Age International Private Limited (2008).
12. N. K. Vishnoi, ***Advanced Practical Organic Chemistry***, Vikas 2nd, (1996)
13. Gunter Zweig***, Insecticides: Pesticide Plant Regulators and Food Additives*** - Vol I to IV, Academic press (2013).

Course	Details				
Course Code	**CH060407**				
Course Title	**INDUSTRIAL CHEMISTRY PRACTICAL III**				
Degree	M.Sc.				
Branch (Specialization)	Industrial Chemistry				
Year/Semester	2/ III & IV				
Type	Practical Course				
Credits	2	Hrs/Week	3	Total Hours	54+54

Module	Course Description	Hrs
Part I	**(At least 6 experiments are to be carried out in Part I)**	54
1.1	Synthesis of some typical organic medicinal compounds a) Aspirin b) Paracetamol c) Calcium Lactate **d)** sulphanilamide	
1.2	Assay and purity of following synthetic drugs and Vitamins a) Aspirin b) Paracetamol c) Ibuprofen d) Riboflavin e) Ascorbic acid	
1.3	Characterization of medicinal compounds by a) IR, UV method b) Determine the Rf value and compare with standard Rf	
1.4	Colorimetric/Spectrophotometric Estimation of the following drugs a) Aspirin b) Curcuminoids c) Paracetamol d) Gingiberene e) Caffeine f) Aceclofenac	
1.5	Pre formulation studies: - characterization of Granules a) Flow Rate b) Angle of Repose c) Bulk Density and Tapped Density d) Moisture Content e) Particle Size Analysis	
1.6	Formulation a) Paracetamol (wet / dry method) b) Aspirin tablet	

	c) Calamine lotion d) Compound benzoic acid ointment	
Part II	**(At least 6 experiments are to be carried out in part II)**	54
2.1	Synthesis of some polymeric materials a) Bulk polymerization of Methyl Methacrylate with AIBN b) Preparation of Isotactic and Syndiotactic PMMA With Butyl lithium in Solution. c) Copolymerization of styrene and Methyl Methacrylate d) Preparation of a polyester using Diethylene glycol & adipic acid e) Preparation of a composite materials from unsaturated polyester resin and glass fibers	
2.2	Characterization of prepared polymers by a) Infra-Red spectroscopy b) Analysis of Physico-Chemical Changes of a Sample on Heating by TGA-DSC Technique	
2,3	Latex properties: a) Determination of total solid and dry rubber content of NR latex. b) Determination of total alkalinity of NR latex.	
2.4	Determination of Physical property of Polymers a) Apparent density and bulk density of polymers b) Moisture and volatile content in plastics / rubbers c) Melt flow index. d) Molecular weight by Viscometry method	
2.5	Testing of mechanical properties of polymers a) Tensile strength. b) Compression strength. c) Flexural strength. d) Tear strength. e) Hardness – Rockwell and Shore.	
2,6	Polymer modification a) Preparation of Cation exchanger by Sulfonation of crosslinked polystyrene. b) Preparation of Anion exchanger from crosslinked polystyrene by Chloromethylation and Amination.	
2.7	Demonstration of Rubber Compounding a) Determination carbon black content in rubber. b) Determination of non – black filler content in rubber.	

REFERENCES

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