<table>
<tr><th>Sem</th><th>Discipline specific courses - core (60/62 Credits) (only to be offered for Dept Students)</th><th>Minor (24 Credits) (Dept students may opt to chose from relevant disciplines as decided by Dept./Dean Acad./Dean</th><th colspan="3">Multidisciplinary courses (total three introductory courses to be completed from available 5 categories – one in each sem – total three semesters – each 3 credits – total 9 Credits (to be taken by all discipline students for limited semesters , i.e., up to 3rd sem, as per following)

(for example, a Chemistry student can opt Principle of Chemistry in 1st sem chosen from 1st group, one course of from Mass Comm (chosen from 4th group), and one course from Humanities and Soc.Sci, chosen from 5th group) – distributed over 3 sem.</th><th>AEC (language) – total 8 Credits – 4 semesters) – 2 Cr per sem (to be taken by all students for limited sem i.e, up to 4th sem)</th><th>Skill enhancement courses/internship/ Dissertation – total 9 Credits – 3 Semester – 3 credit per semester (to be offered by dept. Student may also have the option to chose from available course from a pool floated by Dean acad. In case of limited infrastructure of dept.</th><th>Value added course (common to all streams – mandatory for all) – total 6 credits – 2 semesters – 3 credits per semester</th><th>Total credits</th></tr>
<tr><td rowspan="15">I</td><td rowspan="15">(100 level) – 5 Cr –

1. organic Chem-I – Theory (3 Credits)

2. org.Chem.Practical_2 Cr</td><td rowspan="15">(100 level) – – Physics – Cr (Theory) – 2 Cr/ Physics Practical – 2 Cr

(For Chemistry Student may have the option to chose one such similar course from following relevant disciplines: Math/Life Sci/Statistics/Env.Sci – constituting total 4 Credits)

Principle of Chemistry</td><td colspan="3">(1 course) – 3 Cr</td><td rowspan="15">(1 course – 2 Cr) – English for communication – 2 Cr</td><td rowspan="15">(1 course – 3 Cr)

Chemistry – IT Skill for Chemist/IPR and Business Skill (any one)</td><td rowspan="15">Understanding India – 3 Cr</td><td rowspan="15">20</td></tr>
<tr><td rowspan="3">1st Group – Natural & Physical Sci</td><td>Chemistry</td><td>Chemistry in Everyday life</td></tr>
<tr><td>Physics</td><td>Example; Basic of Physics (Dean Office (Dean Academic and/or Dean of respective School may ask for one course at least from each dept)</td></tr>
<tr><td>Life Sci.</td><td></td></tr>
<tr><td rowspan="3">2. Mathematics/ Statistics/ computer application</td><td>Math</td><td></td></tr>
<tr><td>Statistics</td><td></td></tr>
<tr><td>Computer Application</td><td></td></tr>
<tr><td rowspan="2">3. Lib/Information/Media Sci</td><td>Masscomm.</td><td></td></tr>
<tr><td>Information Sci.</td><td></td></tr>
<tr><td rowspan="2">4. Commerice/Mgt</td><td>Commerce</td><td></td></tr>
<tr><td>Mgt</td><td></td></tr>
<tr><td rowspan="3">5.Humanities and Soc.Sc</td><td>Pol.Sci/Pub. Admin</td><td></td></tr>
<tr><td>Anthropology</td><td></td></tr>
<tr><td>Economics</td><td></td></tr>
</table>

				Politics and IR					
II	(100 level) 1.Inorganic Chemistry-I (3 Credits) 2.Inorganic Chem. Practical (2 Credits)	(100 level) Physics-II (Theory) – 2 Cr Physics-Practical-2 Principle of Chemistry-II	(1 course – 3 credits) – must be different from the course chosen in 1st sem, should be within the rest 4 groups		(1 course – 2 Cr) – Basics of Hindi language	(1 course – 3 Cr) Water conservation studies/Renewable energies (any one)	Env.Education – 3 Cr	20
Certificate – additional 4 Cr to be earned.									
III	(200 level course) – 8 Cr (2 theory papers – 3x2 = 6 Cr + 1 Practical – 2 Cr) Organic-II (3cr) Organic practical (1 cr) Physical chem. (3 cr) Physical practical (1 Cr)	(200 level) – 4 Cr Principle of Chemistry-III (3 Cr) Chemistry practical (1 Cr)	(1 course – 3 credits) – must be different from the course chosen in 1st and 2nd sem - should be within rest 3 groups.		(1 course – 2 Cr) – English language	(1 course – 3 Cr) Chemoinformatics/Analytical biochemistry/Forensic Sci (any one)	-	20
IV	(200 level course) – 14 Credits (3 theory - 3x3 = 9 credits) (3 practical = 3 x 1 = 3 credits) One seminar paper – 2 Cr Physical chem. II Inorg II Org. III Three practicals	(200 level) – 4 Cr Environmental chemistry	-		(1 course – 2 Cr) – Basics of Hindi language	-	-	20
Diploma – additional 4 Credits to be earned.									
V	(300 level) – 14 Credits 3 Theory papers (3 x3 = 9 Credits) 2 Practical	(200 level) – 4 Cr Material Chemistry	-		-	Internship – to be decided at Dept level by designated coordinator of dept for the purpose – 02 /04Credits		20/22

	papers (2 x 2 = 4 Credits) **3. One Seminar – 1 Cr** **Physical Chem III** **Inorganic Chem III** **Heterocyclic Chem I** **Inorganic Pract.** **Heterocyclic Practical**						
VI	**(300 level) 16 Credits** **3 Theory (3 X3 = 9 Cr)** **2 Practical (2 x 2 = 4 Cr)** **One** **Minor Research – 2 Cr** **One Industrial hands on training/or a research/industry course practical offered by dept – 1 Cr** **Physical IV** **Nuclear Chemistry** **Organic Spectroscopy** **Physical practical** **Organic Practical**	**(200 level) – 4 Cr** **Polymer Chemistry**	**-**	**-**	**-**	**-**	**20**
	62 Credits	**24 Cr**	**9 Cr**	**8 Cr**	**11/13 Cr**	**6 Cr**	**Total = 120/ 122**
UG Degree in relevant disciplne/Subject							

1st Sem_(100 level)

Organic Chemistry-I: 3 Credits

***Course Learning Objectives (CO)*: This course is intended to introduce students to basics of organic chemistry.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have an understanding of the development of scientific ideas about organic chemistry thus creating, evaluating, analyzing, applying, understanding and remembering concepts of basic organic chemistry, stereochemistry, aliphatic and aromatics compounds**

Unit-I

Basics of Organic Chemistry: Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties. Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength. Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophlicity and basicity; Types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals and Carbenes).

Organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

Stereochemistry:

Concept of asymmetry, Fischer Projection, Newmann and Sawhorse projection formulae and their interconversions; Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with C.I.P rules. Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixtures, Relative and absolute configuration: D/L and R/S designations.

Unit-II

Chemistry of Aliphatic Hydrocarbons:

A. Carbon-Carbon sigma bonds

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz- Fittig Reactions, Free radical substitutions: Halogenation - relative reactivity and selectivity.

B. Carbon-Carbon pi-bonds

Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations. Reactions of alkenes: Electrophilic additions their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroboration- oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation). 1, 2- and 1, 4- addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene. Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions.

Unit-III

Cycloalkanes and Conformational Analysis

Cycloalkanes and stability, Baeyer strain theory, Conformation analysis, Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms.

Aromatic Hydrocarbons

Aromaticity: Huckel's rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft's alkylation/acylation with their mechanism. Directing effects of substituent groups.

Recommended Books/References:

1. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Pine S. H. Organic Chemistry, Fifth Edition, McGraw Hill, (2007)
3. F. A. Carey, Organic Chemistry, Seventh Edition, Tata McGraw Hill (2008).

Organic Chemistry Practical – 2 Cr

***Course Learning Objectives (CO)*: This course is intended to introduce students to basic practical skills in organic laboratory.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have an understanding of the development of scientific ideas about organic chemistry laboratory**

(List of experiments given are suggestive. One experiment from each group to be demonstrated)

1. Checking the calibration of the thermometer.
2. Purification of organic compounds by crystallization using the following solvents:
   a. Water b. Alcohol c. Alcohol-Water
3. Determination of the melting points of given organic compounds and unknown organic compounds (using Kjeldahl method and electrically heated melting point apparatus).
4. Effect of impurities on the melting point – mixed melting point of two unknown organic compounds.
5. Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and capillary method)

1.Functional group tests for alcohols, phenols, carbonyl and carboxylic acid group.

Recommended Books/Reference:

1.Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)

2.Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012)

Minor for 1st Sem (chemistry dept course to be offered to other allied Dept students)

Principles of Chemistry-I (3 Credits)

(Common Chemistry syllabus for all Natural Science and all Technology courses)

***Course Learning Objectives (CO)*: This course is intended to introduce students to principles of chemistry such as atomic structure, chemical periodicity, chemical bonding, basic organic chemistry, acid base and material chemistry.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have a comprehensive understanding of the development of scientific ideas about principles of chemistry thus creating, evaluating, analyzing, applying, understanding and remembering atomic structure, chemical periodicity, chemical bonding, basic organic chemistry, acid base and material chemistry.**

Unit-I

Atomic structure

Bohr's theory of hydrogen-like atoms and ions; spectrum of Hydrogen atom. Quantum numbers. Introduction to the concept of atomic orbitals; shapes, radial and angular probability diagrams of s, p and d orbitals (qualitative ideas). Many electron atoms and ions: Pauli's exclusion principle, Hunds rule, Exchange energy, Aufbau Principle and its limitation.

Chemical periodicity

Periodic classification of elements, periodicity in properties, classification into metals, non-metal and insulators.

Chemical bonding and Shapes of compounds

Structure and bonding, VSEPR theory, molecular orbital theory, shapes of molecules, hybridization, dipole moment and bond moment, ionic solids and lattice energy, Born Haber Cycle.

Unit-II

Basic concepts in Organic Chemistry

Valence bond theory: concept of hybridization, orbital picture of bonding (sp3, sp2, sp: C –C, C N and C- O system), Electronic (inductive, electromeric, hyperconjugation and resonance) effects. bond polarization and bond polarizability, steric effect, steric inhibition of resonance.

Reactive Intermediates (formation, stability, and structure) Free radicals, carbonium ions and carbanions.

Electrophlic Aromatic Substitutions

Mechanisms of nitration, halogenation, sulphonation and Friedel-Crafts (alkylation and acylation) reactions. Effects of substituents on reactivity and orientation. Aryl Halogen Compounds: Chlorobenzene, comparative reactivity of aryl, benzyl, vinyl and allyl halides.

Unit-III

Acid Base Chemistry

Acid Base concepts: Arrhenius concept, Bronsted-Lowry's concept, Lux-flood salvation system, Lewis concept, Hard-soft Acid base theory (HSAB theory), indicators, Liquid ammonia system with reference to acid-base reaction, solvolysis and metathetical reaction, liquid SO2 as non-aqueous solvent.

Materials in applied chemistry and engineering

Macromolecules: Basic idea about polymeric materials, its classification and uses, preparation of polymers using addition and condensation mechanism, molecular weight of polymeric materials and its importance, some examples of industrially important polymeric materials (polyethylene, PVC, Nylon 6, Nylon 6,6, Nylon 6,10, phenol-formaldehyde resin, urea-formaldehyde resin, polystyrene, Kevlar, PMMA), Examples of biodegradable polymers.

Recommended text Books:

1. J.D Lee, Concise Inorganic Chemistry, Wiley Indian Edition, 5th Edition (2008)
2. F. A. Cotton, R.G. Wilkinson, Basic Inorganic Chemistry, Wiley, Third edition (2007)
3. P. K. Dutt. General and Inorganic Chemistry (Vol-I + Vol-II), Sarat Book House, Fifteenth Edition (2014)
4. S. Sengupta, Organic chemistry, Oxford University Press, First Edition (2014)
5. D. A. Mcquarrie and J. D. Simon, Physical chemistry a molecular approach, Viva Books, Viva Students Edition (2019)
6. G. W. Castellen, Physical Chemistry, Narosa, 3rd Edition (2004)
7. P. C. Rakshit, Physical Chemistry, Sarat Book House; Revised ed & enlarged ed edition (2014)
8. T. E. Brown, H. E. Lemay, B. E. Bursten, C. Murphy, Chemistry: The Central Science, 11th Edition, Prentice Hall
9. J. Clayden, N. Greeves, S. Warren, P. Wothers, Organic Chemistry, Oxford University Press, Second Edition (2014)

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Chemistry Practical – 1 Cr (minor group)

***Course Learning Objectives (CO)*: This course is intended to introduce students to basic practical skills in organic laboratory.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have an understanding of the development of scientific ideas about organic chemistry laboratory**

(List of experiments given are suggestive. One experiment from each group to be demonstrated)

1. Checking the calibration of the thermometer.
2. Purification of organic compounds by crystallization using the following solvents:
   a. Water b. Alcohol c. Alcohol-Water
3. Determination of the melting points of given organic compounds.
4. Effect of impurities on the melting point – mixed melting point of two unknown organic compounds.
5. Functional group tests for alcohols, phenols, carbonyl and carboxylic acid group.

Recommended Books/Reference:

1.Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)

2.Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012)

Multidisciplinary courses

Chemistry in everyday life (paper offered from the Dept of Chemistry)

***Course Learning Objectives (CO)*: This course is intended to introduce students to basic knowledge about the use of chemistry in daily life.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have an understanding of the development of scientific ideas about chemistry in societal use.**

Unit-I: Respiration and energy production
Respiration, Respiratory enzymes, brief outline of haemoglobin and myoglobin, oxygen transport mechanism in body, co-operativity, Respiration in lower animals, hemocyanin, hemerythrin, non-heme Fe-S proteins.
Energy production in body, ATP, enzyme responsible for food digestion, mechanism of food digestion, active site of cytochrome c-oxidase.

Unit-II:
Chemical aspects of some common health hazards
Anaemia, sickle cell anaemia, leukaemia, mechanism, blood pressure regulation, blood sugar, arthritis, carbon monoxide poisoning in mines, cyanide poisoning, fluorosis, poisoning of Hg, Cd, Pb, As etc. , toxicity arising from daily used chemicals.

Unit-III: Vitamins and minerals
Need for vitamin in body, types of vitamins, water soluble and fat soluble vitamins, Vitamin B-12 (Cyanocobalamin), vitamin C,Vitamin D, Vitamin K. Role of minerals in body, iodine deficiency, effects and remedies.

Unit-IV: Significance of Radical chemistry in living system
Radical production in environment, superoxide and peroxide, health impact, action of radicals, cell mutation, diseases caused by free radical, cancer, radical quencher, anti-oxidants, natural anti-oxidants like vegetables, beverages like tea and coffee, fruits.
Radical destroying enzymes: superoxide dismutase, catalase, peroxidase, mechanism of action.

Books recommended:

1. Elements of Bio-Inorganic Chemistry, G. N. Mukherjee, A. Das; 3rd Ed, UN Dhur & sons Pvt Ltd, Kolkata, 2008.

2. Chemistry in Daily Life, Kirpal Singh; 3rd Ed, PHI Learning Pvt Ltd, New Delhi, 2012

Skill enhancement course **(offered from the Dept of Chemistry) – 3 Cr. (A range of course to be offered depending upon the availability of infrastructure and students interest in a subject depending upon students' basic understanding and level of study)**

1. **IT Skills for Chemists**

Fundamentals, mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, inter-conversion of units, constants and variables, equation of a straight line, plotting graphs.

Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities. Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression). Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms).Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations). Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

Computer programming:

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

BASIC/FORTRAN programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

Recommended books/References:

1.McQuarrie, D. A. *Mathematics for Physical Chemistry University* Science Books (2008).
2. Mortimer, R. *Mathematics for Physical Chemistry*. 3rd Ed. Elsevier (2005).
3.Steiner, E. *The Chemical Maths Book* Oxford University Press (1996).
4.Yates, P. *Chemical calculations.* 2nd Ed. CRC Press (2007).

5.Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.

6. Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.

7.Noggle, J. H. *Physical chemistry on a Microcomputer*. Little Brown & Co. (1985).

8. Venit, S.M. *Programming in BASIC: Problem solving with structure and style*. Jaico Publishing House: Delhi (1996).

2. Intellectual property right (IPR) and business skills for chemists

Introduction to Intellectual Property:

Historical Perspective, Different Types of IP, Importance of protecting IP.

Copyrights

Introduction, How to obtain, Differences from Patents.

Trade Marks

Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, Trade names, etc. Differences from Designs.

Patents Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Healthcare – balancing promoting innovation with public health, Software patents and their importance for India.

Geographical Indications

Definition, rules for registration, prevention of illegal exploitation, importance to India.

Industrial Designs

Definition, How to obtain, features, International design registration.

Layout design of integrated circuits

Circuit Boards, Integrated Chips, Importance for electronic industry.

Trade Secrets

Introduction, Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.

Different International agreements

(a) Word Trade Organization (WTO):

(i) General Agreement on Tariffs & Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement (ii) General Agreement on Trade related Services (GATS) (iii) Madrid Protocol (iv) Berne Convention (v) Budapest Treaty

(b) Paris Convention

WIPO and **TRIPS, IPR** and Plant Breeders Rights, IPR and Biodiversity

IP Infringement issue and enforcement – Role of Judiciary, Role of law enforcement agencies – Police, Customs etc. Economic Value of Intellectual Property – Intangible assets and their valuation, Intellectual Property in the Indian Context – Various laws in India Licensing and technology transfer.

Business Basics

Key business concepts: Business plans, market need, project management and routes to market.

Chemistry in Industry

Current challenges and opportunities for the chemistry-using industries, role of chemistry in India and global economies.

Financial aspects

Financial aspects of business with case studies.

Recommended Books/References:

1. Acharya, N.K. *Textbook on intellectual property rights*, Asia Law House (2001).

2.Guru, M. & Rao, M.B. *Understanding Trips: Managing Knowledge in Developing Countries*, Sage Publications (2003).

3. Ganguli, P. *Intellectual Property Rights: Unleashing the Knowledge Economy*, Tata McGraw-Hill (2001).

4. Miller, A.R. & Davis, M.H. *Intellectual Property: Patents, Trademarks and Copyright in a Nutshell*, West Group Publishers (2000).

5. Watal, J. *Intellectual property rights in the WTO and developing countries*, Oxford University Press, New Delhi.

3 Chemoinformatics

Introduction to Chemoinformatics: History, Prospects of chemoinformatics, Molecular Modelling and Structure elucidation.

Representation of molecules and chemical reactions: Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and Sdfiles, Libraries and toolkits, Different electronic effects, Reaction classification.

Searching chemical structures: Full structure search, sub-structure search, basic ideas, similarity search, three dimensional search methods, basics of computation of physical and chemical data and structure descriptors, data visualization.

Applications: Prediction of Properties of Compounds; Linear Free Energy Relations; Quantitative Structure-Property Relations; Descriptor Analysis; Model Building; Modeling.

Toxicity; Structure-Spectra correlations; Prediction of NMR, IR and Mass spectra; Computer Assisted Structure elucidations; Computer Assisted Synthesis Design, Introduction to drug design; Target Identification and Validation; Lead Finding and Optimization; Analysis of HTS data; Virtual Screening; Design of Combinatorial Libraries; Ligand and structure based drug design; Applications in Drug Design.

Recommended Books/references:

1. Andrew R. Leach and Valerie, J. Gillet (2007) *An introduction to Chemoinformatics.* Springer: The Netherlands.

2. Gasteiger, J. and Engel, T. (2003) *Chemoinformatics: A text-book.* Wiley-VCH.

3. Gupta, S. P. (2011) *QSAR & Molecular Modeling.* Anamaya Pub.: New Delhi.

4. Analytical clinical biochemistry

Structure, properties and functions of carbohydrates, lipids and proteins:

Carbohydrates: Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle. Isolation and characterization of polysachharides.

Proteins: Classification, biological importance; Primary and secondary and tertiary structures of proteins: α-helix and β- pleated sheets, Isolation, characterization, denaturation of proteins.

Enzymes: Nomenclature, Characteristics (mention of Ribozymes), Classification; Active site, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme

inhibitors, Introduction to Biocatalysis: Importance in "Green Chemistry" and Chemical Industry.

Lipids: Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications. Lipoproteins: Properties, functions and biochemical functions of steroid hormones. Biochemistry of peptide hormones.

Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy. *Enzymes*: Nomenclature, classification, effect of pH, temperature on enzyme activity, enzyme inhibition.

A diagnostic approach to biochemistry:

Blood: Composition and functions of blood, blood coagulation. Blood collection and preservation of samples. Anaemia, Regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.

Urine: Collection and preservation of samples. 6. Formation of urine. Composition and estimation of constituents of normal and pathological urine.

Recommended books/references:

1. Cooper, T.G. *Tool of Biochemistry*. Wiley-Blackwell (1977).

2. Wilson, K. & Walker, J. *Practical Biochemistry*. Cambridge University Press (2009).

3. Varley, H., Gowenlock, A.H & Bell, M.: *Practical Clinical Biochemistry*, Heinemann, London (1980).

4. Devlin, T.M., *Textbook of Biochemistry with Clinical Correlations*, John Wiley & Sons, 2010.

5. Berg, J.M., Tymoczko, J.L. & Stryer, L. *Biochemistry*, W.H. Freeman, 2002.

6. Talwar, G.P. & Srivastava, M. *Textbook of Biochemistry and Human Biology*, 3rd Ed. PHI Learning.

7. Nelson, D.L. & Cox, M.M. *Lehninger Principles of Biochemistry*, W.H. Freeman, 2013.

8. O. Mikes, R.A. Chalmers: *Laboratory Handbook of Chromatographic Methods*, D. Van Nostrand & Co., 1961.

5. Analytical Clinical Biochemistry Practical

Identification and estimation of the following:

1. Carbohydrates – qualitative and quantitative.
2. Lipids – qualitative.
3. Determination of the iodine number of oil.
4. Determination of the saponification number of oil.
5. Determination of cholesterol using Liebermann- Burchard reaction.
6. Proteins – qualitative.
7. Isolation of protein.
8. Determination of protein by the Biuret reaction.
9. Determination of nucleic acids.
(visit to clinical laboratory/medical centre(s))

Recommended Books/References:

1. Cooper, T.G. *Tool of Biochemistry*. Wiley-Blackwell (1977).
2. Wilson, K. & Walker, J. *Practical Biochemistry.* Cambridge University Press (2009).
3. Varley, H., Gowenlock, A.H & Bell, M.: *Practical Clinical Biochemistry*, Heinemann, London (1980).
4. Devlin, T.M., *Textbook of Biochemistry with Clinical Correlations*, John Wiley & Sons, 2010.
5. Berg, J.M., Tymoczko, J.L. & Stryer, L. *Biochemistry*, W.H. Freeman, 2002.
6. Talwar, G.P. & Srivastava, M. *Textbook of Biochemistry and Human Biology*, 3rd Ed. PHI Learning.
7. Nelson, D.L. & Cox, M.M. *Lehninger Principles of Biochemistry*, W.H. Freeman, 2013.
8. O. Mikes, R.A. Chalmers: *Laboratory Handbook of Chromatographic Methods*, D. Van Nostrand & Co., 1961.

6. Introduction to Forensic Science and technology

Scope of forensic science, Evidences in criminal law (act, case studies), Physical evidences (identification, collection and preservation of sample, physical properties of sample material, use of physical evidences in criminal proceedings), biological evidences (drugs, effects, identification, serology of blood, semen, saliva, DNA evidence, use of biological evidence in criminal proceedings), trace evidences (finger print, blood stream, hair, firearms, fibers, paints, etc), basic techniques of chemical analysis (FTIR, Mass spectroscopy, HPLC and GC with

example of analysis). Admissible and non-admissible scientific evidence in legal system, Principle and limitation of DNA finger printing.

Recommended Books/references:

1.B.B. Nanda and R.K. Tiwari, Forensic Science in India: A Vision for the Twenty First Century, Select Publishers, New Delhi (2001).

2. M.K. Bhasin and S. Nath, Role of Forensic Science in the New Millennium, University of Delhi, Delhi (2002).

3. S.H. James and J.J. Nordby, Forensic Science: An Introduction to Scientific and Investigative Techniques, 2nd Edition, CRC Press, Boca Raton (2005)

4.W.J. Tilstone, M.L. Hastrup and C. Hald, Fisher's Techniques of Crime Scene Investigation, CRC Press, Boca Raton (2013).

7. Water conservation studies

Introduction to water conservation and erosion of soil, forms of water erosion, factors affecting water erosion, types of water erosion, mechanics of water erosion control, agronomical measures of water erosion control, Terraces for water erosion control:

Modeling of watershed processes, Case study of water-shed modeling for water conservation and water quality.

8. Renewable energies (solar and biogas)

Introduction to renewable energy sources – solar, wind, small hydro, biomass, geothermal and ocean energy, energy flow in ecosystem Solar Energy Resources Solar radiation: Spectrum of EM radiation, sun structure and characteristics, extraterrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution

Measurement of solar radiation Instruments: sunshine recorder, Pyranometer, Pyrheliometer, Albedometer. Radiation measurement stations in India (NIWE, IMD etc.), solar radiation data, graphs, Meteonorm and NASA-SSE databases Hands-on measurement of beam, diffuse and total radiation

Solar mapping using satellite data, Typical Meteorological Year

Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components

Basics Biomass resources: plant derived, residues, aquatic and marine biomass, various wastes, photosynthesis. Biomass resource assessment Estimation of woody biomass, non woody biomass and wastes, ASTM standards

Bulk chemical properties Moisture content, proximate and ultimate analyses, calorific value, waste water analysis for solids

Chemical composition of biomass Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass, extractable, COD.

Structural properties Physical structure, particle size and size distribution, permeability. Physical properties: Bulk density, angle of repose, thermal analysis (thermogravimetric, differential thermal and differential scanning calorimetry).Properties of microbial biomass: Protein estimation, flocculating ability, relative hydrophobicity of sludge, sludge volume index.

(The above mentioned courses are indicative. Based on the facilities/expertise available, more similar courses can be introduced. The list of courses offered/recommended by UGC may also be considered/referred to while designing new courses/incorporating revision in the courses. References/Text books may be incorporated as per requirements/necessities of the subject concerned).

2nd Semester (100 level)

Inorganic Chemistry-I: (3 Credits)

Course objective: This course is an introduction to the basic concepts of chemistry. It includes the atomic structure, the periodic table, ionic and covalent bonding. The course is also designed to serve the Engineering students. Some fundamental mathematical concepts crucial to chemistry are also covered.

Learning outcome:

1. Student could be able to understand the atomic structure and chemical periodicity.

2. Students will be able to explore the nature of chemical bonds and know theories of chemical bonding including forces that influence molecular shapes.
3. After the fundamental insight, student could be able to explain the basic reaction mechanism concept and applying the same with examples.
4. Student could understand acid/base and pH concept.
5. Students can explore the polymeric materials and their properties for Engineering applications.

Unit-I: Atomic Structure:

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics: de' Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and $\psi 2$. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of *s, p, d* and *f* orbitals. Contour boundary and probability diagrams. Pauli's Exclusion Principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.

Unit-II: Periodicity of Elements:

s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to *s* and *p*-block.

(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.

(b) Atomic radii (van'der Waals)

(c) Ionic and crystal radii.

(d) Covalent radii (octahedral and tetrahedral)

(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.

(f) Electron gain enthalpy, trends of electron gain enthalpy.

(g)Electronegativity, Pauling, Mullikan, Allred Rachow scales, electronegativity and bond order, partial charge, hybridization, group electronegativity. Sanderson electron density ratio.

Unit-III: Chemical Bonding:

(i) *Ionic bond:* General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation, expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.

(ii) *Covalent bond:* Lewis structure, Valence Shell Electron Pair Repulsion Theory (VSEPR), Shapes of simple molecules and ions containing lone-and bond-pairs of electrons multiple bonding, sigma and pi-bond approach, Valence Bond theory, (Heitler-London approach). Hybridization containing s, p and s, p, d atomic orbitals, shapes of hybrid orbitals, Bents rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of simple homonuclear and heteronuclear diatomic molecules, MO diagrams of simple tri and tetra-atomic molecules, e.g., N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, HCHO, (idea of s-p mixing and orbital interaction to be given). Covalent character in ionic compounds, polarizing power and polarizability. Fajan rules, polarization. Ionic character in covalent compounds: Bond moment and dipole moment. ionic character from dipole moment and electronegativities.

Metallic bonding and Weak chemical forces:

(iii) *Metallic Bond:* Qualitative idea of free electron model, Semiconductors, Insulators.

(iv) *Weak Chemical Forces:* van'der Waals, ion-dipole, dipole-dipole, induced dipole dipole-induced dipole interactions, Lenard-Jones 6-12 formula, hydrogen bond, effects of hydrogen bonding on melting and boiling points, solubility, dissolution.

Recommended Books/References:

1. J.D. Lee, Concise Inorganic Chemistry, Wiley Indian Edition, 5th Edition (2008)

2. Douglas, B.E., McDaniel, D.H., Alexander J.J., Concepts & Models of Inorganic Chemistry, John Wiley & Sons, 3rd Edition (1999)

3. Atkins, P. W. and DePaula, J. Physical Chemistry, Oxford University Press, Tenth Edition (2014)

4. Rodger, G. E. Inorganic and Solid State Chemistry, Cengage Learning (2002)

Inorganic Chemistry Practical-I (2 Credits)

Course Objectives: understanding of various analytical methods of analysis, complexometric titration, and estimation of concentration of elements present in any compound.

Learning Outcomes: Upon Successful learning Students could be able to understand the complexometric titrations and estimate the concentration of elements present in compound.

(A)Semi-micro Analysis of Salt/mixture of salts

(B) Titrimetric Analysis

(i) Calibration and use of apparatus.

(ii) Preparation of solutions of different Molarity/Normality of titrants.

(iii) Use of primary and secondary standard solutions.

(C) Acid-Base Titrations

(i) Estimation of carbonate and hydroxide present together in mixture.

(ii) Estimation of carbonate and bicarbonate present together in a mixture.

(iii) Estimation of free alkali present in different soaps/detergents

(D) Oxidation-Reduction Titrimetric

(i) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution.

(ii) Estimation of oxalic acid and sodium oxalate in a given mixture.

(iii) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books/References:

1. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis* Sixth Edition, Pearson, 2009.
2. Svehala G. and Sivasankar I. B, Vogel's Qualitative Inorganic Analysis, Pearson, India, 2012.

Minor for 2nd Sem

Course Code: CHM120031

Title of the Course: Principles of Chemistry-II

L-T-P: L-2/T-1/P-0

Course Learning Objective (CO): To Develop a solid understanding of fundamental concepts in general chemistry, including atomic structure, chemical bonding, stoichiometry, and thermodynamics. Also, to acquire proficient problem-solving skills, utilizing mathematical and chemical principles to solve quantitative and qualitative problems in chemistry.

Course Learning Outcomes (CLO):

CLO-1: Students will have understanding surface chemistry and catalysis

CLO-2: Understanding basic principle and applications of instruments in chemistry

CLO-3: To Gain insight into the principles underlying nuclear energy, exploring its technological applications and implications

CLO-4: Understanding stereochemistry and related reaction mechanism.

CLO-5: Understanding the importance of water and its chemistry/technology.

Unit-I

Surface Chemistry and catalysis

Adsorption, types of adsorption, difference between adsorption and absorption, adsorption of gases on solids, adsorption isotherms –Langmuir, Freundlich adsorption isotherms and its importance, Catalysis, general characteristics of catalytic reactions, examples of homogenous and heterogeneous catalysis, theories of heterogeneous and homogenous catalysis. Examples of some catalyst having industrial importance (vanadium pentoxide, platinum, etc.,).

Instrumental Methods of analysis

Introduction; Principles of spectroscopy; Laws of absorbance.

IR: Principle, Instrumentation, Applications to simple carbonyl, amine, alcohol compounds.

UV: Principle, Instrumentation, Application to simple carbonyl, amine, alcohol compounds.

Unit-II

IUPAC Nomenclature of Organic compounds:

Alkane, alkene, alkyne, alcohol, thiol, ether, aldehyde, ketone, acid, acid derivatives, amines, nitriles, cyclic compounds and common names of few aromatic compounds.

Optical isomerism. Absolute configuration. D-L and R-S configuration of in compounds containing one and two asymmetric centres. Aromaticity and Huckel's rule, Establishment of structure of benzene (heat of hydrogenation, calculation of resonance energy).

Unit III

Radioactivity and Nuclear chemistry

Origin of radioactivity, decay law, half-life, liquid drop model, and shell model, uses of radioactivity such as radiocarbon dating, radiotracers, agricultural and medicinal uses including imaging. Nuclear reactions, fission, fusion, spallation; reactions involving α, β, γ rays; neutron diffraction. Counting techniques, Geiger-Muller counter, Scintillation counter, nuclear reactors, nuclear reactions as alternative source of energy, nuclear reactors, variable energy cyclotron.

Recommended Books:

1. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education; 6th edition (2009)
2. T. W.G. Solomons and C.B. Fryhle, Organic Chemistry, John Wiley, 8th Edition (2007)
3. Organic Chemistry, Stanley H Pine, McGraw Hill Education, Special Indian edition, 5th Edition, (2006)
4. Shashi Chawla, A Text Book of Engineering Chemistry, Dhanpat Rai & Co. (P) Limited (2017)
5. A. W. Adamson and A.P. Gast, Physical Chemistry of surfaces, Wiley India Pvt Ltd, Sixth edition (2011)
6. H. J. Arnikar, Essentials of Nuclear Chemistry, New Age International Private Limited, Fifth edition (2022)

7. William Kemp, Organic spectroscopy, Palgrave Macmillan; 2nd edition (1987)

Chemistry Practical-I (1 Credits) - MINOR

Course Objectives: understanding of various salt anlalysi, analytical methods of analysis, complexometric titration, and estimation of concentration of elements present in any compound.

Learning Outcomes: Upon Successful learning Students could be able to understand the complexometric titrations and estimate the concentration of elements present in compound.

(A).Semi-micro Analysis of Salt/mixture of salts

(B) Titrimetric Analysis

(i) Calibration and use of apparatus.

(ii) Preparation of solutions of different Molarity/Normality of titrants.

(iii) Use of primary and secondary standard solutions.

(C) Acid-Base Titrations

(i) Estimation of carbonate and hydroxide present together in mixture.

(ii) Estimation of carbonate and bicarbonate present together in a mixture.

(iii) Estimation of free alkali present in different soaps/detergents

Recommended Books/References:

3. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis* Sixth Edition, Pearson, 2009.
4. Svehala G. and Sivasankar I. B, Vogel's Qualitative Inorganic Analysis, Pearson, India, 2012.

3rd Semester (200 level)

Organic Chemistry-II (3 Cr)

Learning objective:

1. Familiarization about classes of organic compounds and their methods of preparation.
2. Basic uses of reaction mechanisms.
3. Name reactions, uses of various reagents and the mechanism of their action.

Course outcome:

1. Preparation and uses of various classes of organic compounds.
2. Organometallic compounds and their uses.

3. Organic chemistry reactions and reaction mechanisms.
4. Use of reagents in various organic transformation reactions.

Self-study:

1. Elucidating reaction mechanisms for organic reactions.
2. Organometallic compounds and their uses.
3. Use of active methylene groups in organic mechanism and preparation of new organic compounds.

Unit-I

Chemistry of Halogenated Hydrocarbons:

Alkyl halides: Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_N^i mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.

Aryl halides: Preparation, including preparation from diazonium salts. nucleophilic aromatic substitution; SNAr, Benzyne mechanism.

Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions.

Organometallic compounds of Mg and Li and their use in synthesis.

Unit-II

Alcohols, Phenols, Ethers and Epoxides:

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement.

Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe's–Schmidt Reactions, Fries and Claisen rearrangements with mechanism.

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$

Unit-III

Carbonyl Compounds:

Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin

condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α-substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, PDC and PGC);

Addition reactions of unsaturated carbonyl compounds: Michael addition.

Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

Carboxylic Acids and their Derivatives:

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids; Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.

Sulphur containing compounds:

Preparation and reactions of thiols, thioethers and sulphonic acids.

Recommended Books/references:

1. T. W.G. Solomons and C.B. Fryhle, Organic Chemistry, John Wiley, 8th Edition (2007)

2. McMurry, J.E. *Fundamentals of Organic Chemistry*, Seventh edition Cengage Learning, 2013.

3. P Sykes, *A Guide Book to Mechanism in Organic Chemistry*, 6th Edition (1997), Orient Longman, New Delhi.

4. Morrison R. T. and Boyd R. N. Organic Chemistry, Sixth Edition Prentice Hall India, 2003.

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Organic Chemistry Practical (1 Cr)

(List of experiments given are suggestive. One experiment from each group to be demonstrated)

1.Chromatography

a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography

b. Separation of a mixture of two sugars by ascending paper chromatography

c. Separation of a mixture of *o*-and *p*-nitrophenol or o-and p-aminophenol by thin layer chromatography (TLC).

2. Organic preparations:

i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*-toluidines and *o*-, *m*-, *p*-anisidine) and phenols (β-naphthol, vanillin, salicylic acid) by any one method: (Using conventional method.and Using green chemistry approach)

ii. Benzolyation of one of the amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and one of the phenols (*β*-naphthol, resorcinol, *p*-cresol) by Schotten-Baumann reaction.

iii. Oxidation of ethanol/ isopropanol (Iodoform reaction).

iv. Bromination (any one)

a. Acetanilide by conventional methods

b. Acetanilide using green approach (Bromate-bromide method)

v. Nitration: (any one)

a. Acetanilide/nitrobenzene by conventional method

b. Salicylic acid by green approach (using ceric ammonium nitrate).

vi. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.

vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.

viii. Hydrolysis of amides and esters.

ix. Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.

x. *S*-Benzylisothiouronium salt of one each of water soluble/ insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).

xi. Aldol condensation with either conventional or green method.

xii. Benzil-Benzilic acid rearrangement.

Collected solid samples may be used for recrystallization, melting point and TLC.

Recommended Books/References:

1 Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry*, Pearson Education (2009)

2 Furniss, B.S., Hannaford, A.J., Smith, P.W.G. & Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.* Pearson (2012)

3 Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000)

4 Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000)

Physical Chemistry I (3 Cr)

Learning objective:

1. Familiarization with various states of matter.
2. Physical properties of each state of matter and laws related to describe the states.
3. Calculation of lattice parameters.
4. Electrolytes and electrolytic dissociation, salt hydrolysis and acid-base equilibria.

Course outcome:

1. Understanding Kinetic model of gas and its properties.
2. Maxwell distribution, mean-free path, kinetic energies.
3. Behavior of real gases, its deviation from ideal behavior, equation of state, isotherm, and law of corresponding states.
4. Liquid state and its physical properties related to temperature and pressure variation.
5. Properties of liquid as solvent for various household and commercial use.
6. Solids, lattice parameters – its calculation, application of symmetry, solid characteristics of simple salts.
7. Ionic equilibria – electrolyte, ionization, dissociation.
8. Salt hydrolysis (acid-base hydrolysis) and its application in chemistry.

Self-study:

1. Determination of lattice parameters of given salt.
2. Study of X-Ray diffraction pattern and finding out reference from JCPDI file.
3. Numerical related to salt hydrolysis, ionic equilibria.

Unit-I

Gaseous state:

Behaviour of real gases: Deviations from ideal gas behavior, compressibility factor, and its variation with pressure for different gases. Causes of deviation from ideal behavior. van der Waals equation of state, its derivation and application in explaining real gas behaviour; van der Waals equation expressed in virial form, Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, critical and van der Waals constants, law of corresponding states.

Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Unit-II

Liquid state:

Structure and physical properties of liquids; vapour pressure, surface tension, viscosity, and their dependence on temperature, Effect of addition of various solutes on surface tension, cleansing action of detergents. Structure of water.

Ionic equilibria:

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di- and tri-protic acids.

Salt hydrolysis, hydrolysis constants, degree of hydrolysis and pH for different salts. Buffer solutions; Henderson equation, buffer capacity, buffer range, buffer action, applications of buffers in analytical chemistry, Solubility and solubility product.

Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB) Application of HSAB principle.

Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolytes.

Unit-III

Solid state:

Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Various types of defects in crystals, Glasses and liquid crystals.

Recommended Text books/references:

1. Atkins, P. W. & Paula, J. de *Atkin's Physical Chemistry* 8th Ed., Oxford University Press (2006).

2. Ball, D. W. *Physical Chemistry* Thomson Press, India (2007).

3. Castellan, G. W. *Physical Chemistry* 4th Ed. Narosa (2004).

4. Mortimer, R. G. *Physical Chemistry* 3rd Ed. Elsevier: NOIDA, UP (2009).

5. G. M. Barrow, Physical Chemistry Tata McGraw Hill (Fifth Edition) (2007)

6. K. L. Kapoor, *A Textbook of Physical Chemistry, States of Matter and Ions in Solution (SI Units) - Vol. 1* McGraw Hill Education, Sixth edition (2019)

Physical Chemistry Practical

(A list of suggested experiments are given. However, more experiments can be added based on facilities available in the laboratories).

1. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.
2. Study the equilibrium of at least one of the following reactions by the distribution method:
(i) I_2 (aq) + I^- ---→ I_3^-(aq)
(ii) Cu^{2+}(aq) + $n$$NH_3$ → $Cu(NH_3)_n$
3. Study the kinetics of the following reactions.
a. Acid hydrolysis of methyl acetate with hydrochloric acid.
b. Saponification of ethyl acetate.

Adsorption

Verification of Freundlich and Langmuir isotherms for adsorption of acetic acid and selected organic dye(s) on activated charcoal.
(Use of calorimeter for calculation of heat of reactions may be demonstrated)

Recommended Books/References:

1.Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R. Chand, New Delhi, 2011.
2.Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry,* Eighth Edition, McGraw-Hill(2003).
3 Halpern, A. M. and McBane, G. C. *Experimental Physical Chemistry,* Third Edition, W, H. Freeman (2003).

Minor_for other Dept (3rd sem)

Principles of Chemistry-III (3 Cr)

***Course Learning Objectives (CO)*: This course is intended to introduce students to principles of chemistry such as gaseous state, chemical kinetics, chemical bonding, crystal structure in solids and reaction mechanism in organic chemistry.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have a comprehensive understanding of the development of scientific ideas about principles of chemistry thus creating, evaluating, analyzing, applying, understanding and remembering gaseous state, chemical kinetics, chemical bonding, crystal structure in solids and reaction mechanism in organic chemistry.**

Unit-I

Gaseous state:

Kinetic theory of gases, ideal gas laws and kinetic theory. Collision in a gas- mean free path, collision diameter, collision number. Behaviour of real gases - the van der Waal's equation, brief mention of other equations of state. Critical phenomena - critical constants of a gas and theirdetermination, continuity of state, the van der Waals equation and critical state, Principle of corresponding states, liquefaction of gases.

Chemical Kinetics:

Order and molecularity of a reaction, zero order, first order, second order reaction, half life period, general methods of determination of order of a reaction, Effect of temperature on rate and Arrhenius equation, Activation energy, collision theory and transition state theory, reversible, parallel and consecutive reactions, steady state approximation.

Reaction kinetics: transition state theory, rate constant and free energy of activation, free enegy profiles for one step and two steps reactions, catalyzed reactions, kinetic and thermodynamic control of reactions, isotope effects.

Unit-II

Chemical bonding:

Electrovalent bond-ionic structure, radius ratio effect and coordination number, semiconductors, solvation energy and polarization power and polarizability (Fajan's rule), Covalent bonding – VBT, Heitler-London treatment of hydrogen molecule, Hybridization - sp, sp^2, sp^3, dsp^2, d^2sp^3, dsp^3, sp^3d^2.

Crystal structure of solids:

Fundamental of lattices, unit cell, atomic coordinates, Bravais lattices, crystal direction and planes, types of close packing, packing efficiency, radius ratios; few important crystal structures, Crystal defects.

Unit-III

Basic concept in organic reaction mechanism:

Conformational analysis of organic compounds: conformation vs configuration. Conformation of ethane, n-Butane, cyclohexane. Projection formula.

Mechanistic classification: Ionic, radical and pericyclic (introduction only); homo and heterolytic bond cleavage, representation of mechanistic steps using arrow formalism.

Reactive intermediates: carbocation, carbanion, carbenes, nitrene and ylides – formation, structure and stability.

Reaction thermodynamics: free energy and equilibrium, enthalpy and entropy factor, inter and intra-molecular reactions. Application of thermodynamic principles in tautomeric equilibrium [keto – enol tautomerism, composition of equilibrium in different systems (simple carbonyls, 1,3 and 1,2 – dicarbonyl systems, phenols and related systems), substituents and solvent effects].

Concept of acids and bases: effect of structure, substituents and solvent on acidity and basicity.

Aromatic aldehydes, amines: synthesis and reactions. Azo compounds.

Recommended Books

1. Physical Chemistry, I. Levine, McGraw Hill Higher Education, 6th edition, 2008.
2. Physical Chemistry, G. M. Barrow, McGraw Hill, 5th Edition, 2007
3. Chemical Kinetics, K. J. Laidler, Pearson Education India; 3rd edition 2003
4. Atkins Physical Chemistry, Peter Atkins, Oxford University Press, 8th Edition, 2006
5. Basic Inorganic Chemistry, F. A. Cotton, G. Wilkinson, Wiley; Third edition, 2007
6. Inorganic Chemistry: Principles of Structure and Reactivity, James E Huheey, E. A Keiter, R. L. Keiter, Pearson; 4th edition 1997
7. Reaction mechanism in organic chemistry by Singh & Mukherjee.
8. Advanced organic chemistry by J. March.

Chemistry Practical (Minor group)_1Cr

(A list of suggested experiments are given. However, more experiments can be added based on facilities available in the laboratories).

1. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.
2. Study the equilibrium of at least one of the following reactions by the distribution method:
(i) I_2 (aq) + I^- ---→ I_3^-(aq)
(ii) Cu^{2+}(aq) + $n$$NH_3$ → $Cu(NH_3)_n$
3. Study the kinetics of the following reactions.
a. Acid hydrolysis of methyl acetate with hydrochloric acid.
b. Saponification of ethyl acetate.

Adsorption

Verification of Freundlich and Langmuir isotherms for adsorption of acetic acid and selected organic dye(s) on activated charcoal.
(Use of calorimeter for calculation of heat of reactions may be demonstrated)

Recommended Books/References:

1.Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry,* R. Chand, New Delhi, 2011.
2.Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry,* Eighth Edition, McGraw-Hill(2003).
3 Halpern, A. M. and McBane, G. C. *Experimental Physical Chemistry,* Third Edition, W, H. Freeman (2003).

Skill development course (3 Cr)

(From the list provided)

4th Semester (200 level)

Physical Chemistry-II

Learning objective:

1. Laws of thermodynamics and concepts.
2. Thermochemistry and free energy.
3. Phase equilibria.

Course outcome:

1. Understanding the concept of system, variables, heat, work, and laws of thermodynamics.
2. Understanding the concept of heat of reactions and use of equations in calculations of bond energy, enthalpy, etc.
3. Understanding the concept of entropy; reversible, irreversible processes. Calculation of entropy using 3nd law of thermodynamics.
4. Understanding the application of thermodynamics: Joule Thompson effects, partial molar quantities.
5. Understanding phase diagrams.

Self-study:

1. Use of thermochemical equations for calculation of energy and related terms.
2. Use of thermodynamics in explaining chemical behavior of solute/solvent and reactions.
3. Study of calorimeter principle and its use.

Unit-I

Thermodynamics-I:

Thermodynamics, thermodynamic systems, concept of heat, work and energy, internal energy, definition of thermodynamic terms, system, surrounding, etc. Intensive and extensive properties, state and path functions and differentials, First law of thermodynamics, Reversible and irreversible process, Internal energy and enthalpy, heat capacity at constant volume and pressure

and their relationship, work done in the expansion of ideal gases under isothermal and adiabatic conditions.

Standard enthalpy of formation, Hess's law of constant heat summation, heat of reaction, enthalpy of neutralization, bond dissociation energy and its calculation from thermochemical data, temperature dependence of enthalpy, Kirchoff's equation (derivation included).

Unit II

Thermodynamics-II

Limitation of First law of thermodynamics, Second law of thermodynamics: Different statements of the law, Carnot's cycle and its efficiency, Carnot theorem, thermodynamic scale of temperature, efficiency of heat engines, entropy, entropy and state function, entropy changes in reversible and irreversible processes, Joule-Thompson effect and its consequence, entropy changes in ideal gases and mixing of gases, variation of entropy with temperature, pressure and volume, free energy and work function, Clausius-clapeyron equation, Gibbs-Helmohltz equation, partial molar quantities and their significance, chemical potential, Gibbs- Duhem equation.

Unit-III

Phase Equilibria :

Phase rule, phase, component, degree of freedom, thermodynamic derivation of phase rule, phase diagrams of one component systems (water and sulfur), two component systems (phenol-water, lead-silver, tin-magnesium). The distribution law, applications to cases of dissociation and association of solutes in one of the phases, solvent extraction, equilibrium constant from distribution coefficient ($KI + I_2 = KI_3$)

Books Recommended:

1. P. C. Rakshit, Physical Chemistry, Sarat Book House Calcutta, 7^{th} Edition (2014)
2. B. R. Puri, L. R. Sharma, and M. S. Pathania, Principles of Physical Chemistry, Vishal Publishing Co, 47^{th} Edition (2020)
3. Peter Atkins, Atkins Physical Chemistry, Oxford University Press, 8^{th} Edition (2006)
4. S. Glasstone, Thermodynamics for Chemists, MacMillian

5. K. L. Kapoor, A Text Book of Physical Chemistry Volume 2, McGraw Hill Education, 5th Edition (2015)
6. T. Engel, P. Reid, Physical Chemistry: Thermodynamics, Statistical Thermodynamics, and Kinetics, Pearson; 4th edition (2020)

Inorganic Chemistry-II (3 Credits)

Course Objective of studying Inorganic Chemistry-II:

This course focuses on the basic periodic properties like occurrence, extraction, reactivity, stability etc. of transition metals and their complexes, organometallic compound formation to evaluate their spectral and magnetic properties.

Learning outcome:

Understanding d-and f-block elements.
Understanding transition metal complexes and their spectral and magnetic properties.
Understanding organometallic compounds like Li, Mg, Hg, etc. – their bonding and properties.

Unit-I

Chemistry of Second and Third Transition Elements :

A general comparative treatment of 4d and 5d elements with their 3d analogues in respect of ionic radii, oxidation states, magnetic behaviour and electronic spectral properties.

Unit-II

Chemistry of 'f'-block Elements :

Comparative study of lanthanide elements with respect to electronic configuration, atomic and ionic radii, oxidation states and complex formation; occurrence and principles of separation. General features and chemistry of actinides, principles of separation of Np, Pu and Am from U. Trans-Uranium elements.

Unit-III

Transition Metal Complexes, spectral and magnetic properties:

Different types of ligands; Bonding in transition metal complexes, limitation of VBT, elementary idea about crystal field splitting in octahedral, tetrahedral and square planar complexes, factors affecting crystal field parameters, Crystal Field Stabilization Energy. Electronic transition in transition metal complexes, d-d transition, spectrochemical series, energy level diagram from d1 - d9 states, Jahn-Teller distortion and its significance.

Unit IV

Spectral properties and magnetic properties:

Origin of colour, d-d transition, L-S coupling, Orgel diagram for d1-d9 ions in octahedral and tetrahedral field, spectroscopic ground states, selection rules for spectral transition, spectrochemical series, charge transfer spectra, discussion of electronic spectrum of [Ti(H2O)6]3+ complex ion. Magnetism in complexes: para, dia, ferro and anti-ferro magnetism, magnetic susceptibility, Orbital and spin moments spin only magnetic moments, orbital contributions, quenching of magnetic moments, variations of magnetic susceptibility with temperature,

Recommended books

1. *"Concise Inorganic Chemistry",* J. D. Lee, 5th Edition (1996), Chapman & Hall, London.
2. *"Modern Inorganic Chemistry",* R. C. Aggarwal, 1st Edition (1987), Kitab Mahal, Allahabad.
3. *"Basic Inorganic Chemistry",* F. A Cotton, G. Wilkinson, and Paul L. Gaus, 3rd Edition (1995), John Wiley & Sons, New York.
4. *"Inorganic Chemistry",* A. G. Sharpe, 3rd International Student Edition (1999), ELBS / Longman, U.K.
5. Inorganic Chemistry: Huheey Keiter Keiter
6. Atomic spectra: Harvey Elliatt White

Organic Chemistry-III

Unit-I

Non kinetic and kinetic methods of determination of reaction mechanism:

Non kinetics and kinetic methods: trapping of intermediate, isotropic levelling, cross over expt. Linear free energy relationship: Hammet equation and Taft equation.

Unit – II

Chemistry of Dye Stuffs:

Colour in relation to structure, modern views, synthesis of malachite green, fluorescein and methyl orange. Structure and synthesis of indigo and alizarin. Chemistry of dyeing.

Unit-III

Aromatic Nucleophilic Substitution:

The S_NAr, S_Ni, benzyne mechanisms. Reactivity-effect of substrate structure, leaving group and attacking nucleophile. The von Richter, Sommelet-Hauser, and Smiles rearrangements.

Unit IV

Free Radical Reactions:

Types of free radical reactions: Free radical substitution, mechanism, mechanism at an aromatic substrate, neighbouring group assistance. Reactivity for aliphatic and aromatic substrates at a bridgehead. Reactivity in the attacking radicals. The effect of solvents on reactivity. Birch reduction. Allylic halogenation (NBS), oxidation of aldehydes to carboxylic acids, auto-oxidation, coupling of alkynes and arylation of aromatic compounds by diazonium salts. Sandmeyer reaction, free radical rearrangement, Hunsdiecker reaction.

Books Recommended:

1. Organic chemistry: J. Clayden, N. Greeves, S. Warren and P. Wothers, Oxford University Press, 2nd Edition (2014)
2. Advanced Organic Chemistry Reactions, Mechanism and Structure: Jerry March. Wiley; Seventh edition (2015)

3. Advanced Organic Chemistry Part A and Part B: FA Carey and RJ. Sundberg, Springer, 5th Edition (2008)
4. A Guide Book to Mechanism in Organic Chemistry: Peter Sykes, Longman/Pearson Education. 6th Edition (2003)
5. Structure and Mechanism in Organic Chemistry: CK Ingold. CBS Publishers and Distributors Pvt. Ltd. (2018)
6. Organic Chemistry: R T. Morrison and RN. Boyd, Pearson Education India; 7th edition (2010)
7. Modern Synthetic Reactions: Second Edition, H.O. House, Benjamin, Menlo Park, 1972.
8. Principles of Organic Synthesis: R.O.C. Norman and J.M. Coxon. Blackie Academic and Professional / CBS Publishers.
9. A logical Approach to Modern Organic Chemistry: Dr. Jagdamba Singh and Dr. S. Anandvardhan. Pragati Prakasan.
10. Reaction Mechanism in Organic Chemistry: S. Mukherji and S.P. Singh, Macmillan.
11. Advanced Organic Chemistry: Reactions and Mechanism: B. Miller and R Prasad. Pearson-Education.

Physical Chemistry-Practical (1 Cr)

***Course Learning Objectives (CO)*: This course is intended to introduce students to basic practical skills in physical chemistry laboratory.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have an understanding of the development of scientific ideas about physical chemistry chemistry laboratory**

(A list of suggested experiments are given. However, more experiments can be added based on facilities available in the laboratories).

Conductometry

1 Determination of cell constant

2 Equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

3.Conductometric titrations of: Strong acid Vs. strong base (ii) Weak acid vs. strong base, (iii) Mixture of strong acid and (iv)weak acid vs. strong base, Strong acid vs. weak base.

Potentiometry

Potentiometric titrations of: (i) Strong acid vs. strong base (ii) Weak acid vs. strong base

(iii) Dibasic acid vs. strong base (iv) Potassium dichromate vs. Mohr's salt.

Recommend books/References:

1 Khosla, B. D.; Garg, V. C. and Gulati, A. *Senior Practical Physical Chemistry,* R. Chand New Delhi, 2011.

2 Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry* Eighth Edition*;* McGraw-Hill: New York, 2003.

3 Halpern, A. M. and McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York, 2003.

(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).

Inorganic practical (1 Credits)

***Course Learning Objectives (CO)*: This course is intended to introduce students to basic practical skills in inorganic chemistry laboratory.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have an understanding of the development of scientific ideas about inorganic chemistry laboratory**

1. Standardization of sodium thiosulphate solution and volumetric estimation of Cu(II) iodometrically.
2. Volumetric estimation of Zn(II), Ca(II) and Mg(II) by EDTA titration, using Eriochrome black – T indicator
3. Gravimetric estimation of Nickel(II), using dimethylglyoxime.
4. Estimation of: (a) total manganese content in manganese ore (pyrolusite);
   (b) total iron content in Fe_2O_3 (haematite).
5. To study the composition of ferric-sulfosalicylic acid complex by Job's method of continuous variation, and to determine the stability of the complex, spectrophotometrically.
6. Determination of the composition of a binary mixture (potassium dichromate and potassium permanganate) spectrophotometrically.
7. Estimation of calcium in milk powder through EDTA complexometry
8. Synthesis of Rinecke Salt, $NH_4[Cr(NCS)_4(NH_3)_2].H_2O$, and study of its UV-Visible and IR spectra.
9. Estimation of potassium ions in coconut water, by Flame Photometry.

Recommended Books

1. Vogel's Text Book of Qualitative Chemical Analysis, G. H. Jeffery, J. Bassett, J. Mendham and R. C. Denny, 5th Edn., ELBS, 1991.
2. A Collection of General Chemistry Experiments, A. J. Elias, Universities Press, 2007.

Organic practical (1 Cr)

***Course Learning Objectives (CO)*: This course is intended to introduce students to advanced practical skills in organic chemistry laboratory.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have an understanding of the development of advanced scientific ideas about organic chemistry laboratory**

1. Trapping of free radical
2. Quenching a reaction
3. Formation of Benzyne from Anthranilic acid and its reaction with nucleophiles
4. Allylic bromination using NBS
5. Sandmayer's reaction
6. Arylation of aromatic compounds by diazonium salts
7. Synthesis of some dyes

Seminar paper (2 Cr)

The student need to prepare for himself for a given topic of choice in discussion with mentor/faculty member. It is expected that the student should be able to understand collection of reference books/journal. He is expected to present the topic to the examiner(s) with his (i). systematic and coherent understanding of the fundamental concepts in Physical chemistry, Organic Chemistry, Inorganic Chemistry, Analytical Chemistry and all other related allied chemistry subjects.

(ii). A number of academic and research options are available to students in various fields such as pharmaceuticals, food products, environmental monitoring and assessments, environmental chemistry, fuel chemistry, cosmetic chemistry, biochemistry, biomaterials, nano-chemistry, materials chemistry, polymer chemistry, industrial chemistry, water chemistry, etc. in addition to physical, organic and inorganic chemistry that a student can explore for choosing a professional career.

(iii). The student can apply appropriate methodology to conduct chemical syntheses, analysis and chemical investigations with relevant knowledge and skills.

(iv).Further, use of ICT/MOOCs can enhance broader scope of the subjects.

(v). Learning outcome also includes finding sustainable solution to societal need in an appropriate scientific manner.

Minor for 4th Sem

Environmental Chemistry (4 Cr)

Unit-I

Environment: Composition of atmosphere, temperature variation of earth atmospheric system (temperature vs. altitude curve), biogeochemical cycles of C, N, P, S and O system.

Hydrosphere: Hydrological cycle, aquatic pollution and water quality parameters – Dissolve oxygen, biochemical oxygen demand, chemical oxygen demand with determination, Analytical methods for the determination fluoride, chromium and arsenic, residual chlorine and chlorine demand, purification and treatment of municipal water and waste water.

Unit-II

Atmosphere: Chemical composition of atmosphere – particle, ions, and radicals in their formation, chemical and photochemical reactions in atmosphere, smog formation, oxides of N, C, S, and O and their effect, pollution by chemicals, CFC, Green House effect, acid rain, air pollution and control.

Unit-III

Aquatic chemistry: Water and its necessities, various water quality parameters (DO, BOD, COD, conductivity, pH, alkalinity, hardness) and its determination, Industrial, municipal water treatment processes, Waste water treatment procedure (primary, secondary and tertiary), Solid waste treatment.

Unit IV

Soil pollution and Noise pollution. e-waste and its management.

Reference Books:

1. De. A. K. Environmental Chemistry, Wiley Eastern ltd,
2. Miller T.G. Jr., Environmental Science, Wadsworth publishing House, Meerut Odum. E. P. 1971.
3. Fundamental of Ecology. W.B. Saunders Co.U.S.A.
4. Environmental chemistry: S. E. Manahan, Lewis publisher
5. Environmental chemistry, Sharma and Kaur, Krishna publishers
6. Environmental chemistry, A. K. De, Wiley Eastern
7. Environmental Pollution, Monitoring and control, S.M. Khopker, New Age International.
8. Environmental chemistry, C. Baird, W.H. Freeman.
9. Principles of instrumental analysis: D. A. Skoog, 5th edn, Sauns College Publishing Philadelphia (London).
10. Basic concepts of analytical chemistry: S.M.Khopkar, Wiley Eastern

5th Semester (300 level course)

Physical Chemistry III (3 Cr)

Learning objective:
Introduction to Quantum chemistry.
Molecular Spectroscopy
Photochemistry

Course outcome:
Basic understanding of quantum chemistry, molecular spectroscopy and photochemistry.
Applying the concepts to some standard systems.
Draw connection among ideas and solve numerical problems

Self-study:

Quantum chemistry using computers.
Correlation between molecular and organic spectroscopy

Unit-I

Introduction to Quantum Chemistry:

A review of the black body radiation and the old quantum theory. The wave nature of electron. The Uncertainty Principle. Schrödinger's wave mechanics. Eigenfunctions and normalizations. Quantum mechanical operators. Expectation value of a physical quantity. Orthogonality of wave

functions. The particle in a one dimensional box problem and its solutions. Particle in a three dimensional box. Degeneracy. The hydrogen atom problem.

Unit-II

Molecular Spectroscopy :

Emission and absorption spectra. Transition probabilities and selection rules. Pure rotational spectra. Diatomic molecules. Rigid rotor model. Linear triatomic molecules. Vibrationalrotational spectra. Diatomic molecules. Harmonic oscillator-rigid rotor approximation. Anharmonicity effect. Normal modes of vibration. Infrared spectra of linear and bent AB2 molecules. Characteristic group frequencies. Electronic spectra of diatomic molecules. Vibrational structure. Franck-Condon principle.

Unit-III

Photochemistry:

Photophysical and Photochemical processes: Introduction; excitation and the excited states; laws of photochemistry: Grotthus-Draper's Law, Einstein's law of photochemical equivalence; quantum yield. Jablonski diagram: Franck-Condon principle, Law of photochemical equivalence, quantum efficiency, reasons for low and high quantum efficiency. Kinetics of photochemical reactions ($H_2 + Br_2 = HBr$, $2HI = H_2 + I_2$), fluorescence, phosphorescence, and chemiluminescence with example.

Reference books:

1. Atkins Physical Chemistry, Peter Atkins, Oxford University Press, 8th Edition, 2006.
2. Physical chemistry: a molecular approach, Donald A. McQuarrie, and John D. Simon, Viva Books, First Edition, 2019
3. Quantum Chemistry, R K Prasad, NEW AGE; Fourth edition, 2020
4. Fundamentals of Molecular Spectroscopy, Colin N Banwell, McGraw Hill Education; Fourth edition, 2017
5. A Textbook of Physical Chemistry - Quantum Chemistry and Molecular Spectroscopy, K. L. Kapoor, Volume 4, McGraw-Hill, 6th Edition, 2020
6. Fundamentals of Photochemistry, K. K. Rohatgi, New Age Publishers; Third edition, 2017

Inorganic chem-III (3 Cr)

Unit-I

1. **Representative Chemistry of Main Group Elements**

   a. Organometallic chemistry of lithium and magnesium: synthesis, structure and reactivity.
   b. Chemistry of boron: Boranes, bonding in boranes, topology of boranes and higher boranes, synthesis and reactivity, Carboranes and metallacarboranes. New Lewis acids based on boron; polymer-supported Lewis acids.
   c. Chemistry of Aluminum: Aluminum alkyls and their uses in polymerization of olefins.
   d. C_{60} and carbon nanotubes: discovery, preparation and selected reactions.
   e. Chemistry of Silicon: Organosilicon compounds, Silicates and aluminosilicates.

Unit-II

2. **Unusual Compounds of Main Group Elements**

   Chemistry of multiple bonding: Multiple bonding in heavier main group elements. Unusual compounds of main group elements: (i) Si=Si, Si≡Si, P=P double bond, Bi-Bi double bond. Synthesis, structure and reactivity.

   a. Chemistry of low valent compounds: Synthesis, structure and bonding models and reactivity; examples of Al(I), Si(II) low valent compounds.
   b. Inorganic rings and polymers. Cyclo- and heterocyclophosphazenes and the polymers derived from them. Polysilanes. Borazine and boron nitride.
   c. Chemistry of halides of noble gases: recent trends. CFC's and ozone layer depletion.

Unit-III

3. Organometallic Chemistry

(a) σ – bonded ligands:
Metal - carbonyls / Metal - phosphines / metal - nitrosyls / metal isocyanide: structure, reactivity and bonding.
Metal - carbenes, metal - carbynes, Fischer carbenes, Schrock carbenes, N-heterocyclic carbenes, olefin metathesis.

(b) π - bonded ligands:
Metal-olefins, metal-alkynes, metal-dienes, Metal-Cp Metal-Cp* complexes : Synthesis, structure, bonding and reactivity.

Unit-IV

4. **Applications of organometallics in organic synthesis:**
   (c) C-C bond coupling reactions (Heck, Sonogoshira, Suzuki).
   (d) Reduction reactions using transition metal hydrides; asymmetric hydrogenation, hydroxylation, hydroformylation.

Recommended Books:

1. Organometallics: A Concise Introduction, C. Elschenbroich and A. Salzer, 3rd Edn. 1999.
2. Chemistry of the Elements, N. N. Greenwood and A. Earnshaw, 2nd Edn., Elsevier, 2005.
3. Modern Inorganic Chemistry, W. L. Jolly, McGraw Hill, New York, 2nd Edn., 1991.
4. Concepts and Models of Inorganic Chemistry, B. Douglas, D. McDaniel and J. Alexander, John Wiley, New York, 3rd Edn., 1993.
5. Organometallic Chemistry of the Transition Metals, R. H. Crabtree, Wiley, New York, 1988.

Heterocyclic chemistry-I (3 Cr)

***Course Learning Objectives (CO)*: This course is intended to introduce students to heterocyclic chemistry.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have a comprehensive understanding of the development of scientific ideas about heterocyclic chemistry thus creating, evaluating, analyzing, applying, understanding and remembering three, four, five and six member rings.**

Unit -I

Three-membered rings with one heteroatom: Chemistry of oxiranes, aziridines and episulphides - synthetic approaches and reactivities.

Unit-II

Four-membered heterocycles: oxitanes, azatidanes and thietanes - synthetic approaches and reactivities.

Five-membered aromatic heterocycles:

a) With one heteroatom: furans, pyrroles and thiophenes - general synthetic approaches, properties and reactivities.

b) With two heteroatoms: oxazoles, isoxazoles, imidazoles, thiazoles, pyrazoles and isothiazoles - general synthetic approaches and reactivities.

c) With three and four heteroatoms: triazoles and tetrazoles - synthetic approaches and reactivity.

Unit-III

Condensed five-membered Heterocycles:
Benzofuran, indoles and benzothiazoles, benzimidazole - general synthetic approaches, with greater emphasis on the chemistry of Indoles

Six-membered Heterocycles with one, two and three heteroatoms:

a) Chemistry of pyridine group;
b) Chemistry of pyridazines and pyrimidines.
c) Chemistry of pyrazines and triazines.

Recommended Books

1. Principles of Modern Heterocyclic Chemistry, L. A. Paquette, W. A. Benjamin, New York, 1968.
2. Heterocyclic Chemistry, J.A. Joule and G. F. Smith, van Nostrand, London, 1978.
3. Comprehensive Heterocyclic Chemistry. The structure, reactions, synthesis and use of Heterocyclic compounds, (Ed. A.R. Katritzky and C. W. Rees), Vol 1-8, Pergamon Press, 1984.
4. Heterocyclic chemistry: Parikh

Inorganic Practical (1 Cr)

1.Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given on understanding of the chemistry of different reactions. Following radicals may be analyzed:

Carbonate, nitrate, nitrite, sulphide, sulphate, sulphite, acetate, fluoride, chloride, bromide, iodide, borate, oxalate, phosphate, ammonium, potassium, lead, copper, cadmium, bismuth, tin, iron, aluminum, chromium, zinc, manganese, cobalt, nickel, barium strontium, calcium, magnesium. Mixtures containing one interfering anion, or insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) **or** combination of anions e.g. $CO_3^{2-}$and SO_3^{2-}, NO_2^- and NO_3^-,Cl^- and Br^-, Cl^- and I^-, $Br^-$and I^-, NO_3^- and Br^-, NO_3^- and I^-. Spot analysis/tests should be done whenever possible.

2. Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs thermodynamic factors.

3. Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}. (Also find the λ_{max} of the prepared complex using instrument).

4. Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

Recommended text books/references:

1. Vogel's *Qualitative Inorganic Analysis*, Revised by G. Svehla. Pearson Education, 2002.

2. Marr & Rockett *Practical Inorganic Chemistry.* John Wiley & Sons 1972.

Organic Chemistry Practical (1 Cr)

(List of experiments given are suggestive. One experiment from each group to be demonstrated)

Organic Prepartion

i. Oxidation of ethanol/ isopropanol (Iodoform reaction).

ii. Bromination (any one)

a. Acetanilide by conventional methods

b. Acetanilide using green approach (Bromate-bromide method)

iii. Nitration: (any one)

a. Acetanilide/nitrobenzene by conventional method

b. Salicylic acid by green approach (using ceric ammonium nitrate).

iv. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.

v. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.

vi. Hydrolysis of amides and esters.

vii. Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.

viii. *S*-Benzylisothiouronium salt of one each of water soluble/ insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).

ix. Aldol condensation with either conventional or green method.

x. Benzil-Benzilic acid rearrangement.

Collected solid samples may be used for recrystallization, melting point and TLC.

(Heterocyclic Chemistry practical)

After gaining knowledge in basic synthesis of organic chemistry, synthesis of Pyrrazole, imidazole, pyrimidine, derivatives; Synthesis of Benzimidazole, benzthiazole, Indole derivatives; Some reactions of isatin may be attempted.

Seminar (1 Cr)

Minor Chemistry

Materials Chemistry (4 Cr)

Unit-I

Crystal structure of solids:

Fundamental of lattices, unit cell, atomic coordinates, Bravais lattices, crystal direction and planes, types of close packing, packing efficiency, radius ratios; few important crystal structures.

Synthesis of Inorganic solids:

Solid state, solution phase and vapour phase synthesis; precipitation, hydrothermal, sol-gel, surfactant based synthesis. Growth of single crystals.

Crystal structure determination:

X-ray diffraction, d-spacing formula, symmetrically absent reflections, Multiplicities, Scattering of X-rays by an atom and a crystal. Single crystal and powder diffraction. Electron and neutron diffraction. Concept of reciprocal lattice. Electron microscopy techniques.

Unit-II

Basics Nanomaterials Synthesis Methods:

Bottom-up vs. Top-down Methods. Solution phase synthetic methods. Role of surfactant in shape and size control of nanomaterials. Synthesis of nanowires and nanotubes by CVD and MOCVD method.

Nanomaterials Characterization:

XRD of nanomaterials, Electron microscopy (SEM, TEM, HRTEM and EDX) of nanomaterials, Scanning probe microscopy.

Nanomaterial properties and applications:

Magnetic properties of nanoparticles; superparamagnetism, ferromagnetism in antiferromagnetic nanoparticles and single domain to multidomain transition. Use of magnetic nanoparticles as MRI contrast agents. Nanomaterial in catalysis.

Unit-III

Frontier areas of polymer science and technology:

Conducting polymers: basic principles of conducting polymers, delocalized electronic states of conjugated polymers, polyanilines, polyacetylenes, polythiophenes, applications of conducting polymers. Biodegradable polymers: Definition classification of natural biodegradable polymers, cellulose, cellulose acetate, cellophane, soy protein, corn, zein protein, wheat gluten protein, synthetic biodegradable polymers, polyhydroxy alkanoates, polycarpolactone, poly(vinyl alcohol), polyacetic acid, application of

biodegradable and biomedical polymers, contact lens, dental polymers, artificial heart, kidney, skin, and blood cells.

Fibers:

Natural fibers, cotton, wool, silk, rayon, artificial fibers, polyamides, acrylic acid, PVC, PVA.

Rubber: Compounding and elastomeric properties, vulcanization, reinforcement.

Books and References:

1. Zhen Guo and Li Tan, *Fundamentals and Applications of Nanomaterials*.
2. Physical methods in chemistry: R. S. Drago, Saunders college.
3. Polymer science, V. R. Gowariker, N. V.Viswanathan, J. Sreedhar, New Age International.
4. Principle of polymer chemistry: P. J. Flory

Polymer Science and technology, Plastics, Rubber and composites, P. Ghosh, Tata McGraw Hill.

Semester –VI (300 level course)

Physical Chemistry-IV (3 Cr)

***Course Learning Objectives (CO)*: This course is intended to introduce students to Physical Chemistry with emphasis of chemical kinetics, thermodynamics of solution and electrochemistry.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have an understanding of the development of scientific ideas about physical chemistry Physical Chemistry with emphasis of chemical kinetics, thermodynamics of solution and electrochemistry**

Unit-I

Chemical Kinetics :

Order and molecularity of a reaction, zero order, first order, second order reaction, half life period, general methods of determination of order of a reaction, Effect of temperature on rate and Arrhenius equation, Activation energy, collision theory and transition state theory, reversible, parallel and consecutive reactions, steady state approximation. Reaction kinetics: transition state

theory, rate constant and free energy of activation, free enegy profiles for one step and two steps reactions, catalyzed reactions, kinetic and thermodynamic control of reactions, isotope.

Unit-II

Thermodynamics of Solutions:

Partial molal quantities, chemical potential, the Gibbs-Duhem equation, determination of partial molal quantities, variation of chemical potential with temperature and pressure, chemical potential in case of a system of ideal gases, chemical potential of real gases and fugacity, activity and activity coefficient (concept and physical significance), reference and standard states. Variation of fugacity with temperature and pressure, Lewis-Randall rule, thermodynamic functions of mixing (ΔG_{mix} , ΔS_{mix} , ΔV_{mix} , ΔH_{mix}), ideal solutions and their characteristic properties, Duhem- Margules equation and its application, Henry and Raoult's law. Thermodynamics of colligative properties **:** Freezing point depression, elevation of boiling point, osmotic pressure. van't Hoff equation. Measurement of osmotic pressure and determination of molecular weight of macromolecules.

Unit-III

Electrochemistry

Electrolytic conductance, mechanisms of electrolytic conductance, Laws of electrolysis, relationship between conductance-specific conductance-equivalent conductance, cell constant, variation of molar conductance with dilution, Arrhenius theory of electrolytic dissociation, classification of electrolytes; Hydrolysis of salts, hydrolysis constant, Migration of ions: transference number and its determination (Hittorf and Moving Boundary methods). Conductance of solutions, variation of molar conductance with concentration (Kohlrausch square root law), Kohlrausch law of independent migration of ions, ionic mobility, hydration of ions, application of conductance measurements. Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements

References:

1. “Physical Chemistry”, P. C. Rakshit, 5th Edition (1985), 4th Reprint (1997), Sarat Book House, Calcutta.
2. “Principles of Physical Chemistry”, B. R. Puri, L. R. Sharma, and M. S. Pathania, 37th Edition (1998), Shoban Lal Nagin Chand & Co., Jalandhar.
3. “Physical Chemistry”, K. J. Laidler and J. M. Meiser, 3rd Edition, Houghton Mifflin Comp., New York, International Edition (1999).
4. “Physical Chemistry”, I. N. Levine, 4th Edition (International Edition, 1995), Mc Graw-Hill Inc., New York.
5. “Physical Chemistry - A Molecular Approach”, D. A. McQuarrie and J. D. Simon, South Asian Edition (1998), University Science Books, Sausalito CA, by Viva Books, New Delhi.
6. Atkins Physical Chemistry, Peter Atkins, Oxford University Press, 8th Edition (2006)
7. An Introduction to Electrochemistry, Samuel Glasstone, East-West Press (Pvt.) Ltd. (2006)

Physical Chemistry Practical (2 Cr)

***Course Learning Objectives (CO)*: This course is intended to introduce students to principles of physical chemistry laboratory.**

***Course Learning Outcomes (CLO)*: After the completion of the course, the students will have a comprehensive understanding of the development of scientific ideas about principles of physical chemistry laboratory**

1. Acid hydrolysis of methyl acetate with hydrochloric acid.
2. Saponification of ethyl acetate.
3. Determination of cell constant.
4. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
5. Perform the following conductometric titrations:

i. Strong acid vs. strong base
ii. Weak acid vs. strong base
iii. Strong acid vs. weak base

6. Potentiometry

I Perform the following potentiometric titrations:

i. Strong acid vs. strong base
ii. Weak acid vs. strong base
iii. Dibasic acid vs. strong base

Organic Chemistry Practical (2 Cr)

1. Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, for e.g. salicylic acid, cinnamic acid, nitrophenols, etc.

2. Identification of functional groups of simple organic compounds by IR spectroscopy and NMR spectroscopy (IR and NMR of simple organic compounds may be done wherever facilities

are available, otherwise sample spectra may be provided for simple organic compounds like Ethanol, Aniline, Phenol, acetic acid, other simple aldehydes, carboxylic acid, etc., for identification of functional groups. References from standard spectroscopy books may also be taken for such purpose for enhancing students understanding and skill).

3. Preparation of methyl orange.

4. Extraction of caffeine from tea leaves.

5. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars using simple lab procedures.

Recommended Books/References:

1.Vogel, A.I. *Quantitative Organic Analysis,* Part 3, Pearson (2012).

2. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)

3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012)

4. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).

5. Ahluwalia, V.K. & Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).

Inorganic Chemistry-III (Nuclear & Radiation Chemistry) (3 Cr)

Course Objective of studying Nuclear & Radiation Chemistry:

Students could be able to understand general concept of nuclear model, principles underlying the measurement of radiation, how various form of electromagnetic radiation are emitted, and to describe the forms of energy in three main stages of nuclear reactions.

Learning outcome:

1. Understanding classification of nuclides, nuclear stability and nuclear models.
2. Understanding radio-active decay and decay kinetics.
3. Understanding quantum radio-active isotopes separation and analysis.

Unit I: Classification of nuclides, nuclear stability, binding energy and nuclear models. Characteristics of radioactive decay, decay kinetics, parent-daughter decay growth relationships,

Unit II: 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.

Unit III: Nuclear fission, nuclear fuels and nuclear reactors, nuclear fuel reprocessing, fast breeder reactors, radiological safety aspects and radioactive waste managements.

Unit IV: Interaction of radiation with matter, effect of ionizing/non-ionizing radiations on water, aqueous solutions and on 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. Precautionary measures.

Recommended Books

1. G. Friendlander, J.W. Kennedy & J.M. Miller Nuclear and Radiochemistry, Wiley Interscience,
New York.
2. B.G. Harvey, Introduction to Nuclear Physics & Chemistry, Prentice - Hall, Englewood Cliffs (N.J)/ Prentice-Hall, India, EEE Edn.
3. R.T. Overman, Basic concept of Nuclear Chemistry, Chapman & Hall.
4. A. N. Nesmeyanov, Radiochemistry, MIR Publication, Moscow.
5. J.W.T. Spinks & R.J. Woods, An Introduction to Radiation Chemistry, Wiley, New York.
6. H. J. Arnikar, Essentials of Nuclear Chemistry, Wiley Eastern Ltd., 2nd Edition.

Organic Spectroscopy (3 Cr)

Unit-I

Basic Principles of UV Spectroscopy:

Application of Woodward-Fiser rule in interpretation of Organic compounds.

Basic principles of IR Spectroscopy:

Identification of Functional groups of various classes of organic compounds,

Unit-II

NMR (^{1}H and ^{13}C NMR):

Application of Chemical Shifts, Splitting of signals, Spin coupling and Over Houser effect in interpretation of NMR spectra, Significance of decoupling phenomenon and Isotopic exchange reaction in NMR.

Unit-III

Basic principles Mass Spectrometry:

Application of fragmentation rule in characterization of organic compounds. Problems on structure elucidation of organic compounds based on spectral data.

Recommended Books

1. I Flemming & B.H.Williams, T.C. Mornil (4th edition) McGraw Hill Book Company 1987.
2. R.M. Silverstein, G.C. Bassler, T. C. Mornil (5th edition) John Wiley & Sons, Inc New York,
3. John R. Dyer, Applications of absorption spectroscopy of organic compounds, PHI, 2012.
4. Spectroscopy by P. S. Kalsi.

Spectroscopy by Parikh.

MINOR Chemistry

Polymer Chemistry (4 Cr)

Unit-I:

Introduction to polymer:

Polymer, monomer, examples of polymers, biopolymers, classification, polymerization process, degree of polymerization, condensation, addition polymers, kinetics of addition polymerization process.

Polymer Structure and Property Relationship:

Structure of polymers - Linear, branched, cross linked, and network polymers, molecular weight (number average, weight average, viscosity average) and distribution of molecular weight, polydispersity index, crystallinity in polymer, melting temperature and glass transition temperature, Volumetric properties - molar volume, density, Van der Waals volume - Coefficient of linear thermal expansion and volumetric thermal expansion - Pressure volume temperature (PVT) relationship.

Unit-II

Polymerization Chemistry:

Industrial methods of polymerization such as a bulk, solution, emulsion, suspension. Stereochemistry of polymers and stereo-specific polymerization, Catalysts-their utility in polymers and stereo-specific polymerizations, Catalysts-their utility in polymer manufacture, Zieglar-Natta, Metallocene and others.

Unit-III

Polymer Characterization:

Molecular Weight Determination by Light Scattering, Osmometry, End-Group Analysis, Viscosity, Gel Permeation Chromatography; Application, of FTIR, UV-visible, NMR, and Mass Spectroscopy for Identification of polymers.

Reference Books

1. D.W. Van Krevelen And P.J. Hoftyzen, "Properties Of Polymer , 3rd Edition Elsevier Scientific, Publishing Company Amsterdam - Oxford - Newyork. 1990.
2. J.E. Mark Ed.AIP, Physical Properties Of Polymers Hand Book, Williston, Vt, 1996.
3. Reaction Engineering of Step Growth Polymerization, S K Gupta and Anil Kumar, Plenum Press, 1987
4. Odian; George, Principles of Polymerization, McGraw-Hill Book Co., New York (1970)

Billmeyer Jr.; Fred W., Textbook of Polymer Science, Wiley- Interscience Publishers, New York (1962).

Minor Research (2 Cr)

A student at the beginning of the semester shall chose a topic in consultation with Mentor/Faculty member/Guide. The student is expected to carry out some lab work related to the work and the same shall be presented before the faculty committee/examiner during the end semester examination. The student is expected to give presentation regarding progress in the work in regular interval during the continuation of semester. In addition to work, a write up of the work carried out shall be submitted to the Head of the Dept. The student is expected to learn Referencing (Books, Journals, monographs, etc.). The foundation laid in the progress of the work shall be carred forwarded to subsequent semester in consultation with mentor/guide/faculty member. Student may chose co-guide appropriately within the Dept/outside the Dept (with School), within the University and/or from other Universities/Institute of repute as per the procedure. It is expected that the Student's this project/minor research work shall be a foundation stone for his/her career in Research/Academics.