Course of Studies

for

2 Year Master of Science (M.Sc.)

in

Chemistry

with

Specialization

in

Industrial Chemistry

(Session 2016 – 2017 Onward)

Department of Chemistry
Veer Surendra Sai University of Technology (VSSUT)
Siddhi Vihar, P.O.: Engineering College
Burla, Sambalpur–768018, Odisha, India
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Programme Objective:

- To impart training in Chemistry at advanced level in a more wholistic way and enthuse the students for the subject.
- To train the students to make them confident and capable of accepting any challenge in Chemistry.
- To give a flavour of research in Chemistry and train the students for research career.
- To abreast the students about the status and new developments in Chemistry.
- To make the students aware of the impact of Chemistry on environment and imbibe the concept of sustainable developments.
- To educate the students with respect to skills and knowledge to practice chemistry in ways that are benign to health and environment.

Programme Outcome:

On completion of the MSc programme students should have shown evidence of being able:

- To demonstrate in-depth, specialist knowledge and mastery of techniques relevant to Chemical Process Research and Development and to demonstrate a sophisticated understanding of concepts, information and techniques at the forefront of the discipline.
- To exhibit mastery in the solution of research problems in Chemical Process Research and Development, and deductive problems in associated chemistry and chemical engineering.
- To demonstrate a comprehensive understanding of techniques applicable to their own research in Chemical Process Research and Development.
- To take a proactive and self-reflective role in working and to develop professional relationships with others.
- Proactively to formulate scientific hypotheses and to design and execute experiments which test them.
- Critically and creatively, to evaluate current issues and research topics in process chemistry.
- To disseminate research results orally, and in writing.

Course Structure of 2 Year M.Sc. (Industrial Chemistry)

First Semester

Sl. No.	Course Code	Name of the Course	L–T–P	Credit
1	CH–411	Group Theory & Wave Mechanics	4–0–0	04
2	CH–412	Coordination Chemistry	4–0–0	04
3	CH–413	Structure & Reactivity	4–0–0	04
4	CH–414	Thermodynamics & Chemical Dynamics	4–0–0	04
5	CH–415	Polymer Chemistry	4–0–0	04
6	CH–416	Inorganic General Practical	0–0–3	02
7	CH–417	Organic General Practical	0–0–3	02
		Total Credits		**24**

Second Semester

1	CH–421	Analytical Chemistry	4–0–0	04
2	CH–422	Stereochemistry	4–0–0	04
3	CH–423	Spectroscopy–I	4–0–0	04
4	CH–424	Organic Reaction Mechanism	4–0–0	04
5	CH–425	Surface Chemistry & Nuclear Chemistry	4–0–0	04
6	CH–426	Physical General Practical	0–0–3	02
7	CH–427	Analytical Practical	0–0–3	02
		Total Credits		**24**

Third Semester

1	CH–511	Organometallics	4–0–0	04
2	CH–512	Photochemistry & Pericyclic Reaction	4–0–0	04
3	CH–513	Spectroscopy–II	4–0–0	04
4	CH–514	Environmental Chemistry	4–0–0	04
5	CH–518	Industrial Process	4–0–0	04
6	CH–516	Industrial Practical	0–0–3	02
7	CH–517	Environmental Practical	0–0–3	02
			Total Credits	**24**

Fourth Semester

1	CH–521	Solid State & Nanomaterials	4–0–0	04
2	CH–523	Chemistry of Materials	4–0–0	04
3	CH–527	Material & Energy Balance	4–0–0	04
4	CH–524	Seminar	–	02
5	CH–525	Project	–	08
6	CH–526	Industrial Training report	–	02
			Total Credits	**24**

SEMESTER: 1st

Code: **CH-411** Subject: **GROUP THEORY AND WAVE MECHANICS** Credits: **4 [4-0-0]**

Course Objective:

- The objective of course deals with the application of symmetry, groups and matrices in chemistry along with the application of quantum mechanics in physical models and experiments of chemical systems.

Course Outcome:

- The course delivers the fundamental knowledges of Symmetry operations and symmetry elements and its matrix representations.
- The major outcome of the quantum chemistry includes increasing accuracy of the results for small molecular systems by using different approximation methods.

Module-I: (10 Hours)

Group Theory: Symmetry Elements and Symmetry Operations, Matrix Representation of Symmetry Operation, Classes of Operations, Point Groups (C_n, C_{nv}, C_{nh}, S_n, D_n, D_{nd}, D_{nh}, T_d, O_h, $D_{\infty a}$, $C_{\infty v}$ and $D_{\infty h}$), Properties of Point Groups, Irreducible and Reducible Representation, Bases of Representation, Character of a Representation, Reduction Formula, The Great Orthogonality Theorem (Without Proof) and its explanation, Construction of Character Tables for C_{2v}, C_{3v}, T (Cubic), C_4 (Cyclic) and D_∞ Groups, Projection Operator and Direct Product

Module-II: (10 Hours)

Wave Mechanics of Some Systems: Postulates of Quantum Mechanics, Quantum Mechanical Operators, Application of Schrodinger Wave Equation to Particle in a Box, Harmonic Oscillator, Rigid Rotator, and Hydrogen Atom, Transformation of Co-ordinates, Separations of Variables, ϕ, θ and R Equations, Spherical Harmonics, Shapes of s, p and d Orbital, Probability Density in 1s Orbital, Physical Interpretation of Hydrogen Orbitals, Radial Distribution Function and Curves.

Module-III: (10 Hours)

Angular Momentum: Definition, Generalized Angular Momentum, Eigen Functions and

Eigen Values of Angular Momentum, Operator using Ladder Operators, Addition of Angular Moments, Mutual Interaction of Electron Orbitals and Resultant Vectors, Russel-Saunder's Coupling, j-j Coupling, Ground State Term Symbols and Hund's Rule, Micro States and Derivation of Russel-Saunder's Term for P^2, d^2 and pd Configuration.

Module-IV: (10 Hours)

Approximation Methods: Variation Theorem and its Application to Hydrogen atom in Derivation of its Ground State Energy, Perturbation Theory (First Order and Non-degenerate), Secular Equations, Linear Combination of Atomic Orbitals (LCAO) Approximation (Molecular Orbital Theory) and Its Application to Hydrogen Molecule Ion, Huckel Theory of Conjugated Systems, Bond Order, and Charge Density Calculations, Applications to Ethylene, Butadiene, Cyclopropenyl Radical, Cyclobutadiene, etc., Spin and Anti-symmetric Nature of Wave Function (Pauli's Exclusion Principle)

Prescribed Books:

1. F.A. Cotton, *Chemical Applications of Group Theory*, 3rd Edition, John Wiley & Sons, 1990.

2. A. Vincent, *Molecular Symmetry and Group Theory: A Programmed Introduction to Chemical Application*, 2nd Edition, john Wiley & sons, 2001.

3. R.L. Carter, *Molecular Symmetry and Group Theory*, 1st Edition, John Wiley & Sons, 1997.

4. M. Ladd, *Symmetry and Group theory in Chemistry*, 1st Edition, Horwood publishing, 1998.

5. G. Davidson, *Group Theory for Chemists*, 1st Edition, Macmillan, 1991.

6. R.L. Flurry, *Symmetry Groups: Theory and Chemical Applications*, 1st Edition, Prentice-Hall, 1980.

7. A.M. Lesk, *Introduction to Symmetry and Group Theory for Chemists*, 1st Edition, Kluwer Academic Publishers, 2004.

8. D.M. Bishop, *Group Theory and Chemistry*, 1st Edition, Dover Publications, 1993.

9. B.S. Tsukerblat, *Group Theory in Chemistry and Spectroscopy: A Simple Guide to Advanced Usage*, 1st Edition, Dover Publications, 2006.

10. D.C. Harris and M.D. Bertolucci, *Symmetry and Spectroscopy: An Introduction to Vibrational and Electronic Spectroscopy*, 1st Edition, Dover Publications, 1989.

11. K.V. Reddy, *Symmetry and Spectroscopy of Molecules*, New Age Science, 2nd Edition, 2009.

12. G. Raj, A. Bhagi and V. Jain, *Group theory and Symmetry in Chemistry*, 3rd Edition, Krishna Prakashan, 2010.

13. S.K. Dogra and H.S. Randhawa, *Symmetry and Groups Theory in Chemistry*, 1st Edition, New Age International, 2014.

14. P.K. Bhattacharya, *Group Theory and Its Chemical Applications*, 2ed Edition, Himalaya Publishing House, 2014.

15. K.C. Molloy, *Group Theory for Chemists: Fundamental Theory and Applications*, 2nd Edition, Woodhead Publishing, 2013.

16. M.C. Day and J. Selbin, *Theoretical Inorganic Chemistry*, 2nd Edition, Reinhold Book, 1969.

17. A.K. Chandra, *Introduction to Quantum Chemistry*, 4th Edition, Tata McGraw Hill Education, 2009.

18. R.K. Prasad, *Quantum Chemistry*, 4th Edition, New Age Science, 2009.

19. I.N. Levine, *Quantum Chemistry*, 6th Edition, Prentice Hall, 2008.

20. P.W. Atkins and R.S. Friedman, *Molecular Quantum Mechanics*, 5th Edition, Oxford University Press, 2010.

21. D.A. McQuarrie, *Quantum Chemistry*, 2nd Revised Edition, University Science Books, 2007.

Code: **CH-412** Subject: **COORDINATION CHEMISTRY** Credits: **4 [4-0-0]**

Course Objective:

- To be able to use Crystal Field Theory to understand the magnetic properties (and in simple terms the colour) of coordination compounds.
- To be able to describe the stability of metal complexes by the use of formation constants and to calculate thermodynamic parameters from them.

- Explain how complex reactions can be understood from the points of thermodynamics and kinetics.
- To become familiar with some applications of coordination compounds.

Course Outcome:

- Understand how stability of complex compounds can be determined.
- Establish reaction mechanism of selected complex compound.
- Explain how physical methods can be used to investigate the structure of complexes.
- To prepare complex compounds of select transition metals.
- Determine the magnetic properties metal complexes.
- Understand the mechanism of complex reactions.
- Determine the structure of some complex compounds.

Module-I: (10 Hours)

Theories of Metal-Ligand Bonding:

Crystal Field Theory: Important Aspects of Crystal Field Theory, *d*-Orbitals Splitting in Octahedral, Tetrahedral and Square Planar Complexes, 10Dq Value and Its Calculation, Crystal Field Stabilisation Energy (CFSE) in Weak Field and Strong Field Cases, Factors Affecting Magnitude of 10Dq, Spectrochemical Series, Jahn-Teller Effect, Applications of Crystal Field Theory (Colour and Magnetic Properties of Complexes), Limitations of Crystal Field Theory.

Molecular Orbital Theory (MOT): Nephelauxetic effect, MO Energy Level Diagrams for Octahedral, Tetrahedral and Square Planar Complexes, Measurement of π-Bonding Effects.

Module-II: (10 Hours)

Study of Complexes in Solution: Introduction to Stability Constants, Factors Affecting Stability Constants, Kinetic and Thermodynamic Stability, Irving-William Series, Concept of Hard and Soft Acids and Bases, Methods of Determining Stability Constants (Spectrophotometric and pH-metric Methods).

Module-III: (10 Hours)

Electronic Spectra of Metal Complexes: Spectra of Transition Metal Ions, Term Symbols of d^n Ions, Free Ions in Weak Fields and Strong Crystal Fields, Weak Field Configurations,

Orgel Diagrams for d^n Ions, Tanabe-Sugano Diagrams, Charge Transfer Transitions, Selection Rules and Transition Probabilities Based on Symmetry Considerations.

Magnetic Properties of Complexes: Types of Magnetism (Dia-, Para-, Ferro- and Anti-ferromagnetism), Temperature Independent Paramagnetism, Magnetic Susceptibility and Its Determination by Gouy and Faraday Methods, Calculation of Magnetic Moment from Magnetic Susceptibility, Spin-Orbit Couplings and Its Effect on Magnetic Moments, Orbital Contribution to Magnetic Moment.

Module-IV: (10 Hours)

Reaction Mechanism of Transition Metal Complexes: Energy Profile of a Reaction, Reactivity of Metal Complexes, Inert and Labile Complexes, Kinetic Application of Valence Bond and Crystal Field Theories, Kinetics of Octahedral Substitution. Acid Hydrolysis, Factors Affecting Acid Hydrolysis, Base Hydrolysis, Conjugate Base Mechanism, Direct and Indirect Evidences in Favour of Conjugate Mechanism, Anation Reactions, Reactions without Metal Ligand Bond Cleavage. Substitution Reactions in Square Planar Complexes. The Trans Effect, Mechanism of One Electron Transfer Reactions, Outer Sphere Type Reactions, Inner Sphere Type Reactions.

Prescribed Books:

1. W.U. Malik, G.D. Tuli, and R.D. Madan, *Selected Topics in Inorganic Chemistry*, 17th Edition, S. Chand & Sons, 2010.

2. J.E. Huheey, E.A. Keiter and R.L. Keiter, *Inorganic Chemistry: Principles of Structure and Reactivity*, 4th Edition, Prentice Hall, 1997

3. F.A. Cotton and G. Wilkinson, C.A. Murillo, and M. Bochmann, *Advanced Inorganic Chemistry*, 6th Edition, John Wiley & Sons, 2009.

4. F. Basolo and R.G. Pearson, *Mechanisms of Inorganic Reactions*, 2nd Edition, Byte/McGraw-Hill, 1965.

5. F. Basolo and R. Johnson, *Coordination Chemistry*, W.A. Benzamin, 1964.

6. D. Banerjea, *Coordination Chemistry*, 3rd Edition, Asian Books, 2009.

7. D. Nichols, *Complexes and First Row Transition Elements*, 1st Edition, Macmillan, 1974.

8. O. Kahn, *Molecular Magnetism*, 1st Edition, Wiley-VCH, 1993.

9. J.R. Gispert, *Coordination Chemistry*, 1st Edition, John Wiley & Sons, 2008.

10. G.A. Lawrance, *Introduction to Coordination Chemistry*, 1st Edition, John Wiley & Sons, 2010.

Referred Books:

1. V. Balzani and V. Carasitti, *Photochemistry of Coordination Compounds*, 1st Edition, Academic Press, 1970.

2. B. Douglas, D.H. McDaniel, and J.J. Alexander, *Concepts and Models of Inorganic Chemistry*, 3rd Edition, John Wiley & Sons, 1994.

3. M. Gerloch and E.C. Constable, *Transition Metal Chemistry: The Valence Shell in d-Block Chemistry*, 1st Edition, VCH Publications, 1994.

4. R.G. Wilkins, *Kinetics and Mechanisms of Reactions of Transition Metal Complexes*, 2nd Edition, VCH Publications, 1991.

5. M.L. Tobe and J. Burgess, *Inorganic Reaction Mechanisms*, Longman, 1999.

6. R.B. Jordan, *Reaction Mechanisms of Inorganic and Organometallic Systems*, 2nd Edition, Oxford University Press, 1991.

7. G. Wulfsberg, *Inorganic Chemistry*, University Science Books, 2000.

8. R.K. Sharma, *Text Book of Coordination Chemistry*, 1st Edition, Discovery Publishing, 2007.

9. R. Gopalan and V. Ramalingam, *Concise Coordination Chemistry*, 1st Edition, Vikas Publishing, 2009.

Code: **CH-413** Subject: **STRUCTURE AND REACTIVITY** Credits: **4 [4-0-0]**

Course Objective:

- To learn the basic principles that govern the structure of molecules.
- To provide a basic knowledge of aromatic concept and a fundamental knowledge of organic reaction mechanisms.

Course Outcome:

- Apply fundamental concepts in chemical structure and bonding, including functional groups, to the rationalization of reactions of organic molecules.

- Apply the concepts of electron pushing to the fundamental organic reaction mechanisms.
- Apply logical thinking to evaluate, analyse and use information from different sources.

Module-I: (10 Hours)

Nature of Bonding in Organic Molecules: Delocalized Chemical Bonding, Conjugation, Cross Conjugation, Resonance, Hyperconjugation, Bonding in Fullerenes, Tautomerism. Aromaticity in Benzenoid and Non-benzenoid Compounds, Alternant and Non-alternant Hydrocarbons, Huckel's Rule, Energy Levels of π-molecular Orbitals of Simple Systems, Annulenes, Anti-aromaticity, Homo-aromaticity. Bonds Weaker than Covalent (Addition compounds), Crown Ether Complexes and Cryptands, Inclusion Compounds, Cyclodextrins, Catenanes and Rotaxanes.

Module-II: (10 Hours)

Reaction Mechanism, Structure, and Reactivity: Types of Mechanisms, Types of Reactions, Thermodynamic and Kinetic Requirements, Kinetic and Thermodynamic Control, Hammond's Postulate, Curtin-Hammett Principle. Potential Energy Diagrams, Transition States and Intermediates, Methods of Determining Mechanisms, Hard and Soft Acids and Bases. The Hammett Equation and Linear Free Energy Relationship, Substituent and Reaction Constants. Taft Equation.

Module-III: (10 Hours)

Reaction Intermediates: Non-classical Carbocations, Generation and Structure of Free Radicals, Carbenes, Nitrenes, Arynes. General Discussion on Isotope Effect, Stereoselective, Regioselective, Stereospecific and Regiospecific Reactions.

Module-IV: (10 Hours)

Aliphatic Nucleophilic Substitution Reactions: S_N2, S_N1, Mixed S_N1 and S_N2, and SET Mechanisms. The Neighboring Group Mechanism, Neighboring Group Participations by Sigma and Pi Bonds. Classical and Non-classical Carbocations, Phenonium Ions, Norbornyl System, Nucleophilic Substitution at Allylic, Aliphatic Trigonal and Vinylic Carbon. Reactivity Effects of Substrate Structure, Attacking Nucleophile, Leaving Group and Reaction Medium, Phase Transfer Catalysis, Ambident Nucleophile, Regioselectivity.

Prescribed Books:

1. J. March, *Advanced organic chemistry: Reactions, Mechanisms, and Structure*, 4th Edition,

John Wiley & Sons, 1992.

2. N.S. Isaacs, *Physical Organic Chemistry*, 2nd Edition, Prentice Hall, 1996.

3. T.H. Lowry and K.S. Richardson, *Mechanism and Theory in Organic Chemistry*, 3rd Edition, Benjamin-Cummings, 1997.

4. R.T. Morrison and R.N. Boyd, *Organic Chemistry*, 6th Edition, Pearson Education, 2009.

5. M.G. Moloney, *Structure and Reactivity in Organic Chemistry*, 1st Edition, Blackwell, 2008.

6. H. Maskill, *Structure and Reactivity in Organic Chemistry*, 1st Edition, Oxford University Press, 1999.

7. S.N. Eğe, *Organic Chemistry: Structure and Reactivity*, 5th Edition, Houghton Mifflin Harcourt, 2003.

Code: **CH-414** Subject: **THERMODYNAMICS & CHEMICAL DYNAMICS** Credits: **4 [4-0-0]**

Course Objective:

- Basic definitions and terminology.
- Special definitions from the thermodynamics point of view.
- Why and how natural processes occur only in one direction unaided.
- Explain concept of property and how it defines state.
- How change of state results in a process, why processes are required to build
- Differences between work producing and work consuming cycles.
- How the concept of entropy forms the basis of explaining how well things are done, how to gauge the quality of energy.

Course Outcome:

- Understand and correctly use thermodynamic terminology.
- Define the concepts of heat, work, and energy.
- Explain fundamental thermodynamic properties.
- Develop the General Energy Equation.
- Derive and discuss the first law of thermodynamics.
- Understand the properties and relationships of thermodynamic fluids.
- Analyse basic thermodynamic cycles.

- Develop and discuss the second law of thermodynamics.

Module-I: (10 Hours)

Classical Thermodynamics: Brief Resume of the Concepts of Laws of Thermodynamics, Free Energy, Chemical Potential and Entropy, Third Law of Thermodynamics and Determination of Entropy, Entropy and Probability, Boltzmann-Planck Equation, Partial Molar Properties (Partial Free Energy, Molar Volume and Molar Heat Content), Their Significance and Determination. Concept of Fugacity and its Determination.

Module-II: (10 Hours)

Statistical Thermodynamics: Concept of Distribution, Thermodynamic Probability and Most Probable Distribution. Ensemble Averaging, Postulates of Ensemble Averaging, Canonical, Grand Canonical and Micro-canonical Ensembles, Corresponding Distribution Laws (Using Lagrange's Method of Undetermined Multipliers), Partition Functions (Translational, Rotational, vibrational and Electronic Partition Functions), Calculation of Thermodynamic Properties in Terms of Partition Function. Applications of Partition Functions. Heat Capacity Behaviour of Solids, Chemical equilibria and Equilibrium Constant in Terms of Partition Functions, Fermi-Dirac Statistics, Distribution Law and Application to Metal. Bose-Einstein Statistics, Distribution Law and Application to Helium.

Module-III: (10 Hours)

Electrochemistry: Interionic Attraction Theory and Debye-Huckel Treatment, Derivation of Onsager Limiting Law and Its Verification and Modification, Activities, Activity Coefficients, Debye-Huckel Treatment, Debye-Huckel-Bronsted Equation, Salt Effect, Determination of Activity Coefficients from Solubility Method, Ion Association, Determination of Thermodynamic Dissociation Constant of Weak Electrolytes by Shedlovsky Method and by EMF Method, Amino Acid, Hydrogen Ion Concentration, Ampholytes, Isoelectric Points.

Module-IV: (10 Hours)

Chemical Kinetics: Theories of Reaction Rates, Collision Theory, Transition State Theory of Uni- and Bimolecular Reactions, Lindemann Mechanism. Arrhenius and Activated Complex, Reaction between Ions, Salt Effect, Steady-State Kinetics, Kinetic and Thermodynamic Concept of Reactions, Dynamic Chain Reactions (H_2+Br_2 Reaction, Pyrolysis of CH_3CHO,

and Decomposition of Ethane).

Fast Reactions: General Feature of Fast Reactions, Study of Fast Reactions by Relaxation, Stopped Flow, Flash Photolysis and NMR Techniques.

Prescribed Books:

1. K.L. Kapoor, *A Textbook of Physical Chemistry, Volume I–IV,* 3rd Edition, Macmillan, 2012.

2. D.N. Bajpai, *Advanced Physical Chemistry*, 2nd Edition, S. Chand & Sons, 2001.

3. P. Atkins and J. de Paula, *Physical Chemistry*, 9th Edition, W. H. Freeman, 2009.

4. S.K. Dogra and S. Dogra, *Physical Chemistry through Problems*, 2nd Edition, New Age International, 2015.

5. D.V.S. Jain and S.P. Jauhar, *Physical Chemistry: Principles and Problems*, 1st Edition, Tata McGraw-Hill, 1988.

6. R. P. Rastogi and R. R. Misra, A*n Introduction to Chemical Thermo-dynamics*, 6th Edition, Vikas Publishing, 2009.

7. S. Glasstone, *Thermodynamics for Chemists*, 1st edition, Affiliated East-West Press, 2008.

8. R. Haase, *Thermodynamics of Irreversible Processes*, 1st Edition, Addison-Wesley, 1968.

9. I. Prigogine, *Introduction to Thermodynamics of Irreversible Processes*, 3rd Edition, Interscience Publishers, 1968.

10. M.C. Gupta, *Statistical Thermodynamics*, 2nd Edition, New Age International, 2007.

11. S. Glasstone, *An Introduction to Electrochemistry*, Maurice Press, 2008.

12. J.O. Bockris and A.K.N. Reddy, *Modern Electrochemistry 1: Ionics*, 2nd Edition, Springer

13. A.A. Frost and R.G. Pearson, *Kinetics and Mechanism,* 2nd Edition, John Wiley and Sons, 1961.

14. K.J. Laidler, *Chemical Kinetics*, 3rd Edition, Pearson Education, 2008.

Referred Books:

1. A. Bahl, B.S. Bahl, and G.D. Tuli, *Essential of Physical Chemistry*, 19th Edition, S. Chand

& Sons, 2012.

2. J. Goodisman, *Electrochemistry: Theoretical Foundations - Quantum and Statistical Mechanics, Thermodynamics, the Solid State*, 1st Edition, John Wiley and Sons, 1987.

3. P.L. Houston, *Chemical Kinetics and Reaction Dynamics*, 1st Edition, Dover Publications, 2006.

4. J.I. Steinfeld, J.S. Francisco, and W.L. Hase, *Chemical Kinetics and Dynamics*, 2nd Edition, Prentice Hall, 1999.

5. M.J. Pilling and P.W. Seakins, *Reaction Kinetics*, 2nd Edition, Oxford University Press, 1996.

6. R.J. Gale, *Spectroelectrochemistry: Theory and Practice*, Plenum Press, 1988.

7. P.C. Hiemenz and R. Rajagopalan, *Principles of Colloids and Surface Chemistry*, 3rd Edition, Marcel Dekker, 1997.

8. A.W. Adamson and A.P. Gast, *Physical Chemistry of Surfaces*, 6th Edition, John Wiley & Sons, 1997.

Code: **CH-415** Subject: **POLYMER CHEMISTRY** Credits: **4 [4-0-0]**

Course Objective:

- The study of polymer chemistry in Master Course (MSc) is to provide a technology-based polymer engineering education. Find your springboard into a future-oriented field of global importance. Which other engineering material has such rich innovative properties.
- To be well prepared for a future in plastics technology you need a good basic knowledge of: Polymer Physics and Rheology, Polymer Materials, Polymer Design , Mould Design, Polymer Processing, Polymer Testing.
- A student with a Master of Science you will be an expert in polymer engineering and in demand as a member of staff in industry or scientific research (PhD).

Course Outcome:

- Polymer Chemistry is a course that introduces students to Polymer science, engineering and technology, where types of polymer, reactions to form polymer, polymerization mechanisms, structures, properties and application of polymer will be taught.
- Provides students with an opportunity to identify different types of polymers in our

surrounding, introduces students to the practical application of polymers.

- Differentiate between natural and man-made polymers, explaining polymerization methods; understand polymerization kinetics and uses of polymers.
- The students will be made to recognise different polymeric materials commonly seen in our environment and their applications.
- Differences between natural and artificial polymers will be made clear to the students.
- The students would be taught chain and step growth polymerization mechanisms for addition and condensation polymer respectively.
- Students will be introduced to kinetic models.
- Fibre forming polymers and biopolymers will be taught.
- Homogeneous and heterogeneous polymerization process shall be discussed with the classes.

Module-I: (10 Hours)

Step Polymerisation: Mechanism of Step Polymerisation, Kinetics of Step Polymerisation, Molecular Weight Control in Linear Polymerisation, Molecular Weight Distribution in Linear Polymerisation, Polyfunctional Step Reaction Polymerisation, Newer Types of Step Polymerisation.

Radical Chain Polymerisation: Nature of Radical Chain Polymerisation, Rate of Radical Chain Polymerisation, Initiation, Molecular Weight, Chain Transfer, Inhibition and Retardation, Determination of Absolute Rate Constants, Energetic Characteristics, Auto Acceleration.

Module-II: (10 Hours)

Emulsion Polymerisation: Qualitative Picture, Quantitative Aspects, and Other Characteristics of Emulsion Polymerisation.

Ionic Chain Polymerisation: Comparison of Radical and Ionic Polymerisations, Kinetics, Cationic Polymerisation of the Carbon–Carbon Double Bond, Anionic Polymerisation of the Carbon–Carbon double Bond, Block Copolymers.

Module-III: (10 Hours)

Chain Copolymerisation: Copolymer Composition, Radical Copolymerisation, Ionic Copolymerisation, Kinetics of Copolymerisation, Applications of Copolymerisation.

Ring Opening Polymerisation: General Characteristics, Cyclic Ethers, Cyclic Amides.

Stereochemistry of Polymerisation: Types of Stereo Isomerism in Polymers, Properties of Stereo Regular Polymers, Forces of Stereoregulations in Alkene Polymerisation, Ziegler-Natta Polymerisation of Non-linear Vinyl Polymers, Kinetics

Module-IV: (10 Hours)

Polymer Structure and Physical Properties: Crystalline Melting Point, Glass Transition, Properties Involving Large Deformations, Properties Involving Small Deformations, Property Requirements and Polymer Utilizations.

Mechanical Behaviour of Polymers: An Energy Balance for Deformation and Fracture, Deformation and Fracture in Polymers, Crack Growth, Cyclic Deformations, Molecular Aspects of Fracture and Healing in Polymers, Behaviour of Adhesives. Conducting Polymers: General Characteristics with Examples, Polymer Molecular Weight, Different Types and Their Determination.

Prescribed Books:

1. F.W. Billmeyer Jr., *Textbook of Polymer Science*, 3rd Edition, John Wiley & Sons, 2008.

2. R.J. Young and P.A. Lovell, *Introduction to Polymers*, 3rd Edition, CRC Press, 2011.

3. H.R. Allcock and F.W. Lampe, *Contemporary Polymer Chemistry*, 2nd Edition, Prentice Hall, 1990.

4. G. Odian, *Principles of Polymerisation*, 4th Edition, John Wiley & Sons, 2004.

5. L. H. Sperling, *Introduction to Physical Polymer Science*, 4th Edition, John Wiley & Sons, 2006.

Referred Books:

1. M.P. Stevens, *Polymer Chemistry: An Introduction*, 3rd Edition, Oxford University Press, 2009.

2. C.E. Carraher Jr., *Introduction to Polymer Chemistry*, 3rd Edition, CRC Press, 2013.

3. P.J. Flory, *Principles of Polymer Chemistry*, 16th Edition, Cornell University Press, 1995.

4. A. Ravve, *Principles of Polymer Chemistry*, 1st Edition, Springer, 1995.

5. P.C. Hiemenz and T.P. Lodge, *Polymer Chemistry*, 2nd Edition, CRC Press, 2007.

6. D.J. Walton and J.P. Lorimer, *Polymers*, 1st Edition, Oxford University Press, 2013.

Code: **CH-416** Subject: **INORGANIC GENERAL PRACTICAL** Credits: **2 [0-0-3]**

Course Objective:

- Qualitative analysis of inorganic salts mixture containing different acid and basic radicals in addition to insoluble mixture will be performed.

Course Outcome:

- Identify different acid and basic radicals present in mixture of inorganic salts.
- Identification of insoluble compounds.
- Identification of different interfering radicals.
- Analysis of transition metals such as Tungstate, Vanadate, Molybdate and Cerium(IV) present in a supplied mixture.

Qualitative Analysis: Analysis of An Inorganic Mixture Containing not More Than 6 Radicals. The Mixture will Include Rare Earth Like Tungstate, Vanadate, Molybdate and Cerium(IV). Insoluble Matters and other Interfering Radicals will also be Included. Organic Radicals are Excluded.

Prescribed Books:

1. G. Svehla, *Vogel's Qualitative Inorganic Analysis*, 7th Edition, Pearson Education, 2009.

Code: **CH-417** Subject: **ORGANIC GENERAL PRACTICAL** Credits: **2 [0-0-3]**

Course Objective:

- Qualitative analysis of unknown organic compounds along with their purification will be performed.

Course Outcome:

- Identification of organic functional groups.
- Separation of organic compounds in a binary mixture using different chromatographic techniques.

- Purification of organic compounds.

Qualitative Analysis: Identification of Unknown Organic Compounds, Separation, Purification and Identification of Compounds of Binary Mixture (both are Solids, One Liquid & One Solid) Using TLC & Column Chromatography, Chemical Tests.

Referred Books:

1. D.J. Pasto, C.R. Johnson, and M.J. Miller, *Experiments and Techniques in Organic Chemistry*, 1st Edition, Prentice Hall, 1991.

2. H. Middleton, *Systematic Qualitative Organic Analysis*, 1st Edition, Edward Arnold, 1939.

3. H.T. Clarke, *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Edition, Edward Arnold, 1931.

4. A.I. Vogel, A.R. Tatchell, B.S. Furniss, A.J. Hannaford, and P.W.G. Smith, *Vogel's Textbook of Practical Organic Chemistry*, 5th Edition, Pearson Education, 1996.

5. K.L. Williamson and K.M. Masters, *Macroscale and Microscale Organic Experiments*, 6th Edition, Cengage Learning, 2010.

6. V.K. Ahluwalia, S. Dhingra, *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, 1st Edition, Universities Press, 2000.

SEMESTER: 2nd

Code: **CH-421** Subject: **ANALYTICAL CHEMISTRY** Credits: **4 [4-0-0]**

Course Objective:

- The course discusses the general theories behind the use of each instrument as well analysis of experimental data.
- This course begins with a review of general chemistry and an introduction to analytical terminology.
- Students will learn terms relevant to the process of measuring chemical compounds, such as sensitivity and detection limit.
- The course continues with a unit on common spectrochemical methods, followed by an extension of these methods in a unit on atomic spectroscopy.
- These methods allow the qualitative and quantitative analysis of compounds of interest.

Students will also learn about chromatography, which is the science behind purifying samples.

- Separations of complex mixtures are achieved through a variety of chromatographic techniques.
- The course concludes with a section on electrochemical methods, examining the interaction between the electrolyte and current of potential during chemical reactions.

Course Outcome:

- Demonstrate a mastery of various methods of expressing concentration.
- Use a linear calibration curve to calculate concentration.
- Describe the various spectrochemical techniques as described within the course.
- Use sample data obtained from spectrochemical techniques to calculate unknown. concentrations or obtain structural information where applicable.
- Describe the various chromatographies described within this course and analyze a given chromatogram.
- Demonstrate an understanding of electrochemistry and the methods used to study the response of an electrolyte through current of potential.

Module-I: (10 Hours)

Reliability of Analytical Data: Errors in Chemical Analysis, Classification of Errors, Significant Figures, Precision And Accuracy, Methods of Expressing Accuracy, Absolute Error and Relative Error, Methods of Expressing Precision, Average Deviation, Standard Deviation, Confidence Limits, Median Value, Range, Coefficient of Variation.

Module-II: (10 Hours)

Sampling in Analysis: Definition, Theory of Sampling, Technique of Sampling, Statistical Criteria of Good Sampling and Required Size, Stratified Sampling, Transition and Storage Samples.

Module-III: (10 Hours)

Solvent Extraction: Basic Principles, Classification of Extraction, Mechanism of Extraction, Extraction Equilibria, Technique of Extraction, Applications in Analytical Chemistry.

Ion Exchange: Synthesis and Characteristics of Ion Exchange, Ion Exchange Equilibria, Technique of Ion Exchange, Application of Ion Exchange for Separation.

Module-IV: (10 Hours)

Ultraviolet and Visible Spectrophotometry: Introduction, Nature of Absorbing Species, Visual Colorimetry, Photoelectric Cell and Filters, Photoelectric Filter Photometry, Errors in Photoelectric Photometry, Spectrophotometry, Working of Spectrophotometer, Simultaneous Spectrophotometry, Differential Spectrophotometry, Reflectance Spectrophotometry, Photometric Titrations, Composition of Colored Complex Sandell's Sensitivity, Relative Concentration and Ringbon's Plot.

Atomic Fluorescence Spectrometry: Theory, Instrumentation and Applications.

X-ray Methods: X-ray Absorption and X-ray Diffraction.

Electron Spectroscopy: Photoelectron Spectroscopy (PES), Auger Electron Spectroscopy (AES), X-ray Photoelectron Spectroscopy or Electron Spectroscopy for Chemical Analysis (ESCA).

Electron Microscopy: Scanning Electron Microscope (SEM), Transmission Electron Microscopy (TEM), Atomic Force Microscopy (AFM).

Prescribed Books:

1. Principles of Instrumental Analysis, by D.A. Skoog, F.J. Holler and T.A. Nieman, 5th Ed., Saunders College publishing 1998.

2. D.A. Skoog, F.J. Holler, and S.R. Crouch, *Principles of Instrumental Analysis*, 6th Edition, Thomson Brooks/Cole, 2006.

3. P. Kissinger and W.R. Heineman, *Laboratory Techniques in Electroanalytical Chemistry*, 2nd Edition, Marcel Dekker, 1996.

4. H.A. Mottola, *Kinetic Aspects of Analytical Chemistry (Chemical Analysis: A Series of Monographs on Analytical Chemistry and Its Applications)*, John Wiley and Sons, 1988.

5. J. Tölgyessy and M. Kyrš, *Radioanalytical Chemistry, Volume I & II*, Ellis Horwood, 1989.

6. D.A. Skoog, D.M. West, F.J. Holler, and S.R. Crouch, *Fundamentals of Analytical Chemistry*, 9th Edition, Cengage Learning, 2014.

7. J. Wang, *Analytical Electrochemistry*, 3rd Edition, John Wiley and Sons, 2006.

Referred Books:

1. R.M. Smith, *Supercritical Fluid Chromatography*, Royal Society of Chemistry, 1988.

2. D.L. Andrews, *Perspectives in Modern Chemical Spectroscopy*, Springer-Verlag, 1990.

3. G.D. Christian, P.K. Dasgupta, and K.A. Schug, *Analytical Chemistry*, 7th Edition, Wiley & Sons, 2013.

4. R.A. Day and A.L. Underwood, *Quantitative Analysis*, 6th Edition, Prentice Hall, 1991.

5. J. Mendham, R.C. Denney, J. D. Barnes, and M.J.K. Thomas, *Vogel's Quantitative Chemical Analysis*, 6th Edition, Prentice Hall, 2000.

Code: **CH-422** Subject: **STEREOCHEMISTRY** Credits: **4 [4-0-0]**

Course Objective:

- To provide knowledge on Stereochemistry, it is the branch of chemistry concerned with the three-dimensional arrangement of atoms and molecules and the effect of this on chemical reactions.

Course Outcome:

- Fundamentals which are required to understand stereochemistry such as Chirality, Fischer projection and R and S notations, threo and erythro nomenclature, E and Z nomenclature, Optical isomerism in biphenyls and allenes.
- Concept of Prostereoisomerism and Assymetric synthesis (including enzymatic and catalytic nexus), Conformation of a few acyclic molecules (alkanes, haloalkanes), Conformation of cyclic systems having one and two sp^2 carbon atoms.
- Knowledge on Molecular dissymmetry and chiroptical properties, linearly and circularly polarised lights, circular birefringence and circular dicroism, ORD, Plane curves, Cotton effect.

Module-I: (10 Hours)

Chirality, Fischer Projection and R and S Notations, Threo and Erythro Nomenclature, E and Z Nomenclature, Optical Isomerism in Biphenyls and Allenes, Concept of Prostereoisomerism and Assymetric Synthesis (Including Enzymatic and Catalytic Nexus),

Conformation of Acyclic Molecules (Alkanes, Haloalkanes), Conformation of Cyclic Systems Having One and Two sp^2 Carbon Atoms.

Module-II: (10 Hours)

Dynamic Stereochemistry: Conformation and Reactivity, Selection of Substrates, Quantitative Correlation between Conformation and Reactivity, (Weinstein-Eliel Equations and Curtin-Hammett Principles), Conformational Effects on Stability and Reactivity in Acyclic Compounds (Ionic Elimination, Intramolecular Rearrangements, NGP) and in Cyclic Systems (Nucleophilic Substitution Reaction at Ring Carbon, Formation and Cleavage of Epoxide Rings, Addition Reactions to Double Bonds, Elimination Reactions).

Module-III: (10 Hours)

Molecular Dissymmetry and Chiroptical Properties, Linearly and Circularly Polarised Lights, Circular Birefringence and Circular Dichroism, ORD, Plane Curves, Cotton Effect, Rotatory Dispersion of Ketones, the Axial Haloketone Rule, the Octane Rule. Helicity Rule, Lowe's Rule, Empirical Rule Involving the Benzene Chromophore.

Prescribed Books:

1. D. Nasipuri, *Stereochemistry of Organic Compounds: Principles and Applications*, 4th Edition, New Academic Science, 2012.

2. P.S. Kalsi, *Stereochemistry: Conformation and Mechanism*, 7th Edition, New Age International, 2009.

3. E.L. Eliel and S.H. Wilen, *Stereochemistry of Organic Compounds*, John Wiley and Sons, 1994.

4. E. Eliel, *Stereochemistry of Carbon Compounds*, 1st Edition, Tata McGraw Hill Education, 2008

5. D.G. Morris, *Stereochemistry*, Royal Society of Chemistry, 1st Edition, 2002.

6. M. North, *Principles and Applications of Stereochemistry*, 1st Edition, Stanley Thornes, 1998.

7. K. Mislow, *Introduction to Stereochemistry*, 3rd Edition, Dover Publications, 2002.

Code: **CH-423** Subject: **SPECTROSCOPY-I** Credits: **4 [4-0-0]**

Course Objective:

- The objective of the subject is to provide the knowledge of spectroscopy with emphasis on electronic, rotation, vibration, Raman spectroscopy, Mossbauer spectroscopy and their applications.

Course Outcome:

- How light interacts with matter and electromagnetic spectrum.
- Microwave, Infrared, Rotational-Vibrational Spectra and their applications for chemical analysis.
- Qualitative description about principle of Raman spectroscopy and its application in chemical analysis.
- Electronic spectroscopy of different elements and simple molecules.
- Mossbauer spectroscopy and its application.

Module-I: (10 Hours)

Atomic Spectroscopy: Electromagnetic Spectrum, General Discussion on Various Molecular Excitation Processes, Spectra of Hydrogen and Hydrogen Like Atoms, Alkali Metals Spectra, L-S Coupling, Term Symbols, Space Quantization, Zeeman Effect, Stark Effect, Paschen-Back Effect.

Module-II: (10 Hours)

Vibrational and Rotational Spectroscopy: Molecular Spectra of Diatomic Gases, Classification of Molecules, Rotational Spectra, Vibrational Spectra, Vibrational-Rotational Spectra, P, Q and R Branches.

Module-III: (10 Hours)

Raman Spectroscopy: Theory of Raman Spectra, Rotational Raman Spectra, Vibrational Raman Spectra, Rotational-Vibrational Raman Spectra, comparison with IR spectra.

Module-IV: (10 Hours)

Photoelectron Spectroscopy: Basic Principles, Photoelectric effect, Ionization Process, Koopman's Theorem. Photoelectron Spectra of Simple Molecules, ESCA, Chemical Information from ESCA. Auger Electron Spectroscopy – Basic Idea.

Mossbauer Spectroscopy: Principles of Mossbauer Spectroscopy, Experimental Methods, Theoretical Aspects, Quadrupole Splitting, Magnetic Hyperfine Interaction.

Prescribed Books:

1. C.N. Banwell and E.M. McCash, *Fundamentals for Molecular Spectroscopy*, 5th Edition, Tata McGraw Hill Education, 2013.

2. J.M. Hollas, *Modern Spectroscopy*, 4th Edition, John Wiley & Sons, 2004.

3. H. Windawi and F.F.L. Ho, *Applied Electron Spectroscopy for Chemical Analysis*, John Wiley & Sons, 1982.

4. R.V. Parish. *NMR, NQR, EPR and Mössbauer Spectroscopy in Inorganic Chemistry*, Ellis Horwood, 1990.

5. R.S. Drago, *Physical Methods for Chemists*, 2nd Edition, Saunders College Publishing, 1992.

6. G.M. Barrow, *Introduction to Molecular Spectroscopy*, 1st Edition, McGraw Hill, 1962.

7. R. Chang, *Basic Principles of Spectroscopy*, 1st Edition, McGraw Hill, 1971.

8. H.H. Jaffe and M. Orchin, *Theory and Applications of Ultraviolet Spectroscopy*, 1st Edition, John Wiley & Sons, 1966.

9. P. K. Ghosh: *Introduction to Photoelectron Spectroscopy*, John Wiley & Sons, 1983.

10. A. Carrington and A.D. McLachlan, *Introduction to Magnetic Resonance*, 1st Edition, Harper & Row, 1967.

Code: **CH-424** Subject: **ORGANIC REACTION MECHANISM** Credits: **4 [4-0-0]**

Course Objective:

- To provide an understanding of Organic reaction mechanisms for future studies in chemistry and allied subjects.
- To provide students with the tools to describe and work out reaction mechanisms using the 'curly arrow' notation.

Course Outcome:

- Design experiments to probe mechanisms.

- Combine reactions to achieve simple synthesis of target molecules.

Module-I: (10 Hours)

Alipahatic Electrophilic Substitution Mechanism: S_E^1, S_E^2 and S_E^i Mechanisms, Effect of Substrate, Leaving Group and Solvent, Reactions (Hydrogen Exchange, Migration of Double Bonds, Keto-Enol Tautomerism, Halogenation, Aliphatic Diazonium Coupling, Stork-Enamine Reaction).

Aromatic Electrophilic Substitution Mechanism: Structure Reactivity, Relationship in Mono-substituted Benzene, Orientation in Benzene Ring with More than One Substituent, Vilsmeier-Haack Reaction, Pechmann Reaction.

Aromatic Nucleophilic Substitution Mechanism: Introduction, Mechanisms of Aromatic Nucleophilic Substitutions (S_NAr, S_N^1, Aryne), Effect of Substrates, Leaving Groups, and Nucleophile, Reactions: Nucleophilic Displacement in Areno-diazonium Salts by Different Nucleophiles, Chichibabin Reaction.

Module-II: (10 Hours)

Addition to Carbon-Carbon Multiple Bonds: Electrophilic, Nucleophilic and Free Radical Addition, Orientation and Reactivity, Addition to Cyclopropanes, Reactions: Hydroboration, Michael Reaction, Sharpless Asymmetric Epoxidation.

Addition to Carbon-Heteroatom Multiple Bonds: Mechanism and Reactivity, Reactions: Mannich Reaction, $LiAlH_4$ Reduction of Carbonyl Compounds, Acids, Esters, Nitriles, Addition of Grignard Reagents, Reformatsky Reaction, Aldol Condensation, Knoevenagel Condensation, Perkin Reaction, Tollens Reaction, Wittig Reaction, Prins Reaction, Benzoin Condensation.

Module-III: (10 Hours)

Elimination Mechanism: E^1, E^2, E^1_{CB} Mechanisms, Orientation, Effect of Substrate, Base, Leaving Group and Medium, Orientation of Double Bond, Saytzeff and Hoffman Rules, Pyrolytic Elimination Reaction, Oxidative Elimination (Oxidation of Alcohol by Chromium, Moffatt Oxidation). Reactions: Cleavage of Quaternary Ammonium Hydroxides, Chugaev Reaction, Shapiro Reaction.

Module-IV: (10 Hours)

General Mechanistic Considerations: Nature of Migration, Migratory Aptitude, Memory Effects, Detailed Study of the Following Rearrangements: Wagner-Meerwein, Favorskii, Arndt-Eistert Synthesis, Neber, Hofmann, Baeyer-Villiger, Sommelet-Hauser Rearrangement.

Prescribed Books:

1. J. March, *Advanced organic chemistry: Reactions, Mechanisms, and Structure*, 4th Edition, John Wiley & Sons, 1992.

2. P.S. Kalsi, *Organic Reactions and Their Mechanisms*, 3rd Edition, New Age International, 2009.

3. R. K. Bansal, *Organic Reaction Mechanisms*, 3rd Edition, Tata McGraw Hill, 2006.

4. N.S. Isaacs, *Physical Organic Chemistry*, 2nd Edition, Prentice Hall, 1996.

5. R.B. Grossman, *The Art of Writing Reasonable Organic Reaction Mechanisms*, 2nd Edition, Springer, 2003.

6. R. Bruckner and M. Harmata, *Organic Mechanisms: Reactions, Stereochemistry and Synthesis*, Springer, 2010.

7. R. Bruckner, *Advanced Organic Chemistry: Reaction Mechanisms*, Academic Press, 2002.

8. P. Sykes, *A Guidebook to Mechanism in Organic Chemistry*, 6th Edition, Pearson Education, 2009.

9. A. Miller and P.H. Solomon, *Writing Reaction Mechanisms in Organic Chemistry*, 2nd Edition, Academic Press, 2000.

Code: **CH-425** Subject: **SURFACE CHEMISTRY AND NUCLEAR CHEMISTRY** Credits: **4 [4-0-0]**

Course Objective:

- The course deals with important principles and phenomena related to colloid systems and nuclear systems.
- These subjects are fundamental to the understanding and design of a range of processes like e.g. adhesion, lubrication, cleaning, oil recovery, water and air purification, nuclear processes.
- Furthermore, the subjects are essential for the application and design of a number of

chemical products like e.g. paint, glue, detergents, cosmetics, drugs and foods.

- Finally, the course offers understanding of several naturally occurring phenomena like e.g. fog, rain drops, the capillary effect, the red sunset, the blue sky, the rainbow, nuclear fission fusion processes, radioactive nature of substances.

Course Outcome:

- Evaluate and describe colloidal nano-technological and chemical systems, processes and products.
- Use different theories to calculate surface and interfaces tensions and use this to estimate e.g. wetting and other system characteristics.
- Identify mechanisms for adhesion between surfaces and materials and use different methods to estimate this.
- Describe the most important and fundamental theories in surface chemistry.
- Explain micellation of surfactants, know how to measure this and calculate dependencies of salt concentration, system temperature and surfactant chain length.
- Compare and understand adsorption in gas-liquid and solid-liquid surfaces and perform quantitative adsorption calculations.
- Calculate molar mass and molecular shape of colloid particles and polymers based on experimental data.
- Describe the interactions between colloidal particles and identify similarities and differences for the governing molecular forces and interactions.
- Explain the most important parameters for the theories of colloidal interaction and perform calculations using the theories.
- Describe the conditions for stability of colloidal systems and discuss and compare different mechanisms for stabilization.
- Describe mechanisms for stabilization of emulsions and foam, and design emulsions and foam by using various semi-empirical methods.
- Calculate mass differences and binding energies for nuclei and nuclear reactions; use this information to identify species that can undergo fusion or fission.

- Calculate kinetic parameters for nuclear decay including applications to radioactive dating.
- Balance nuclear reactions identifying which nuclear particles are involved in the process and use the neutron to proton ratio to predict the possible types of nuclear decay an isotope could undergo.

Module-I: (10 Hours)

Phase Rule and Catalysis: Derivation of Phase Rule, Brief Concept on One and Two Component System, Application of Phase Rule to Three Component Systems of Both Solids and Liquids.

Kinetics of Catalytic Reactions: Acid-Base Catalysis, Enzyme Catalysis, Heterogeneous Catalysis.

Module-II: (10 Hours)

Adsorption: Surface Tension, Capillary Action, Adsorption, Types of Adsorption, Gibbs Adsorption Isotherm, Freundlich's Adsorption Isotherm, Langmuir's Adsorption Isotherm and Its Limitations, BET Adsorption Isotherm and Its Applications, Heat of Adsorption, Estimation of Surface Areas of Solids from Solution Adsorption Studies.

Module-III: (10 Hours)

Micelles: Concepts on Micelle, Surface Active Agents, Classification of Surface Active Agents, Micellization, Hydrophobic Interaction, Critical Micellar Concentration (CMC), Kraft Temperature, Factors Affecting the CMC of Surfactants, Counter Ion Binding to Micelles, Thermodynamics of Micellazation, Phase Separation and Mass Action Models, Solubilization, Microemulsion, Reverse Micelles.

Module-IV: (10 Hours)

Nuclear Chemistry: Classification of Nuclides, Nuclear Stability, Binding Energy and Nuclear Models. Characteristics of Radioactive Decay, Decay Kinetics, Parent-Daughter Decay Growth Relationships, Detection and Measurement of Radioactivity, Advances in the Solid and Liquid Scintillation Counting Techniques, Methods for the Determination of Half Life Period of Single and Mixed Radionuclides. Nuclear Fission, Nuclear Fuels and Nuclear Reactors, Nuclear Fuel Reprocessing, Fast Breeder Reactors, Radiological Safety Aspects and Radioactive Waste Managements. Interaction of Radiation with Matter, Effect of Ionizing/Non-ionizing Radiations on Water, Aqueous Solutions and Organic Compounds,

Radiation Dosimetry. Preparation and Separation of Radioactive Isotopes, Application of Radioisotopes and Radiations in Various Fields, Isotopic Dilution Techniques, Neutron Activation Analysis and Its Applications.

Prescribed Books:

1. K.L. Kapoor, *A Textbook of Physical Chemistry, Volume I–IV*, 3rd Edition, Macmillan, 2012.

2. D.N. Bajpai, *Advanced Physical Chemistry*, 2nd Edition, S. Chand & Sons, 2001.

3. A. Bahl, B.S. Bahl, and G.D. Tuli, *Essential of Physical Chemistry*, 19th Edition, S. Chand & Sons, 2012.

4. S.K. Dogra and S. Dogra, *Physical Chemistry through Problems*, 2nd Edition, New Age International, 2015.

5. D.V.S. Jain and S.P. Jauhar, *Physical Chemistry: Principles and Problems*, 1st Edition, Tata McGraw-Hill, 1988.

6. G. Friedlander, J.W. Kennedy, E.S. Macias, and J.M. Miller, *Nuclear and Radiochemistry*, 3rd Edition, John Wiley & Sons, 1981.

7. B.G. Harvey, *Introduction to Nuclear Physics & Chemistry*, Prentice Hall, 1969.

8. R.T. Overman, *Basic concept of Nuclear Chemistry*, Chapman & Hall, 1965.

9. N. Nesmeyanov, *Radiochemistry*, Mir Publication, 1974.

10. J.W.T. Spinks and R.J. Woods, *An Introduction to Radiation Chemistry*, 3rd Edition, John Wiley & Sons, 1990.

11. H.J. Arnikar, *Essentials of Nuclear Chemistry*, 4th Edition, New Age International, 1995.

12. G. Choppin, J.-O. Liljenzin, J. Rydberg, and C. Ekberg, *Radiochemistry and Nuclear Chemistry*, 4th Edition, Elsevier, 2013.

13. W.D. Loveland, D.J. Morrissey, and G.T. Seaborg, *Modern Nuclear Chemistry*, 1st Edition, John Wiley & Sons, 2006.

Code: **CH-426** Subject: **PHYSICAL GENERAL PRACTICAL** Credits: **2 [0-0-3]**

(Any Six from the Following)

Course Objective:

- To perform Conductometric, Potentiometric and spectrometric experiments for the analysis of different chemical reactions.

Course Outcome:

- Conductometric titration of a mixture of acid and bases of different strengths.
- Potentiometric titration of a mixture of acids and bases of different strengths.
- Determination of unknown concentration of a solution spectro-photometrically.
- Determination of rate constant of hydrolysis of ester titrometrically.
- Study of complex formation.
- Study of inversion of cane sugar in acid medium by polarimetry.

1. Determination of Ionization Constants of Weak Acids and Verification of Oswald's Dilution Law.

2. Verification of Onsager's Limiting Law.

3. Conductometric Titration of a Mixture of HCl + CH_3COOH with NaOH.

4. Determination of Solubility Product of $BaSO_4$.

5. Potentiometric Titration of Strong Acid with Strong Base.

6. Verification of Beer's Lambert Law and Unknown Concentration Determination.

7. Verification of Additivity Rule Spectrophotometrically.

8. Determination of Temperature Coefficient and Energy of Activation of Hydrolysis of Ethyl Acetate.

9. To Determine the Rate Constant of Base Hydrolysis of Ester Titrometrically.

10. To Study the Complex Formation Between Ammonia and Cu^{+2}.

11. To Study of an Equilibrium $KI + I_2 = KI_3$.

12. To Study the Simultaneous Equilibria in Benzoic Acid-benzene Water System.

13. Determination of Unknown Dextrose Solution by Polarimetry.

14. Study of Inversion of Cane Sugar in Acid Medium by Polarimetry.

Prescribed Books:

1. R.C. Das and B. Behera, *Experimental Physical Chemistry*, 1st Edition, Tata McGraw-Hill, 1984.

2. P.S. Sindhu, *Practical's in Physical Chemistry: A Modern Approach*, 1st Edition, Macmillan, 2006.

Code: **CH-427** Subject: **ANALYTICAL CHEMISTRY PRACTICAL** Credits: **2 [0-0-3]**

Course Objective:

- To perform quantitative analysis of Ores/alloys along with the determination of complex composition and separation of different metal ions using ion-exchange method.

Course Outcome:

- Determination of complex composition and stability constant of a complex by Job's method spectro-photometrically
- Determination of total cation concentration and separation of different metal ions using cation exchange resin.
- Quantitative analysis of cement/dolomite/brass.
- Determination of half-cell potential of Cd(II) ion in KCl solution and estimation of Cd(II) ion in unknown solution by polarography.

Spectrophotometry:

1. Determination of Composition of a Complex by Job's Method.

2. Determination of Stability Constant of a Complex.

Ion Exchange Methods:

1. Determination of Total Cation Concentration in a Given Sample of Water.

2. Separation of Ni(II) & Co(II) in Cation Exchange Column Using Citrate buffer as a Chelating Agent.

Polarography:

1. Determination of Half Wave Potential of Cd(II) Ion in KCl Solution and Estimation of Cd Ion in Unknown Solution Containing 0.1M KCl.

Quantitative Analysis of Ores and Alloys:

1. Analysis of Cement/Dolomite/Brass.

Prescribed Books:

1. R.C. Das and B. Behera, *Experimental Physical Chemistry*, 1st Edition, Tata McGraw-Hill, 1984.

2. O.P. Vermani and A.K. Narula, *Applied Chemistry: Theory and Practice*, 2nd Edition, New Age International, 2005.

3. P.K. Kar, S. Dash, and B. Mishra, *B. Tech. Practical Chemistry*, 1st Edition, Kalyani Publishers, 2005.

SEMESTER: 3rd

Code: **CH-511** Subject: **ORGANOMETALLICS** Credits: **4 [4-0-0]**

Course Objective:

- Introduction to transition metal-mediated organic chemistry.
- Organometallic mechanisms will be discussed in the context of homogeneous catalytic systems currently being used in organic synthesis (e.g. cross coupling, olefin metathesis, asymmetric hydrogenation, etc.).
- Emphasis will be placed on developing an understanding of the properties of transition metal complexes and their interactions with organic substrates that promote chemical transformations.

Couse Outcome:

- Have a good overview of the fundamental principles of organo-transition-metal chemistry and know how metals and ligands affect chemical properties.
- Be able to use knowledge about structure and bonding issues to understand the stability and reactivity of simple organometallic complexes.
- Have insight into the use of modern methods to characterize organometallic compounds.
- Understand fundamental reaction types and mechanisms, and how to combine these to understand efficient catalytic processes.

- Know important applications of organometallic homogeneous catalysis in the production of large-scale (bulk) and smaller-scale (fine chemicals) production.

Module-I: (10 Hours)

Compounds of Transition Metal Carbon Multiple Bonds (Alkylidines, Alkylidynes, Low Valent Carbenes and Carbines- Synthesis Nature Bond Structural Characteristics, Nucleophilic and Electrophilc Reactions on the Ligands Role in Organic Synthesis

Module-II: (10 Hours)

Transition Metal Pi Complexes with Unsaturated Organic Molecules (Alkenes, Alkynes and Allyl, Diene Complex) Preparation, Properties, Nature of Bonding and Structural Features

Module-III: (10 Hours)

Transition Metal Pi Complexes with Unsaturated Organic Molecules (Dienyl, Arene and Trienyl Complexes) Preparation, Properties, Nature of Bonding and Structural Features. Important Reactions Relating to Nucleophilic and Electrophilic Attack on Ligands and to Organic Synthesis.

Module-IV: (10 Hours)

Organometallic compounds and homogeneous catalytic reactions: Coordinating Unsaturation, Acid Base Behaviour of Metal Complexes, Oxidative Addition Reaction, Stereochemistry and Mechanism of Addition, Insertion Reactions, Intra Molecular Hydrogen Transfer, Isomerization, Hydrogenation of Alkenes, Hydroformylation, Zigler-Natta Polymerization, Alkene Metathesis.

Prescribed Books:

1. J.P. Collman, L.S. Hegedus, J.R. Norton, and R.C. Finke, *Principles and Applications of Organotransition Metal Chemistry*, 2nd Edition, University Science Books, 1987.

2. R.H. Crabtree, *The Organometallic Chemistry of the Transition Metals*, 6th Edition, John Wiley & Sons, 2014.

3. A.J. Pearson, *Metallo-Organic Chemistry*, 1st Edition, John Wiley & Sons, 1985.

4. R.C. Mehrotra and A. Singh, *Organometallic Chemistry*, 2nd Edition, New Age International, 2014.

5. B.D. Gupta and A.J. Elias, *Basic Organometallic Chemistry: Concepts, Syntheses, and*

Applications of Transition Metals, 1st Edition, CRC Press, 2010.

6. J.F. Hartwig, *Organotransition Metal Chemistry: From Bonding to Catalysis*, 1st Edition, University Science Books, 2010.

7. D. Astruc, *Organometallic Chemistry and Catalysis*, 1st Edition, Springer, 2007.

8. G.O. Spessard and G.L. Miessler, *Organometallic Chemistry*, 3rd Edition, Oxford University Press, 2015.

Code: **CH-512** Subject: **PHOTOCHEMISTRY & PERICYCLIC REACTION** Credits: **4 [4-0-0]**

Course Objective:

- The course will involve a discussion of molecular organic photochemistry and pericyclic reactions.
- Fundamental principles of photochemistry including photochemical reactions and pericyclic reactions along with their applications will be discussed.

Course Outcome:

- Understand detailed mechanism about first order photochemical processes including luminescence such as Fluorescence and phosphorescence.
- Understand detailed mechanistic investigations of photochemical reactions such as dissociation, reduction, cycloaddition etc.
- Understand different pericyclic reactions and their application in organic synthesis.

Module-I: (10 Hours)

First Order Photochemical Processes: Light Absorption, Fluorescence and Phosphorescence.

Photo Reactions: Dissociation, Reduction, Isomerisation, Cycloaddition, Paterno-Buchi Reaction, Norrish type I and II Reactions, Di-Pi-Methane Reaction, Photochemistry of Arenes.

Module-II: (10 Hours)

Pericyclic Reactions: Molecular Orbital Symmetry, Frontier Orbitals of Ethylene, 1,3-Butadiene, 1,3,5-Hexatriene and Allyl System. Classification of Pericyclic Reactions. Woodward-Hoffmann Correlation Diagrams. FMO and Aromatic Transition State Concept.

Electrocyclic Reactions: Con- and Dis-rotatory Motions, 4n, 4n+2 and Allyl Systems. ***Cycloaddition Reactions:*** Supra- and Antara-facial Additions, 4n and 4n+2 Systems, 2+2 Additions of Ketenes, 1,3 Dipolar Cycloadditions and Cheletropic Reactions.

Module-III: (10 Hours)

Sigmatropic Rearrangements: Supra and Antara-facial Shifts of H, Sigmatropic Shift of Carbon Moieties, 3,3- and 5,5- Sigmatropic Rearrangements, Claisen, Cope and Aza-Cope Rearrangements. Fluxional Tautomerism, Ene Reaction.

Module-IV: (10 Hours)

Reagents in Organic Synthesis: Gilman's Reagent, Lithium Dimethyl Cuprate, Lithium Diisopropyl Amide, DCC, 1,3-Dithiane, Trimethyl Sillyl Iodide, Tri-n-Butyl Tin Hydride, Osmium Tetroxide, Selenium Dioxide, Phase Transfer Catalysis (Crown Ether, Merrifield Resin, Wilkinson's Catalyst), Dichloro Dicyano Benzoquinone (DDQ).

Prescribed Books:

1. J. Singh and J. Singh, *Photochemistry and Pericyclic Reaction*, 3rd Edition, New Age International, 2009.

2. C.E. Wayne and R.P. Wayne, *Photochemistry*, 1st Edition Oxford University Press, 1996.

3. S. Sankararaman, *Pericyclic reactions - A Textbook: Reactions, Applications and Theory*, 1st Edition, John wiley & sons, 2005.

4. I. Fleming, *Pericyclic Reactions*, 2nd Edition, Oxford University Press, 2015.

5. G.B. Gill and M.R. Wills, *Pericyclic Reactions*, 1st Edition, Springer, 1974.

6. S. Kumar, V. Kumar, and S.P. Singh, *Pericyclic Reactions: A Mechanistic and Problem-Solving Approach*, 1st Edition, Elsevier, 2016.

7. R.B. Woodward and R. Hoffmann, *The Conservation of Orbital Symmetry*, 2nd Edition, Verlag Chemie/Academic Press, 1970.

8. T.L. Gilchrist and R.C. Storr, *Organic Reactions and Orbital Symmetry*, 2nd Edition, Cambridge University Press, 1979.

9. T.H. Lowry and K.S. Richardson, *Mechanism and Theory in Organic Chemistry*, 3rd Edition, Harper & Row, 1987.

10. J.D. Roberts and M.C. Caserio, *Basic Principles of Organic Chemistry*, 1st Edition, W.A. Benjamin, 1965.

11. B.P. Mundy, M.G. Ellerd, and F.G. Favaloro Jr., *Name Reactions and Reagents in Organic Synthesis*, 2nd Edition, John Wiley & Sons, 2005.

12. M.B. Smith, *Fiesers' Reagents for Organic Synthesis: Collective Index for Volumes 1-22*, 1st Edition, John Wiley & Sons, 2005.

Code: **CH-513** Subject: **SPECTROSCOPY-II** Credits: **4 [4-0-0]**

Course Objective:

- To introduce the application of different spectroscopic techniques like ESR, UV, IR, NMR and Mass spectroscopy for analysis of organic compounds.

Course Outcome:

- Understand the basic principle, instrumentation and application of ESR, IR, NMR and Mass spectroscopy in the elucidation of structure of organic compounds.
- Deduce organic structures involving UV, IR, NMR and Mass Spectroscopy data.
- Analyse the spectra of different organic compounds.
- Study the spectra of compounds and propose structures for compounds.
- Study spectra of compounds, determine functional groups and write structures.

Module-I: (10 Hours)

Electron Spin Resonance (ESR) Spectroscopy: Basic Principles, Zero Field Splitting and Kramer's Degeneracy, Factors Affecting the 'g' Value. Isotropic and Anisotropic Hyperfine Coupling Constants, Spin Hamiltonian, Spin Densities and McConnell Relationship, Measurement Techniques, Applications.

IR Spectroscopy: Application in Elucidation of Structure of Organic Molecules.

Module-II: (10 Hours)

Nuclear Magnetic Resonance (NMR) Spectroscopy: General Introduction and Definition, Chemical Shift, Spin-Spin Interaction, Shielding Mechanism, Mechanism of Measurement, Chemical Shift Values and Correlation for Protons Bonded to Carbon (Aliphatic, Olefinic, Aldehydic, and Aromatic Compounds) and Other Nuclei (Alcohols, Phenols, Enols,

Carboxylic Acids, Amines, Amides, and Mercapto), Chemical Exchange, Effect of Deuterium, Complex Spin-Spin Interaction Between Two, Three, Four and Five Nuclei (First Order Spectra), Virtual Coupling, Stereochemistry, Hindered Rotation, Karplus Curve-Variation of Coupling Constant with Dihedral Angle, Simplification of Complex Spectra, Nuclear Magnetic Double Resonance, Contact Shift Reagents, Solvent Effects, Fourier Transform Technique, Nuclear Overhauser (NOE). Resonance of Other Nuclei.

Module-III: (10 Hours)

Carbon-13 NMR Spectroscopy: General Considerations, Chemical Shift (Aliphatic, Olefinic, Alkyne, Aromatic, Heteroaromatic and Carbonyl Carbon), Coupling Constants. Two Dimension NMR Spectroscopy – COSY, NOESY, DEPT, APT and Inadequate Techniques

Nuclear Quadrupole Resonance (NQR) Spectroscopy: Quadrupole Nuclei, Quadrupole Moments, Electric Field Gradient, Coupling Constant, Splitting, Applications.

Module-IV: (10 Hours)

Mass Spectrometry: Introduction, Mass Spectrum, Determination of Molecular Formulae, Parent Peak, Base Peak, Use of Molecular Fragmentation, Mass Spectra of Some Classes of Compounds (Hydrocarbons, Alcohols, Phenols, Ketones, Aldehydes, Acids and Esters).

Problems Involving UV, IR, NMR and Mass Spectroscopy.

Prescribed Books:

1. I.L. Finar, *Organic Chemistry, Volume II*, 6th Edition, Pearson Education, 2002.

2. R.M. Silverstein, F.X. Webster, D.J. Kiemle, and D.L. Bryce, *Spectrometric Identification of Organic Compounds*, 8th Edition, John Wiley & Sons, 2014.

3. A. Lund, S. Shimada, and M. Shiotani, Principles and Applications of ESR Spectroscopy, 1st Edition, Springer, 2011.

4. M. Balci, *Basic ^{1}H- and ^{13}C -NMR Spectroscopy*, 1st Edition, Elsevier, 2005.

5. J.W. Akitt and B.E. Mann, *NMR and Chemistry: An Introduction to Modern NMR Spectroscopy*, 4th Edition, Stanley Thornes, 2000.

6. R.V. Parish. *NMR, NQR, EPR and Mössbauer Spectroscopy in Inorganic Chemistry*, Ellis Horwood, 1990.

7. E. de Hoffmann and V. Stroobant, *Mass Spectrometry: Principles and Applications*, 3rd

Edition, John Wiley & Sons, 2007.

Code: **CH-514** Subject: **ENVIRONMENTAL CHEMISTRY** Credits: **4 [4-0-0]**

Course Objective:

- To prepared trend manpower in chemistry to serve the country in the field of science and technology, higher research in country.
- In addition, the manpower can work for the growth of nation in the field of pharmaceutical lab, Quality control lab, defence and other.

Course Outcome:

- The course is designed in such a way that it will cover entire field of chemistry and full fill the give of basic knowledge of students in chemistry.

Module-I: (10 Hours)

Air Pollution: Air Pollutants, Air Quality Standards, Production, Fate, Effects and Control of Gaseous Pollutants, Oxides of Carbon, Nitrogen and Sulphur, Organic Air Pollutants, Photochemical Reactions, Photochemical Smog, Greenhouse Effect, Climate Change, Global warming, Acid Rain and Ozone Depletion.

Water Pollution: Water World, Source of Water**,** Water Quality, Water Pollutants (Inorganic and Organic), Sources, Fate, Effects and Controlling Measures, Chemical Speciation, Pollution by Radionuclides, Biochemical Oxygen Demand, Chemical Oxygen Demand, Eutrophication, Biodegradation of Pollutants.

Module-II: (10 Hours)

Water Treatment: Treatment of Water for Drinking, Electro-dialysis, Ion Exchange, Reverse Osmosis, Desalination Processes, Removal of Iron, Manganese, Phosphorous, Calcium and Nitrogen and Treatment of Water for Industrial Purposes, Sedimentation, Coagulation, Flocculation, Filtration, Adsorption, Disinfection of Water, Sewage Treatment (Physical and Chemical Methods), Health Effects of Drinking Water Treatment Technologies, Impact of Detergents, Pesticides and Other Additives on Sewage Treatment.

Module-III: (10 Hours)

Oils in Fresh & Marine Water: Sources of Oil Pollution, Chemistry and Fate of Hydrocarbons Oil in Run Off and Ground Water, Biodegradation, Effect on Aquatic

Organisms and Communities, Treatment and Disposal Technology.

Soil Pollution: Soil Pollutants (Inorganic, Organic, Pesticides, Radionuclides), Sources and Effects on Nature and Properties of Soil, Crops, Plants and Terrestrial Animals.

Module-IV: (10 Hours)

Hazardous Wastes: Nature and Sources of Hazardous Wastes, Classification, Characteristics and Constituents, Transport and Effects, Treatment by Physical and Chemical Methods, Thermal Treatment Methods, Biodegradation of Wastes, Disposal of Hazardous Wastes. Waste Management and Industrial by Products, Natural Hazards and Management, Control of Subsurface Migration of Hazardous Waste, Biomedical Waste Management, Environmental Management and Sustainable Development.

Prescribed Books:

1. S.E. Manahan, *Environmental Chemistry*, 9th Edition, CRC Press, 2010.

2. A.K. De, *Environmental Chemistry*, 2nd Edition, New Age International, 2006.

3. J.H. Vandermeulen and S.E. Hrudey, *Oil in Freshwater: Chemistry, Biology, Countermeasure Technology*, 1st edition, Pergamon Press, 1987.

4. M. Lippmann and R.B. Schlesinger, *Chemical Contamination in the Human Environment*, 1st Edition, Oxford University Press, 1979.

5. H.M. Dix, *Environmental Pollution: Atmosphere Land Water and Noise*, 1st Edition, John Wiley & Sons, 1981.

6. J.C. Crittenden, R.R. Trussell, D.W. Hand, K.J. Howe, G. Tchobanoglous, *MWH's Water Treatment: Principles and Design*, 3rd Edition, John Wiley & Sons, 2012.

7. R.M. Harrison, *Pollution: Causes, Effects and Control*, 5th Edition, Royal Society of Chemistry, 2014.

8. C. Binnie, M. Kimber, and G. Smethurst, *Basic Water Treatment*, 3rd Edition, Thomas Telford, 2003.

9. G.W. Dawson and B.W. Mercer, *Hazardous Waste Management*, 1st edition, John Wiley & Sons, 1986.

10. M.D. LaGrega, P.L. Buckingham, and J.C. Evans, *Hazardous Waste Management*, 2nd

Edition, Waveland Press, 2010.

Referred Books:

1. L.K. Wang, Y.-T. Hung, and N.K. Shammas *Handbook of Advanced Industrial and Hazardous Wastes Treatment*, 1st Edition, CRC Press, 2010.

2. J. Pichtel, Waste Management Practices: Municipal, Hazardous, and Industrial, 2nd Edition, CRC Press, 2014.

3. G. Woodside, *Hazardous Materials and Hazardous Waste Management*, 2nd Edition, John Wiley & Sons, 1999.

4. C. Ray and R. Jain, *Drinking Water Treatment: Focusing on Appropriate Technology and Sustainability*, 1st Edition, Springer, 2011.

5. B.J. Finlayson-Pitts and J.N. Pitts Jr., *Chemistry of the Upper and Lower Atmosphere: Theory, Experiments, and Application,* 1st Edition, Academic Press, 2000.

6. M.M. Varma and J.H. Johnson, *Hazardous and Industrial Waste: Proceedings of the Twentieth Mid-Atlantic Industrial Waste Conference*, Hazardous Materials Control Research Institute (HMCRI), 1988.

Code: **CH-518** Subject: **INDUSTRIAL PROCESSES** Credits: **4 [4-0-0]**

Course Objective:

- To teach students about Petroleum and Coal based chemicals, surface active agents, pesticides and liquid crystals.

Course Outcome:

- Students can apply the knowledge when working in an industry.

Module-I: (10 Hours)

Petroleum and Coal based Chemicals: Composition of Petroleum, Cracking Processes, Commercial Production of Ethylene, Acetylene, Distillation of Coal.

Fuel Cells: General Chemistry of Fuel, Hydrogen-Oxygen Fuel Cell, Hydrocarbon-Oxygen Fuel Cell, Carbon Monoxide Fuel Cell, Methyl Alcohol Fuel Cell, Efficiency of Fuel Cell.

Module-II: (10 Hours)

Oil based Industries: Oils and Fats: Solvent Extraction of Oils, Hydrogenation of Oil, and

Use of Oil in the Manufacturing of Soap, Paints and Varnishes.

Surface Active Agents: Classification and Manufacturing of Detergents used for Cleansing Purpose.

Fermentation Industries: A General Discussion on Fermentation Conditions, Manufacturing of Penicillin.

Module-III: (10 Hours)

Pesticides and Pharmaceutical Industries: DDT Manufacture, BHC Manufacture, 2,4-D Manufacture, Parathion Manufacture, Pharmaceutical Industry.

Module-IV: (10 Hours)

Liquid Crystals: Mesomorphic Behaviour, Thermotropic Liquid Crystals, Nematic and Smectic Mesophases. Optical and Dielectric Properties of Liquid Crystals. Lyotropic Phases and Their Description of Ordering.

Prescribed Books:

1. M.G. Rao and M. Sittig, *Dryden's Outlines of Chemical Technology*, 3rd Edition, East-West Press, 1997.

2. M.G. Rao and M. Sittig, *Dryden's Outlines of Chemical Technology for the 21st Century*, 3rd Edition, East-West Press, 2010.

3. B.K. Sharma, *Industrial Chemistry*, 49th Edition, Goel Publishing, 2013.

4. A. Jess, U. Kragl, and P. Wasserscheid, *Chemical Technology: An Integral Textbook*, 1st Edition, John Wiley & Sons, 2013.

5. G.N. Pandey, Textbook of Chemical Technology, 2nd Edition, Sangam Books, 2000.

6. S. Singh, *Liquid Crystals: Fundamentals*, 1st Edition, World Scientific, 2002.

Code: **CH-516** Subject: **INDUSTRIAL PRACTICAL** Credits: **2 [0-0-3]**

Course Objective:

- To perform experiments which will be helpful when working in an industry.

Course Outcome:

- Determine residual chlorine and ammonia in sewage water.

- Determination of active chlorine in bleaching powder.
- Determination of flash point and viscosity of a lubricating oil.
- Determination of calorific value, carbon residue, volatile matter of a sample of coal.

1. Determination of Percentage of Purity of Commercially Available Different N, P and K Fertilizer.

2. Water Analysis: (a) Residual Chlorine in Town Supply Water (b) Ammonia Content of Sewage Water.

3. Determination of Acid Value, Saponification Value and Iodine Value of Different Oils.

4. Determination of Chlorine in Bleaching Powder.

5. Determination of Flash Point of a Lubricating Oil.

6. Determination of Viscosity of a Lubricating Oil.

7. Determination of Calorific Value, Carbon Residue, Volatile Matter of a Sample of Coal.

Prescribed Books:

1. B. Mishra, S. Dash, and P.K. Kar, *B.Tech. Practical Chemistry*, 1st Edition, Kalyani Publishers, 2005.

2. J.N. Gurtu and A. Gurtu, *Advanced Physical Chemistry Experiments*, 8th Edition, Pragati Prakashan, 2015.

Code: **CH-517** Subject: **ENVIRONMENTAL PRACTICAL** Credits: **2 [0-0-3]**

Course Objective:

- The course describes and gives hands on experience about different environmental related practical to the students

Course Outcome:

- Determination of alkalinity and dissolved oxygen, chlorine, iron content and nitrate in water sample.
- Determination of COD and hardness in a supplied water.
- Determination of phosphate and sulphate in sewage sample.

1. Determination of Alkalinity of Water.

2. Determination of Dissolved Oxygen in a Sample of Water.

3. Determination of Chemical Oxygen Demand.

4. Determination of Chloride Content in a Sample of Water.

5. Determination of Iron Content in a Sample of Water.

6. Determination Organic Carbon in Soil Sample.

7. Determination of Phosphate in Garden Soil.

8. Determination of Nitrate in Water Sample.

9. Estimation of Gaseous Pollutants (SO_x and NO_x) in Ambient Air.

10. Determination of Sulphate in Sewage Sample.

11. Determination of Total Hardness, Calcium Hardness and Magnesium Hardness.

Prescribed Books:

1. B. Mishra, S. Dash, and P.K. Kar, *B.Tech. Practical Chemistry*, 1st Edition, Kalyani Publishers, 2005.

2. O.P. Vermani and A.K. Narula, *Applied Chemistry: Theory and Practice*, 2nd Edition, New Age International, 2005.

SEMESTER: 4th

Code: **CH–521** Subject: **SOLID STATE AND NANOMATERIALS** Credits: **4 [4-0-0]**

Course Objective:

- To provide an introduction to the concepts underlying solid state chemistry and nanomaterials.
- An overview of the synthesis and applications of inorganic materials.
- Structure and compound identification in the solid state.
- Studies of the magnetism, electrical and optical properties of the solid state compounds and nanomaterials.

Course Outcome:

- Give a qualitative description of bonding in solid materials, crystal classes and symmetries

as a basis for space groups.

- Give a qualitative description of old and new concepts to describe the structure of inorganic solids.
- Give a qualitative and quantitative representation of crystal defects in crystalline solids and knowledge of defects related to non-stoichiometry in some important classes of inorganic materials.
- Give a qualitative representation of the relationship between structure/bonding and electronic, electrical, magnetic and optical properties of solids with emphasis on some of the most important classes of inorganic materials.

Module-I: (10 Hours)

Electron Theory of Solids: Free Electron Theory of Metals, Electrical Conductivity, Thermal Conductivity, Quantum Theory of Free Electrons, Band Theory of Solids, Conductivity of Metals.

Type of Material based on Conductivity: Conductors, Insulators, Semiconductors, Intrinsic and extrinsic Semiconductors, Band Theory of Conductors, Hall Effect.

Characterization: Thermal Analysis, Thermogravimetric Analysis (TGA), Differential Thermal Analysis (DTA), Differential Scanning Calorimetry (DSC).

Module-II: (10 Hours)

Super Conductors: Zero Resistivity, Critical Magnetic Field and Critical Current Density, Type I and II Super Conductors, Applications of Superconductors.

Dielectric Materials: Microscopic Displacement of Atoms and Molecules in External DC Electric Field, Polarization and Dielectric Constant, Dielectric Susceptibility, Temperature Dependence of Dielectric Breakdown, Ferroelectric Materials, Piezoelectrics, Pyroelectrics, Dielectric Materials as Electric Insulators.

Magnetic Properties: Dia, Para and Ferromagnetic Materials, Theory of Magnetism, Ferrimagnetic Materials or Ferrites, Comparison of Magnetic Behaviour and Magnetic Parameters of Dia, Para and Ferromagnetic Materials.

Module-III: (10 Hours)

Nanomaterials: Introduction to Nanoscience, History and Scope of Nanoscience, Different

Kind of Small, Interdisciplinary Sciences behind Nanotechnology and Nanoscience. Carbon Nanotubes, Nanowires Quantum Dots, Nanocrystals, Nanoclusters and other Nanostructures.

Synthesis Methods and Strategies: Measuring and Imaging Tools for Nanostructures, Preparation, Synthesis and Fabrication of Nanostructures, Laser Vaporization, Electric Arc, CVD, Laser Pyrolysis, Hydrothermal, Gas Phase Synthesis and Sol-Gel Processing, Self-Assembly.

Module-IV: (10 Hours)

Nanotechnology in Physics, Chemistry, Biology and Engineering: Applications to Nano Electromechanical Systems (NEMS), Nano-optoelectronic Materials and Devices, Medical and Pharmacology Applications, Nanomaterial Thin-films, Optical Limiting Properties, Nanoscale Devices - Transistors, FETs, Quantum Dots Lasers and Other.

Prescribed Books:

1. W.D. Callister and D.G. Rethwisch, *Materials Science and Engineering: An Introduction*, 9th Edition, John Wiley & Sons, 2014.

2. M.S. Vijaya and G. Rangarajan, *Materials Science*, 1st Edition, Tata McGraw-Hill, 2003.

3. V. Rajendran and A. Marikani, *Materials Science*, 1st Edition, Tata McGraw-Hill, 2004.

4. L.H.V. Vlack, *Elements of Material Science and Engineering*, 6th Edition, Pearson education, 1989.

5. C.P. Poole, Jr. and F.J. Owens, *Introduction to Nanotechnology*, 1st Edition, John Wiley & Sons, 2003.

6. M.A. Ratner and D. Ratner, *Nanotechnology: A Gentle Introduction to the Next Big Idea, 1st Edition*, Prentice Hall, 2002.

7. T. Pradeep, Nano: *The Essentials: Understanding Nanoscience and Nanotechnology*, 1st Edition, Tata McGraw-Hill, 2007.

8. Editors of Scientific American, *Understanding Nanotechnology*, 1st Edition, Scientific American, 2002.

9. M. Wilson, K. Kannangara, G. Smith, M. Simmons, and B. Raguse, *Nanotechnology: Basic Science and Emerging Technologies*, 1st Edition, CRC Press, 2002.

10. J. Ramsden, *Nanotechnology: An Introduction*, 1st Edition, Elsevier, 2011.

11. D. Natelson, *Nanostructures and Nanotechnology*, 1st Edition, Cambridge University Press, 2015.

12. B.S. Murty, P. Shankar, B. Raj, B.B. Rath, and J. Murday, *Textbook of Nanoscience and Nanotechnology*, 1st Edition, University Press, 2013.

13. C. Binns, *Introduction to Nanoscience and Nanotechnology*, 1st Edition, John Wiley & Sons, 2010.

14. V.K. Varadan, A.S. Pillai, D. Mukherji, M. Dwivedi, and Linfeng Chen, *Nanoscience and Nanotechnology in Engineering*, 1st Edition, World Scientific, 2010.

Code: **CH-522** Subject: **CHEMISTRY OF MATERIALS** Credits: **4 [4-0-0]**

Course Objective:

- To provide knowledge about the importance of chemistry in understanding various common materials of industrial importance.
- To provide knowledge about nano chemicals and nano composites and their applications.
- To provide knowledge about organic conductors and organic electronics.

Course Outcome:

- To understand and exploit the properties of various chemical materials in day-to-day life.
- To understand how and why the properties of materials are controlled by structure, bonding and processing at the atomic-scale, and by features at the microstructural and macroscopic levels.

Module-I: (10 Hours)

Glasses, Ceramics, Composites, and Nanomaterials: Glassy State, Glass Formers and Glass Modifiers, Applications. Ceramic Structures, Mechanical Properties, Clay Products. Refractories, Characterizations, Properties and Applications. Macroscopic Composites, Dispersion-Strengthened and Particle-Reinforced, Fibre-Reinforced Composites, Macroscopic Composites. Nanocrystalline Phase, Preparation, Procedures, Special Properties, Applications.

Module-II: (10 Hours)

Ionic Conductors: Types of Ionic Conductors, Mechanism of Ionic Conduction, Interstitial Jumps (Frenkel), Vacancy Mechanism, Diffusion Superionic Conductors, Phase Transition and Mechanism of Conduction in Superionic Conductors, Examples and Applications of Ionic Conductors.

Module-III: (10 Hours)

Organic Solids, Fullerenes, and Molecular Devices: Conducting Organics, Organic Superconductors, Magnetism in Organic Materials. Fullerenes-Doped, Fullerenes as Superconductors. Molecular Rectifiers and Transistors, Artificial Photosynthetic Devices, Optical Storage Memory and Switches-Sensors. Nonlinear Optical Materials: Nonlinear Optical Effects, Second and Third Order, Molecular Hyperpolarisability and Second Order Electric Susceptibility, Materials for Second and Third Harmonic Generation.

Module-IV: (10 Hours)

Thin Films and Langmuir-Blodgett Films: Preparation Techniques, Evaporation/Sputtering, Chemical Processes, Sol-Gel, etc. Langmuir-Blodgett (LB) Film, Growth Techniques, Photolithography, Properties and Application of Thin and LB Films.

Polymeric Materials: Molecular Shape, Structure and Configuration, Crystallinity, Stress-Strain Behaviour, Polymer Types and Their Applications, Conducting and Ferroelectric Polymers.

Prescribed Books:

1. N.W. Ashcroft and N.D. Mermin, *Solid State Physics*, 33rd Edition, Holt, Rinehart and Winston, 1976.

2. W.D. Callister and D.G. Rethwisch, *Materials Science and Engineering: An Introduction*, 9th Edition, John Wiley & Sons, 2014.

3. H.V. Keer, *Principles of Solid State*, 1st Edition, New Age International, 1993.

4. J.C. Anderson, K.D. Leaver, R.D. Rawlings, and J.M. Alexander, *Materials Science*, 4th Edition, Springer, 2013.

5. G.W. Gray, *Thermotropic Liquid Crystals*, 1st Edition, John Wiley & Sons, 1987.

6. H. Kelker and R. Hatz, Handbook of Liquid Crystals, 1st Edition, Verlag Chemie, 1980.

7. D. Singh, D. Zhu, W.M. Kriven, S. Mathur, H.-T. Lin, *Design, Development, and*

Applications of Structural Ceramics, Composites, and Nanomaterials, 1st Edition, John Wiley & Sons, 2014.

8. C. S. Sunandana, *Introduction to Solid State Ionics: Phenomenology and Applications*, 1st Edition, CRC Press, 2016.

9. T. Torres and G. Bottari, *Organic Nanomaterials: Synthesis, Characterization, and Device Applications*, 1st Edition, John Wiley & Sons, 2013.

10. M. Ohring, *Materials Science of Thin Films: Deposition and Structure*, 2nd Edition, Academic Press, 2002.

11. F. Mohammad, *Specialty Polymers: Materials and Applications*, 1st Edition, I.K. International, 2007.

Code: **CH-227** Subject: **MATERIAL AND ENERGY BALANCE** Credits: **4 [4-0-0]**

Course Objective:

- To teach the students about the application of basis chemical stoichiometry in real industrial problems.

Course Outcome:

- Students can apply the knowledge in industrial process control in an optimum manner.

Module-I: (10 Hours)

Material Balances Without Chemical Reactions: Process Flow-Sheet, Material Balances, Recycling Operations, Material Balances of Unsteady State Operations.

Module-II: (10 Hours)

Material Balances Involving Chemical Reactions: Definition of Terms, Electrochemical Reactions, Recycling, Parallel and Bypassing Operations, Metallurgical Applications

Module-III: (10 Hours)

Energy Balances: Energy and Thermo-Chemistry, Energy Balances, Heat Capacity, Heat Capacity of Gases at Constant Pressure, Sensible Heat Changes in Liquids, Heat Capacity of Gaseous Mixtures, Latent Heats, Enthalpy Changes During Phase Transfers Accompanied by Sensible Heat Changes, Enthalpy Changes Accompanying Chemical Reactions, Effect of Temperature on Heat of Formation, Heat of Reaction, Adiabatic Reactions, Effect of Pressure

on Heat of Reaction, Thermochemistry of Mixing Process, Dissolution of Solids, Liquid-Liquid Mixtures, Heat of Solution by Partial Molal Quantities.

Module-IV: (10 Hours)

Stoichiometry and Unit Operations: Distillation, Absorption and Stripping, Extraction and Leaching, Crystallisation, Psychrometry, Drying, Evaporation, Less Conventional Operation.

Prescribed Books:

1. G.V. Reklaitis, *Introduction to Material and Energy Balances*, 1st Edition, John Wiley & Sons, 1983.

2. A.E. Morris, G. Geiger, and H.A. Fine, *Handbook on Material and Energy Balance Calculations in Material Processing*, 3rd Edition, John Wiley & Sons, 2011.

3. C. Oloman, *Material and Energy Balances for Engineers and Environmentalists*, 3rd Edition, Imperial College Press, 2009.

4. V.V. Veverka and F. Madron, *Material and Energy Balancing in the Process Industries: From Microscopic Balances to Large Plants*, 1st Edition, Elsevier, 1997.

5. B.I. Bhatt and S.B. Thakore, *Stoichiometry*, 5th Edition, Tata McGraw Hill, 2010.

6. F.A. Cotton and G. Wilkinson, C.A. Murillo, and M. Bochmann, *Advanced Inorganic Chemistry*, 6th Edition, John Wiley & Sons, 2009.

7. G. Wilkinson, R.D. Gillard, and J.A. McCleverty, *Comprehensive Coordination Chemistry*, 1st Edition, Pergamon Press, 1987.

8. H.J. Emeléus, A.G. Sharpe, *Modern Aspects of Inorganic Chemistry*, 4th Edition, John Wiley & Sons, 1973.