St Aloysius College (Autonomous)

Mangaluru

Re-accredited by NAAC "A" Grade

Course structure and syllabus of

B.Sc.

CHEMISTRY

CHOICE BASED CREDIT SYSTEM

(2020 – 21 ONWARDS)

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(ಸ್ವಾಯತ್ತ)

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Re-accredited by NAAC with 'A' Grade - CGPA 3.62
Recognised by UGC as "College with Potential for Excellence"
College with 'STAR STATUS' conferred by DBT, Government of India
3rd Rank in "Swacch Campus" Scheme, by MHRD, Govt of India

Date: 25-06-2020

NOTIFICATION

Sub: Syllabus of **B.Sc. Chemistry** under Choice Based Credit System.

Ref: 1. Decision of the Academic Council meeting held on 09-06-2020 vide Agenda No: 10(2020-21)
2. Office Notification dated 25-06-2020

Pursuant to the above, the Syllabus of **B.Sc. Chemistry** under Choice Based Credit System which was approved by the Academic Council at its meeting held on 09-06-2020 is hereby notified for implementation with effect from the academic year **2020-21**.

PRINCIPAL **REGISTRAR**

To:

1. The Chairman/Dean/HOD.
2. The Registrar Office
3. Library

Aims of study of chemistry in B Sc degree programme

The overall aims of study of Chemistry in bachelor's degree programme is to:

- Provide students with learning experiences that help instil deep interests in learning chemistry
- Develop broad and balanced knowledge and understanding of key chemical concepts, principles, and theories related to chemistry
- Equip students with appropriate tools of analysis to tackle issues and problems in the field of chemistry.
- Develop in students the ability to apply the knowledge and skills they have acquired to the solution of specific theoretical and applied problems in chemistry.
- Provide students with the knowledge and skill base that would enable them to undertake further studies in chemistry and related areas or in multidisciplinary areas that involve chemistry and help develop a range of generic skills that are relevant to wage employment, self-employment and entrepreneurship.

Graduate Attributes

Graduate Attributes (GA) are the qualities, skills and understandings that students should develop during their time with St Aloysius College (Autonomous). These are qualities that also prepare graduates as agents of social good in future.

The expected attributes of a graduate in chemistry are:

Disciplinary knowledge and skills: Capable of demonstrating (i) comprehensive knowledge and understanding of major concepts, theoretical principles and experimental findings in chemistry and its different subfields (analytical, inorganic, organic and physical), and other related fields of study, including broader interdisciplinary subfields such as life science, environmental science and material sciences; (ii) ability to use modern instrumentation for chemical analysis and separation.

Skilled communicator: Ability to transmit complex technical information relating to chemistry in a clear and concise manner in writing and orally skills.

Critical thinker and problem solver: Ability to employ critical thinking and efficient problem-solving skills in the four basic areas of chemistry (analytical, inorganic, organic, and physical).

Sense of inquiry: Capability for asking relevant/appropriate questions relating to issues and problems in the field of chemistry, and planning, executing and reporting the results of an experiment or investigation.

***Team player/worker**:* Capable of working effectively in diverse teams in both classroom, laboratory and in industry and field-based situations.

Skilled project manager: Capable of identifying/mobilising appropriate resources required for a project, and manage a project through to completion, while observing responsible and ethical scientific conduct; and safety and chemical hygiene regulations and practices.

Digitally literate: Capable of using computers for chemical simulation and computation and appropriate software for analysis of data, and employing modern library search tools to locate, retrieve, and evaluate chemistry-related information.

Ethical awareness/reasoning: Avoiding unethical behaviour such as fabrication, falsification or misrepresentation of data or committing plagiarism, and appreciate environmental and sustainability issues.

Lifelong learners: Capable of self-paced and self-directed learning aimed at personal development and for improving knowledge/skill development and reskilling.

Qualification descriptors

Following are the qualification descriptors for a Chemistry student at Bachelor level at St Aloysius College (Autonomous):

- Demonstrate (i) a fundamental/systematic or coherent understanding of the academic field of chemistry, its different learning areas and applications, and its linkages with related disciplinary areas/subjects; (ii) procedural knowledge that creates different types of professionals related to chemistry area of study, including research and development, teaching and government and public service; (iii) skills in areas related to specialization area relating the subfields and current developments in the academic field of chemistry.
- Use knowledge, understanding and skills required for identifying problems and issues relating to chemistry, collection of relevant quantitative and/or qualitative data drawing on a wide range of sources, and their application, analysis and evaluation using methodologies as appropriate to the subject(s) for formulating evidence-based solutions and arguments.
- Communicate the results of studies undertaken accurately in a range of different contexts using the main concepts, constructs and techniques of the subject(s).
- Meet one's own learning needs, drawing on a range of current research and development work and professional materials.
- Apply one's subject knowledge and transferable skills to new/unfamiliar contexts to identify and analyse problems and issues and solve complex problems with well-defined solutions.

- Demonstrate subject-related and transferable skills that are relevant to chemistry related job trades and employment opportunities.

Programme learning outcomes

The programme learning outcomes relating to chemistry in B.Sc. degree at St Aloysius College (Autonomous) are:

- Demonstrate (i) a systematic or coherent understanding of the fundamental concepts, principles and processes underlying the academic field of chemistry, its different subfields (analytical, inorganic, organic and physical), and its linkages with related disciplinary areas/subjects; (ii) procedural knowledge that creates different types of professionals in the field of chemistry and related fields such as pharmaceuticals, chemical industry, teaching, research, environmental monitoring, product quality, consumer goods industry, food products, cosmetics industry, etc.; (iii) skills related to specialisation areas within chemistry as well as within subfields of chemistry (analytical, inorganic, organic and physical), and other related fields of study, including broader interdisciplinary subfields (life, environmental and material sciences).
- Apply appropriate methodologies in order to conduct chemical syntheses, analyses or other chemical investigations; and apply relevant knowledge and skills to seek solutions to problems that emerge from the subfields of chemistry as well as from broader interdisciplinary subfields relating to chemistry
- Use chemical techniques relevant to academia and industry, generic skills and global competencies, including knowledge and skills that enable students to undertake further studies in the field of chemistry or a related field, and work in the chemical and non-chemical industry sectors.
- Undertake hands on lab work and practical activities which develop problem solving abilities required for successful career in pharmaceuticals, chemical industry, teaching, research, environmental monitoring, product quality, consumer goods industry, food products, cosmetics industry, etc.
- Recognize and appreciate the importance of the chemical sciences and its application in an academic, industrial, economic, environmental and social contexts.

CHEMISTRY 2020-21

COURSE PATTERN

Course No & Paper / Practical	Teaching Hours per week	Duration of Exam (Hours)	Marks		
			I A	Exam	Total
FIRST SEMESTER					
G502.1: Chemistry Paper I	4	3	20	80	100
G502.1P: Chemistry Practical I	3	3	10	40	50
G502.1E: Essentials of Practical Chemistry	2	2	10	40	50
SECOND SEMESTER					
G502.2: Chemistry Paper II	4	3	20	80	100
G502.2P: Chemistry Practical II	3	3	10	40	50
G502.2E: Food and Industrial Chemistry	2	2	10	40	50
THIRD SEMESTER					
G502.3: Chemistry Paper III	4	3	20	80	100
G502.3P: Chemistry Practical III	3	3	10	40	50
G502.3E: Environmental Chemistry	2	2	10	40	50
FOURTH SEMESTER					
G502.4: Chemistry Paper IV	4	3	20	80	100
G502.4P: Chemistry Practical IV	3	3	10	40	50
G502.4E: Chemistry in Everyday Life	2	2	10	40	50
FIFTH SEMESTER					
G502.5a: Chemistry Paper V	3	3	20	80	100
G502.5b: Chemistry Paper VI	3	3	20	80	100
G502.5P: Chemistry Practical V	4	4	20	80	100
SIXTH SEMESTER					
G502.6a: Chemistry Paper VII	3	3	20	80	100
G502.6b: Chemistry Paper VIII	3	3	20	80	100
G502.6P: Chemistry Practical VI	4	4	20	80	100

PATTERN OF THEORY QUESTION PAPERS

- Question Papers shall consist of Parts A, B and C.
- The Syllabus of each paper shall be grouped into four (4) units (I, II, III, IV semester) and (3) units (V and VI semester).
- The question papers shall consist of Parts A, B and C containing questions drawn equally from each unit.
- Part A shall contain twelve short answer (1 to 3 sentences) type questions carrying 2 marks each drawn equally from each unit of the syllabus. Ten questions are to be answered.
- Part B shall contain twelve questions (to be answered in 2 to 5 sentences) carrying 3 marks each drawn equally from each unit of the syllabus. Ten questions are to be answered.
- Part C shall contain 12 questions carrying 5 marks each drawn equally from each unit. Ten questions are to be answered.

PATTERN OF QUESTION PAPER (Open Elective Papers)

- Question paper shall consist of Parts A, B and C containing questions drawn equally from each unit of the syllabus.
- Part A shall contain 6 short answer (1 to 3 sentences) type questions carrying 2 marks each drawn equally from each unit of the syllabus. 5 questions are to be answered.
- Part B shall contain 6 questions (to be answered in 2 to 5 sentences) carrying 3 marks each drawn equally from each unit of the syllabus. 5 questions are to be answered.
- Part C shall contain 6 questions carrying 5 marks each drawn equally from each unit of the syllabus. 5 questions are to be answered.

COURSE CONTENTS

FIRST SEMESTER	
G 502.1: Chemistry Paper I	**48 Hours**
UNIT I:	
Liquid state, Liquid Crystals, Gaseous State	**12 Hours**
UNIT II:	
Chemical Bonding	**12 Hours**
UNIT III:	
Structure and Bonding in Organic Molecules	**8 Hours**
Dienes	**4 Hours**
UNIT IV:	
Methods of Analysis	**8 Hours**
General Purification Techniques	**4 Hours**
G 502.1P: Chemistry Practical I	**36 Hours**

Open Elective

G 502.1E: Essentials of Practical Chemistry	**30 Hours**
UNIT I:	
Apparatus Handling and Lab Safety and Qualitative analysis	**15 Hours**
UNIT II:	
Quantitative Analysis and Reactions in Solutions	**15 Hours**

SECOND SEMESTER	
G 502.2: Chemistry Paper II	**48 Hours**
UNIT I:	
Solvents	**4 Hours**
Solid State	**5 Hours**
Nuclear and Radiation Chemistry	**3 Hours**
UNIT II:	
Chemistry of s-block Elements	**5 Hours**
Chemistry of p-block Elements	**7 Hours**
UNIT III:	
Organic Halogen Compounds	**5 Hours**
Dihydric Alcohols	**3 Hours**
Ethers and Epoxides	**4 Hours**
UNIT IV:	
Acids and Bases	**3 Hours**
Industrial Chemistry	**2 Hours**
Stereochemistry of Organic Compounds	**7 Hours**
G 502.2P: Chemistry Practical II	**36 Hours**

Open Elective

G 502.2E: Food and Industrial Chemistry	**30 Hours**
UNIT I:	
Food Chemistry	**15 Hours**
UNIT II:	
Industrial Chemistry	**15 Hours**

THIRD SEMESTER	
G 502.3: Chemistry Paper III	**48 Hours**
UNIT I:	
Chemical Kinetics	**5 Hours**
Catalysis	**3 Hours**
Chemical Equilibrium	**4 Hours**
UNIT II:	
Chemistry of d-block Elements	**7 Hours**
Chemistry of f-block Elements	**5 Hours**
UNIT III:	
Aromatic Ring Substitutions	**3 Hours**
Polynuclear Aromatic Hydrocarbons	**4 Hours**
Reactions and Reactivity of Phenols	**3 Hours**
Molecular Rearrangements	**2 Hours**
UNIT IV:	
Flame Photometry	**3 Hours**
Plasma Emission Spectroscopy	**2 Hours**
Atomic Absorption Spectroscopy	**2 Hours**
Thermoanalytical Methods	**5 Hours**
G 502.3P: Chemistry Practical III	**36 Hours**

Open Elective

G 502.3E: Environmental Chemistry	**30 Hours**
UNIT I:	
Air Pollution	**15 Hours**
UNIT II:	
Water Pollution, Soil Pollution and Waste Management	**15 Hours**

FOURTH SEMESTER	
G 502.4: Chemistry Paper IV	**48 Hours**
UNIT I:	
Thermodynamics	**12 Hours**
UNIT II:	
Coordination Compounds	**12 Hours**
UNIT III:	
Reagents in organic synthesis	**12Hours**
UNIT IV:	
Photochemistry	**12 Hours**
G 502.4P: Chemistry Practical IV	**36 Hours**

Open Elective

G 502.4E: Chemistry in Everyday Life	**30 Hours**
UNIT I:	
Cosmetics and Toiletries Industry, Polymers in Everyday Life	**15 Hours**
UNIT II:	
Drugs and Medicines	**15 Hours**

FIFTH SEMESTER	
G 502.5a: Chemistry Paper V	**39 Hours**
UNIT I:	
Dilute Solutions and Colligative properties	**5 Hours**
Binary Mixtures	**3 Hours**
Phase Equilibrium	**5 Hours**
UNIT II:	
Applications of Metal Complexes and Complexation	**3 Hours**
Oxidation and Reduction	**5 Hours**
Magnetic Properties of Transition Metal Complexes	**5 Hours**
UNIT III:	
Heterocyclic Compounds	**10 Hours**
Bioinorganic Chemistry	**3 Hours**
G 502.5b: Chemistry Paper VI	**39 Hours**
UNIT I:	
Quantum Mechanics	**7 Hours**
Rotational Spectroscopy	**6 Hours**
UNIT II:	
Electronic Spectroscopy	**6 Hours**
Electronic Spectra of Transition Metal Complexes	**4 Hours**
Inorganic Polymers	**3 Hours**
UNIT III:	
Carbohydrates	**4 Hours**
Amino acids, Peptides and Proteins	**4 Hours**
Lipids	**3 Hours**
Vitamins and Hormones	**2 Hours**
G 502.5P: Chemistry Practical V	**52 Hours**

SIXTH SEMESTER	
G 502.6a: Chemistry Paper VII	**39 Hours**
UNIT I:	
Vibrational Spectroscopy	**7 Hours**
Raman Spectroscopy	**2 Hours**
Mass Spectroscopy	**4 Hours**
UNIT II:	
Thermodynamic and Kinetic Aspects of Metal Complexes	**4 Hours**
Organometallic Chemistry	**5 Hours**
Symmetry and Point groups	**4 Hours**

UNIT III:	
Supramolecular Chemistry	**3 Hours**
Nano Chemistry	**3 Hours**
Organic Synthesis via Enolates	**4 Hours**
Retrosynthesis	**3 Hours**
G 502.6b: Chemistry Paper VIII	**39 Hours**
UNIT I:	
Electrochemistry	**13 Hours**
UNIT II: Sustainable Chemistry	
Green Chemistry	**4 Hours**
Biopolymers and Bioplastics	**4 Hours**
Biodegradable and Conducting Polymers	**5 Hours**
UNIT III:	
NMR spectroscopy and Applications	**7 Hours**
Dyes and Colouring Agents	**3 Hours**
Chemistry of Natural products	**3 Hours**
G 502.6P: Chemistry Practical VI	**52 Hours**

FIRST SEMESTER

G502.1: Chemistry Paper I

Learning Outcomes:

After completion of the course the student shall be able to:

- Understand the properties of liquids and methods to determine surface tension, viscosity and Parachor.
- Classify liquid crystals and their applications.
- Understand Maxwell's distribution and behaviour of real gases, its deviation from ideal behaviour, equation of state, isotherm, and law of corresponding states.
- Understand the bonding fundamentals for both ionic and covalent compounds including electronegativities, bond distances and bond energies using MO diagrams and predicting geometries of simple molecules.
- Learn the structure and bonding in organic compounds and mechanisms of some organic reactions.
- Learn the reactions of hydrocarbons & mono-functional group compounds.
- Evaluate strengths and limitations of the most important chromatographic separation and detection methods in relation to properties of the sample and analysis task.
- Learn common laboratory techniques including reflux, distillation, steam distillation and recrystallization.

UNIT I

Liquid State **5 Hrs**

Structure of Liquids - Qualitative description. Properties of liquids: Viscosity - definition, SI Unit, principle and method of determination. Surface tension - definition, SI unit, Principle and method of determination. Parachor - expression, definition, application in deciding the structures of organic compounds (Vogel's method only). Vapour Pressure: definition, Effect of temperature on vapour pressure, Vapour pressure and boiling point.

Liquid crystals: Explanation, classification with examples - smectic, nematic, cholesteric, disc shaped and polymeric. Structures of nematic and cholesteric phases- molecular arrangements in nematic and cholesteric liquid crystals. Application of liquid crystals in LCDs and thermal sensing.

Gaseous State **7 Hrs**

Critical phenomena: PV isotherms of real gases, Andrew's isotherms of carbon dioxide- continuity of states. Isotherms of Van der Waals equation, Relationship between critical constants and Van der Waals constants - derivation of the expressions for Tc, Pc and Vc based on Vander Waals constants. Boyle's temperature, inversion temperature. The law of corresponding states: Statement, reduced equation of state - derivation of the equation.

Qualitative discussion of the Maxwell's distribution of molecular velocities - explanation with graph. Collision number; mean free path and collision diameter - definitions.

Liquefaction of gases - by Joule-Thomson effect. The application of Joule-Thomson effect to the liquefaction of air and hydrogen by Linde's process.

UNIT II

Chemical Bonding **12 Hrs**

Covalent bond – Valence Bond theory, concept of hybridisation–prediction of hybridization for the molecules and ions - BeF_2, BF_3, CH_4, PF_5, SF_6, ClF_3, $XeOF_2$, CO_3^{2-} and NO_3^-.

Valence Shell Electron Pair Repulsion (VSEPR) Theory- Postulates; geometry of molecules - BeF_2, BF_3, CH_4, PF_5, SF_6, NH_3, NF_3, F_2O, H_2S, H_2O, SF_4, ClF_3, $XeOF_2$, XeF_2, XeF_4 and IF_7 – comparative studies; Geometry of ions - carbonate, nitrate, sulphate, perchlorate, chlorate. Molecular Orbital Theory (MOT)–Molecular orbital configuration, bond order and magnetic properties of species like He_2, B_2, C_2, N_2, O_2, F_2 and ions. molecular orbital configuration and bond order of CO, NO, HF. CN^-,

Ionic bond- Lattice energy, Born-Landé equation; Solvation and solubility of ionic solids. Polarising power and Polarizability of ions. Fajans' rules to explain bond character, covalent character of ionic compounds, relative covalent character. Comparative trend in melting point - NaBr, $MgBr_2$, $AlBr_3$, LiF, LiCl, LiBr, LiI, $CaCl_2$, $HgCl_2$.

UNIT III

Structure and Bonding in Organic Molecules **8 Hrs**

Formation of covalent bond. Types of chemical bonding- localised and delocalised; conjugation and cross conjugation; resonance; Aromaticity - Hückel rule, explanation with examples; antiaromaticity.

Inductive, field effect, mesomeric, electromeric and hyper-conjugative effect - explanation and examples. Notations - curved arrows, drawing electron movements, half-headed (in tautomerism) and double-headed (in resonance) arrows. Types of bond breaking - homolytic and heterolytic, Types of reagents - electrophiles and nucleophiles. Types of reactions - addition, substitution, elimination and rearrangement. Reactive intermediates - carbocations, carbanion, free radicals, formation and their order of stability. Rearrangement of carbocations 1,2-hydride and 1,2-methyl shift by taking dehydration of 2-methylbutan-1-ol and 3,3-dimethyl-2-butanol as examples. Preparation of carbenes, concept of singlet and triplet carbene. Addition reactions of singlet and triplet carbenes. Concept of nitrenes and benzyne.

Dienes **4 Hrs**

Nomenclature, classification - isolated, conjugated and cumulated; Structure - hybridisation; methods of preparation of 1,3-butadiene – dehydration and dehydrohalogenation. Addition reactions of 1,3-butadiene - polymerisation; Mechanism of 1,2- and 1,4- addition of bromine and hydrogen bromide, effect of temperature, free radical addition to 1,3-butadiene; Diels-Alder

reaction and its importance; 1,3-Dipolar cycloaddition and pericyclic reactions – explanation with examples.

UNIT IV

Methods of Analysis **8 Hrs**

Qualitative analysis; Sample size and techniques - macro, semi micro and micro. Type of tests - wet, dry and spot tests. (terms, definition and examples) Quantitative analysis - Volumetry, Gravimetry and Instrumental analytical methods.

Volumetric Analysis – Principle; Standard solution; Indicators - commonly used indicators, selection of indicators. Types of titration - acid base, redox, complexometric and precipitation titrations - principle with example.

Principles of gravimetric analysis - methods of precipitation, optimum conditions for precipitation and coprecipitation.

Errors in quantitative analysis, types of errors - determinate and indeterminate, methods of minimising errors. Accuracy - absolute error, relative error. Precision – mean deviation, relative mean deviation, standard deviation, t-test, F-test and Q-test. Significant figures. Rules for computation of results; Problems.

General Purification Techniques **4 Hrs**

Techniques - sublimation, distillation – types; crystallisation – Principle with examples; applications.

Chromatography **-** Introduction; classification - types of chromatography, partition and adsorption, R_f value. Chromatographic methods for the separation, concentration and identification of organic compounds - Thin layer, paper and column chromatography principles. Solvent extraction - basic principles and applications. Nernst distribution law - definition and applications, Partition coefficient.

Reference Books:

1. *Textbook of Physical Chemistry*, P. L. Soni, O. P. Dharmarha and U. N. Dash, Sultan Chand & Sons (2016).
2. *Atkin's Physical Chemistry*, Peter Atkins & Julio de Paula, Indian Ed., Oxford Publication (2006).
3. *Principles of Inorganic Chemistry*, Puri, Sharma and Kalia, Milestone Publications, 32nd Ed. (2014).
4. *Concise Inorganic Chemistry*, J. D. Lee, Blackwell Science Ltd, 5th Ed (1999).
5. *Organic Chemistry,* Bhupinder Mehta and Manju Mehta, PHI Learning Pvt Ltd, 2nd Ed. (2015).
6. *Organic Reaction Mechanism*, V. K. AhIuwalia and R. K. Parashar, Narosa Publishing House, 4th Ed. (2010).
7. *A Guidebook to Mechanism in Organic Chemistry*, Peter Sykes, Pearson Education, 6th Ed. (2003).
8. *Instrumental Methods of Chemical Analysis*, Willard, Merritt, Dean and Settle, CBS Publishers, 7th Ed. (2004).
9. *Instrumental Methods of Chemical Analysis*, Gurudeep R. Chatwal and Sham Anand, Himalaya Publishing House, 5th Ed. (2014).

502.1 P: Chemistry Practical I

PART I: Volumetric Analysis **(10 Weeks x 3 Hrs)**

1. Preparation of standard decinormal solution of sodium carbonate and standardization of hydrochloric acid and estimation of sodium hydroxide in solution.
2. Preparation of standard decinormal solution of potassium biphthalate and standardization of sodium hydroxide solution and estimation of hydrochloric acid in solution.
3. Estimation of a mixture of oxalic acid and sulphuric acid in a solution using standard potassium permanganate solution and. standard sodium hydroxide solution.
4. Preparation of standard decinormal solution oxalic acid and standardization of potassium permanganate solution and estimation of Mohr's salt in solution.
5. Preparation of standard decinormal solution of ferrous ammonium sulphate (Mohr's salt) and standardization of potassium dichromate solution and estimation of ferric chloride in solution.
6. Estimation of ferrous and ferric in a mixture.
7. Preparation of std. decinormal solution of potassium dichromate and standardization of sodium thiosulphate solution and estimation of copper sulphate in solution.
8. Estimation of manganese in pyrolusite by volumetric method.
9. Estimation of glucose using iodine and sodium thiosulphate.
10. Estimation of vitamin C.
11. Determination of acetic acid in vinegar using NaOH.
12. Determination of alkali content in antacid tablet using HCl.
13. Estimation of calcium content in limestone as calcium oxalate by permanganometry.
14. Estimation of hardness of water by EDTA method.

PART II: Experiments of Radiation Chemistry **(2 Weeks x 3Hrs)**

1. Study of the characteristics of a GM tube and determination of its operating voltage, plateau length / slope etc.
2. Verification of Inverse Square Law for gamma – rays.
3. Study of nuclear counting statistics.
4. Linear and Mass attenuation co-efficient using gamma source (for Aluminium, Lead & Copper).

G 502.1E: Essentials of Practical Chemistry

UNIT-I

Apparatus Handling and Lab Safety **2 Hrs**

Use of balance, glasswares, burette, pipette, dessicator, filtration apparatus.

Safe use of chemicals, Laboratory precautions.

Qualitative Organic Analysis **6 Hrs**

Determination of melting point and boiling point, detection of elements - N, S and halogen (Lassaigne's Test), detection of unsaturation, reactions of functional groups, preparation of derivatives, recrystallization.

Semi-micro Qualitative Inorganic Analysis **7 Hrs**

Advantages of Semi-micro analysis, wet and dry tests, flame test, centrifugation, reactions of anions, classification of cations into groups, Reactions of cations. Preparation of Nessler's Reagent, Tollen's Reagent, lime water, Bromine water, H_2S.

UNIT-II

Quantitative Analysis

Basic Techniques **3 Hrs**

Calibration, washing precipitates, Drying and igniting precipitates, Preparation of common reagents (dilute acids, dilute bases, indicator solutions), problems.

Reactions in Solutions **8 Hrs**

Solubility Product, Common ion effect, Fractional precipitation, Factors affecting solubility (Acid concentration, Temperature, Solvent), Ionic product of water, pH and pOH, Buffer solutions, Solubility and complexation, problems on pH, pOH, buffers, solubility.

Estimation of Elements **4 Hrs**

Principle and calculation involved in the estimation of Nitrogen by Kjeldahl's method, Sulphur and Halogen by Carius method, Carbon and Hydrogen by Leibig's method.

References Books:

1. *Vogel's textbook of Quantitative Chemical Analysis*, G. H. Jeffery, J. Bassett, J. Mendham, R. C. Denney, John Wiley & Sons, 5th Ed.
2. *Vogel's Qualitative Inorganic Analysis, G. Svehla, B. Sivasankar*, Pearson Education India, 7th Ed. (2012).
3. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, V. K. Ahluwalia, Renu Aggarwal, University Press (2000).
4. *Practical Organic Chemistry*, F. G. Mann and B. C. Saunders, Pearson Education India, 4th Ed. (2009).
5. *Practical Chemistry for B.Sc. - I, II, III Year Students*, O. P. Pandey, D. N. Bajpai, S. Giri, S. Chand & Company.
6. *Advanced Practical Chemistry*, Jagadamba Singh, R.K.P. Singh, Jaya Singh, L.D.S. Yadav, I. R. Siddiqui, Jaya Srivastava (2018).
7. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, V.K. Ahluwalia, S. Dhingra, Sangam Books (2001).

SECOND SEMESTER

G 502.2: Chemistry Paper II

Learning Outcomes:

After completion of the course, the student shall be able to:

- Understand the types and characteristics of solvents.
- Learn the principles concerning solid state structures and crystal structures by applying basic crystallographic concepts.
- Understand the chemistry of alpha, beta, neutron, and gamma radiation and calculate the half-life of a radioisotope.
- Define catalysis and different types of catalytic processes.
- Know structure, bonding of s and p block materials and their oxides/compounds.
- Understand chemistry of noble gases and their compounds.
- Familiarise with structure, bonding of organic compounds and mechanisms of some organic reactions.
- Predict the configuration of optical isomers and geometrical isomers.
- Understand reactions of hydrocarbons and mono-functional group compounds.

UNIT I

Solvents **4 Hrs**

Physical properties of a solvent - density, dipole moment, specific conductance, dielectric constant. Types of solvents - classification into protic-aprotic, acidic-basic-amphiprotic, ionizing–non-ionizing (examples). Characteristics liquid range, auto-ionization and solvating properties. Reactions in aqueous and non-aqueous solvents. Water - hydration, hydrolysis, acid-base, reduction-oxidation, complex formation and precipitation. Ammonia - ammoniation, ammonolysis, acid-base, reduction-oxidation, complex formation, precipitation, alkali metals in ammonia. Levelling effect of solvents – examples.

Solid State **5 Hrs**

Elementary account of unit cell and Bravais lattice. Laws of crystallography: Law of constancy of interfacial angles-definition and explanation taking hexagonal crystal system as an example. Law of rationality of indices. Miller indices, calculation of Miller indices for different planes in a cubic crystal system. Law of symmetry-definition. Types of elements of symmetry - (a) axis of symmetry (b) plane of symmetry (c) centre of symmetry - definition and explanation taking cubic crystal system as an example. X-Ray diffraction by crystals. Derivation of Bragg's equation. Determination of crystal structure of NaCl by Bragg's method, calculation of density. Caesium Chloride, Zinc blende structures; Imperfections in crystal - Non-stoichiometric defects.

Nuclear and Radiation Chemistry **3 Hrs**

Nuclear Reactions. Difference between nuclear and chemical reactions. Natural radioactivity, Characteristics of alpha, beta and gamma rays. Group Displacement Law; decay constant; Half-

life period, Artificial transmutation of elements, Artificial radioactivity, Nuclear fission, Nuclear fusion, Carbon-14 dating. Problems.

Radiolysis of water (using γ rays), radiation dosimetry, dosimeter, applications in organic and inorganic reactions. Application of radioisotopes in the study of organic reaction mechanism, medicine and soil fertility. Industrial applications.

UNIT II

Chemistry of s-Block Elements 5 hrs

Hydrogen - isotopes; hydrides – types (ionic, covalent, interstitial, polymeric, complex), preparation and properties; structure of NaH and BeH_2; applications of complex hydrides ($LiAlH_4$, $NaBH_4$). Comparative study of Li and Be with other members of the same group. Comparative study of lattice energy, enthalpy of formation, enthalpy of hydration and solubilities of alkali metal and alkaline earth metal halides, hydroxides and sulphates. Comparison of standard reduction potentials and reducing properties of alkali metals and alkaline earth metals. Complexation tendencies of alkali metals with crown ether, cryptates. Diagonal relationship - reasons for diagonal relationship, comparison of the properties of Li with Mg and Be with Al.

Chemistry of p-Block Elements 7 hrs

Comparative study of p-Block elements and their compounds - comparison between Boron and other members of the group. Halides of Boron, acidic nature – relative acidic strength; Boranes: Diborane - Preparation, properties, structure and bonding; B_4H_{10}, B_5H_9, Preparation and structure, Styx number, Wade's rule – closo-, nido- and arachno-boranes.
Silicates - types, basic units, structure and applications of zeolites.
Oxoacids of nitrogen (hyponitrous, nitroxylic, nitrous, nitric) - structures; Oxoacids of phosphorous (hypophosphorous, phosphorous, phosphoric, orthophosphoric, meta phosphoric, pyrophosphoric acid) - structures. Oxoacids of halogens (hypochlorous, chlorous, chloric, perchloric acid), relative acidic strength. Oxoacids of sulfur (sulphurous, sulfuric, pyrosulfuric, permonosulfuric acid, peroxydisulfuric acid) - structures. Inter halogen compounds (ICl, BrF_3, IF_5 and IF_7) - preparation, properties, structure and uses. Noble gases - structure and bonding in Clathrates, XeF_2, XeF_4, XeF_6 and XeO_3.
Some special characteristics of p-block elements - reluctance of heavier p-block elements to show maximum oxidation states and to involve p-orbitals for *pi* bonding. Participation of d-orbitals in sigma bonding and in *pi* bonding.

UNIT III

Organic Halogen Compounds 5 Hrs

Mechanism of nucleophilic substitution reactions (with energy profile diagrams) of alkyl halides: S_N2 reaction (hydrolysis of methyl bromide), S_N1 reaction (hydrolysis of *tert*-butyl bromide)

Stereochemistry and factors affecting S_N1 and S_N2 reactions. Neighbouring group participation. Mechanisms of nucleophilic aromatic substitution reaction: S_N1 (benzene diazonium salts), S_NAr (*p*-nitrochlorobenzene to *p*-nitrophenol). Relative reactivities of alkyl halides *vs* allyl, vinyl and aryl halide. Mechanism of elimination reactions: E_1 and E_2 mechanisms, Orientation and stereochemistry; Saytzeff and Hofmann elimination.

Dihydric Alcohols 3 Hrs

Dihydric alcohols – Nomenclature (common and IUPAC), Ethylene glycol - Methods of formation from ethylene and ethylene dibromide. Reactions of ethylene glycol with Na, with conc. HNO_3. oxidative cleavage with $Pb(OAc)_4$ and HIO_4 - oxidation with $KMnO_4$, dehydration at 500 °C and with conc. H_2SO_4.

Trihydric alcohols – Nomenclature (common and IUPAC). Glycerol - Synthesis from propene. Chemical reactions of glycerol: reaction with Na, HI, oxalic acid (at 110 and 260 °C), dehydrating agents ($KHSO_4$, conc. H_2SO_4), oxidizing agents (HNO_3, $KMnO_4$).

Ethers and Epoxides 4 Hrs

Metamerism in ethers, crown ethers, Preparation of ethers from alcohols and alkyl halides. Chemical reactions of ethers - formation of oxonium salt, auto-oxidation; Cleavage with sulphuric acid and HI. Zeisel's method for the estimation of ethoxy and methoxy groups. Synthesis of epoxides from alkenes and halohydrins. Mechanism of acid and base-catalysed ring opening of epoxides. Orientation of epoxide ring opening reaction with energy profile diagram. Reactions of Grignard and organolithium reagents with epoxides.

UNIT IV

Acids and Bases 3 Hrs

Br**o**nsted theory of acid and bases; Conjugate acid-base pair; relative strengths of acid and bases – effect of substituent groups; Lewis concepts of acids and bases. Modern concepts of acids and bases. Usanovich concept, Lux-Flood concept. Hard and Soft Acids and Bases (HSAB); Classification of acids and bases as hard and soft. Pearson's HSAB principle; Applications – stability of complexes, coordination in ambidentate ligands, feasibility of a reaction.

Industrial Chemistry **2 Hrs**

Refractories – Characteristics, classification with examples and applications; Abrasives – natural abrasives, synthetic abrasives, characteristics and applications. Silicon carbide and boron nitride – structure and production; Chemical fertilizers - Primary nutrients; Different types of fertilizers, importance, production of urea, CAN and superphosphate of lime.

Stereochemistry of Organic Compounds **7 Hrs**

Optical isomerism, plane of symmetry, molecular chirality, stereogenic centre, chiral and achiral molecules, enantiomers, properties of enantiomers, optical activity in Lactic acid and Tartaric acid. Diastereomers, *threo* and *erythro* diastereomers, meso compounds, resolution of enantiomers (mechanical, biochemical and chemical), Walden inversion, and racemization.
Relative and absolute configuration, DL system of nomenclature, Sequence rules, RS system of nomenclature; Geometrical isomerism (*cis-trans*) including alicyclic compounds. Determination of configuration of geometrical isomers (dipole moment, melting point and ring formation). E & Z system of nomenclature; geometrical isomerism in oximes. Conformational isomerism — conformational analysis of ethane, 1,2-dichloroethane, butane and substituted cyclohexane. Difference between configuration and conformation.

Reference Books:

1. *A Textbook of Inorganic Chemistry*, Puri and Sharma 2000, Milestone Publishers, 33rd Ed. (2017).
2. *A Textbook of Inorganic Chemistry*, Sathya Prakash, Tuli, Basu and Madan, S. Chand & Company (2015).
3. *Concise Inorganic Chemistry*, J. D. Lee, Blackwell Science Ltd, 5th Ed. (1999).
4. *Principles of Physical Chemistry*, Puri, Sharma and Pathania, Vishal Publishing Company (2019).
5. *Atkin's Physical Chemistry*, Peter Atkins & Julio de Paula, Oxford Publication, Indian Ed. (2006).
6. *Nuclear and Radiochemistry*, G. Friedlander G, J. W. Kennedy, E. S. Macias and J. M. Miller, Wiley Interscience.
7. *Introduction to Nuclear Physics & Chemistry*, B. G. Harvey, Prentice Hall.
8. *Organic Chemistry*, R. T. Morrison, R. N. Boyd and S. K. Bhattacharjee, Pearson Education India, 7th Ed. (2010).
9. *Organic Chemistry*, J. Clayden, N. Greeves, S. Warren, Oxford University Press, 2nd Ed. (2012).
10. *Instrumental Methods of Chemical Analysis*, Willard, Merritt, Dean and Settle, CBS Publishers, 7th Ed. (2004).
11. *Instrumental Methods of Chemical Analysis*, Gurudeep R. Chatwal and Sham Anand, Himalaya Publishing House, 5th Ed. (2014).
12. *Organic Chemistry, Volume 2: Stereochemistry and the Chemistry Natural Products*, I. L. Finar, 5th Ed (2002), Pearson Education.

G 502.2P: Chemistry Practical II

I. Organic Chemistry Practicals **(8 Weeks x 3 Hrs)**

1. Systematic qualitative analysis of mono and bifunctional organic compounds.
2. Determination of melting point/boiling point, preparation of suitable solid derivative and identification compound from literature.

   Following compounds may be given - Phenol, oxalic acid, salicylic acid, urea, benzoic acid, aniline, benzaldehyde, acetophenone, benzophenone, chlorobenzene, bromobenzene, nitrobenzene, benzamide and glucose.

II. Separation of Organic Compounds **(4 Weeks x 3Hrs)**

(a) Isolations

(i) Isolation of mucic acid from milk.

(ii) Isolation of citric acid from lemon.

(b) Thin Layer Chromatography

Determination of R_f values and identification of organic compounds,

(i) Preparation and separation of 2,4-dinitrophenylhydrazones of acetone, 2-butanone, hexan-2- and 3-one using toluene and light petroleum (40:60).

(ii) Separation of a mixture of dyes using cyclohexane and ethyl acetate.

G 502.2E: Food and Industrial Chemistry

UNIT-I

Food Chemistry

Introduction **2 Hrs**

Introduction to food chemistry, Basic components of food-water, carbohydrates, proteins, lipids, minerals and vitamins, pH of food.

Lipids in Food **3 Hrs**

Introduction, classification with examples, Lipid oxidation-general mechanism, Rancidity-Hydrolytic and oxidative

Vitamins **3 Hrs**

Classification; Role of vitamins in enzyme function, Bioavailability of vitamins, structures of vitamin A and vitamin C.

Food Additives **7 Hrs**

Food additives - Classification with examples, functions of additives. Flavours - Classification with examples. Food pigments - Natural and artificial food colours, examples. Sweeteners - Classification and examples. Antioxidants - types, examples.

UNIT-II

Industrial Chemistry

Polymers **7 Hrs**

Introduction, examples for polymers with their monomers, Classification of polymers according to mechanical properties, General classification (thermosetting and thermoplastic; condensation and addition polymers), organic polymers, inorganic polymers, copolymers (definition with examples) Applications of polymers– plastics, adhesives, elastomers, fibres, surface coating

Cement **2 Hrs**

Classification, Manufacture of Portland Cement, Setting of cement.

Paints **2 Hrs**

Composition of Paint, Classification of pigments, Manufacture of paint.

Soaps and Detergents **4 Hrs**

General consideration in soap making, manufacture of soap – batch process, Classification of detergents, Principal groups of synthetic detergents, eco-friendly detergents containing enzymes.

Reference Books:

1. *Industrial Chemistry,* B. K. Sharma, Krishnan Prakashan, 17th Ed. (2014).
2. *Engineering Chem*istry, P. C. Jain, M. Jain, Dhanpat Rai Publishing Company, 16th Ed. (2015).
3. *Food Chemistry*, H. K. Chopra, P. S. Panesar, Alpha Science International Ltd (2010).
4. *Textbook of Polymer Science,* Billmeyer, F. W., Wiley Interscience, 3rd Ed. (2007).
5. *Textbook of Polymers (Basic concepts),* M. S. Bhatnagar, S. Chand Publishing, 1st Ed. (2004).
6. *Textbook of Polymers: Volume 2- Processing and Applications – Condensation Polymers,* M.S. Bhatnagar, S. Chand & Company (2014).
7. *Experiments in Polymer Science,* D. G. Hundiwale, V. D. Athawale, U. R. Kapadi, V. V. Gite, New Age Intl Ltd (2009).

THIRD SEMESTER

G502.3: Chemistry Paper III

Learning Outcomes:

After studying the course, the students shall be able to:

- Learn type of reactions, determination of rate, theories of reaction rate, steady state approximation.
- Familiarize with mechanisms of different types of catalysis and action of catalysts.
- Understand the general characteristics of transition elements, oxidation states, colour and magnetic property.
- Calculate magnetic moment and to compare its theoretical and experimental values.
- Understand comparative treatment of 4d and 5d series.
- Define Lanthanide contraction and its causes.
- Predict the electronic configuration, ionic radii, colour and formation of complex.
- Learn mechanisms of aromatic electrophilic substitution reactions and the effect of substituent groups.
- Write mechanism for organic rearrangement reactions.

UNIT I

Chemical Kinetics **5 Hrs**

Rate of a reaction, Order of a reaction - Zero order, I order, II order, pseudo first order; half-life. Rate constants for II order and n^{th} order reactions - derivation with equal and unequal concentrations for second order reaction. Determination of the order of a reaction - differential, integration, half-life period and isolation methods. Problems.

Simple collision theory based on hard sphere model (mention the mathematical expression). Transition state theory (equilibrium hypothesis). Derivation of the relationship between rate constant and equilibrium constant.

Catalysis **3 Hrs**

Introduction – types of catalysis – homogeneous and heterogeneous; Theories of catalysis – intermediate compound formation and adsorption theory; Acid-base catalysis – mechanism; Enzyme catalysis - examples, characteristics, mechanism - Michaelis-Menten equation (no derivation).

Chemical Equilibrium **4 Hrs**

Equilibrium constants Kp and Kc, Relation between them - Concept of free energy. Relation between Equilibrium constant and free energy. Law of mass action - thermodynamic derivation (in terms of partial pressures). Le Chatelier's principle-statement and applications. van't Hoff's reaction isotherm and reaction isochore - Clapeyron equation and Clausius - Clapeyron equation (to be derived) and their applications; Problems.

UNIT II

Chemistry of d-block Elements 7 Hrs

Definition, transition elements four series of d block elements, general electronic configuration) Position in the periodic table. General characteristic properties- metallic character, ionisation energy, oxidation state, reducing property, colour, catalytic property and complexability. Magnetic property – expression for magnetic moment - spin only formula μ_s, calculation of μ_s for 3d series elements, Lande's calculation of theoretical magnetic moment. μ_{s+L}, comparison of magnetic moment μ_s and μ_{s+L} with experimental value of μ. Comparative study of 4d and 5d elements with 3d elements - ionic radii, oxidation states, magnetic behaviour and stereochemistry. Aqueous chemistry of Fe in different oxidation states (potassium ferrocyanide and ferricyanide) - preparation and properties.

Chemistry of f-block Elements 5 Hrs

Lanthanides - Occurrence, properties - electronic state, oxidation state, ionic radii; lanthanide contraction, causes and consequences. Complex formation, colour and magnetic properties. Separation of lanthanides by ion exchange method. Actinides - general features, Electronic configuration, oxidation state, ionic radii, colour of ions, and formation of complex. separation of Neptunium, Plutonium, Americium and Uranium. Problems on calculation of μ_{S+L} for trivalent lanthanide ions, Similarities and dissimilarities between actinides and lanthanides.

UNIT III

Aromatic Ring Substitutions 3 Hrs

Aromatic electrophilic substitution-general pattern of the mechanism with energy profile diagram. Role of σ and π-complexes. Mechanisms of Nitration, Sulphonation, Halogenation, Friedel-Crafts reactions. Activating and de-activating substituents, Orienting influence, ortho-para ratio.

Polynuclear Aromatic Hydrocarbons 4 Hrs

Examples; Naphthalene - Nomenclature of naphthalene derivatives, structure of naphthalene, method of preparation from 4-phenyl-1-butene and Haworth synthesis. Electrophilic substitution reactions of naphthalene - nitration, sulphonation and Friedel Crafts reactions. Reduction and oxidation, Structure of anthracene and phenanthrene.

Reactions and Reactivity of Phenols 3 Hrs

Comparison of acidic properties of phenols with carboxylic acids, alcohols and carbonic acid. Mechanism of Kolbe's and Reimer-Tiemann reactions. Molecular rearrangements – Fries and Claisen rearrangement. Synthesis of aryloxy acetic acids.

Molecular Rearrangement 2 Hrs

Types, Mechanisms of Pinacol-Pinacolone, Beckmann, Hofmann, Benzilic, Curtius rearrangement.

UNIT IV

Flame Photometry **3 Hrs**

Principle; Flames used (fuel-oxidant mixtures), Instrumentation, Types of burners - Total consumption burner and Premix or Laminar flow burner. Interference – spectral, ionization, cation-anion, cation-cation, oxide formation; Effect of organic solvents; Calibration curve; Quantitative determination of metal ions by standard addition method and internal standard method; Qualitative applications; Limitations of Flame Photometry.

Plasma Emission Spectroscopy **2 Hrs**

Principle, Plasma Discharge (Inductively Coupled Plasma - ICP torch), Instrumentation; Application.

Atomic Absorption Spectroscopy (AAS) **2 Hrs**

Difference between absorption and emission spectra; Principle of AAS, Sensitivity; Methods of calibration; Instrumentation - Resonance wavelength, Hollow cathode lamp; Line width – Doppler broadening and Pressure broadening; Interferences; Advantages and disadvantages; Comparison between Flame Emission and Atomic Absorption Spectroscopy; Applications - Qualitative and Quantitative.

Thermo-analytical methods **5 Hrs**

TGA - Principle, instrumentation, types of thermo balances; Deflection and null type; Factors affecting TGA curves – rate of heating and furnace atmosphere; Determination of composition of a compound with example of $CaC_2O_4.H_2O$; Quantitative applications – evaluation of suitable standard, testing of sample purity, study of organic compound, drying and ignition temperature. Qualitative application – determination of curie point.

DTG – Advantages over TGA; Significance of DTG curves.

DTA - Principle, Factors affecting DTA curves – rate of heating and furnace atmosphere (N_2 and O_2) with example of $CaC_2O_4.H_2O$; Simultaneous TGA and DTA curves; interpretation of DTA curve; applications.

DSC – Principle, types – power compensated and heat flux; Advantages of DSC over TGA; applications.

Reference Books:

1. *Physical Chemistry*, Atkins P. W. and De Paula J., Oxford University Press, 11th Ed. (2017).
2. *Physical Chemistry*, Castellan, G. W., Narosa Publishing House, 3rd Ed. (2004).
3. *A Textbook of Inorganic Chemistry*, Puri and Sharma 2000, Milestone Publishers, 33rd Ed. (2017).
4. *A Textbook of Inorganic Chemistry*, Sathya Prakash, Tuli, Basu and Madan, S. Chand & Company (2015).
5. *Concise Inorganic Chemistry*, J. D. Lee, Blackwell Science Ltd, 5th Ed. (1999).
6. *Organic Chemistry*, T.W G. Solomons, B. Craig Fryhle, Scott A. Snyder, 12th Ed., John Wiley & Sons Inc (2016)

G 502.3P: Chemistry Practical III

PART I: Semi-micro Qualitative Analysis of Salt Mixtures (8 Weeks x 3Hrs)

Systematic qualitative analysis of mixtures of two simple inorganic salts (containing two cations and two anions).

Anions: CO_3^{2-}, HCO_3^-, SO_3^{2-}, $S_2O_3^{2-}$, S^{2-}, Cl^-, Br^-, I^-, NO_3^-, BO_3^{3-}, PO_4^{3-}, SO_4^{2-}

Cations: Pb^{2+}, Cd^{2+}, Cu^{2+}, Bi^{3+}, Co^{2+}, Ni^{2+}, Al^{3+}, Fe^{3+}, Mn^{2+}, Zn^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Mg^{2+}, Na^+, K^+, NH_4^+.

PART II: Chromatographic Separation (4 Weeks x 3Hrs)

(i) Paper Chromatography (Ascending and circular) – Separation of inorganic ions Ag^+, Hg^+, Pb^{2+} / Hg^{2+}, Cu^{2+}, Pb^{2+}, Bi^{3+}, Cd^{2+} / Fe^{3+}, Cr^{3+}

(ii) Chromatography – Separation of organic compounds

a) Separation of fluorescein and methylene blue.

b) Separation of leaf pigments from spinach leaves.

c) Separation of a mixture of phenylalanine and glycine, Alanine and aspartic acid, Leucine and glutamic acid. Spray reagent - ninhydrin.

d) Separation of a mixture of D, L-alanine, glycine, and L-Leucine using *n*-butanol, acetic acid-water (4:1:5). Spray reagent – ninhydrin.

e) Separation of monosaccharides-mixture of D-galactose and D-fructose using n butanol: acetone: water (4:5:1), Spray reagent - aniline hydrogen phthalate.

G 502.3E: Environmental Chemistry

UNIT I

Air Pollution **15 Hrs**

Major regions of atmosphere; Chemical and photochemical reactions in atmosphere; Air pollutants and their sources: oxides of carbon, nitrogen and sulphur.

Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming; depletion of ozone layer: ozone layer, effects of oxides of nitrogen, oxides of fluorocarbons.

Particulates and their sources; toxic effects of particulates, smog and its types; control of air pollution.

UNIT II

Water Pollution **10 Hrs**

Nature of water pollutants, surfactants, techniques for measuring water pollution, impacts of water pollution on hydrological and ecosystems; Water purification methods (reverse osmosis, electro dialysis, ion exchange), Effluent treatment plants (primary, secondary and tertiary treatment). Water quality parameters for wastewater, industrial water and domestic water; Industrial wastewater - contamination and treatment.

Non-specific tests: COD, DO, BOD, TOC, chlorine demand, taste and odour, colour and turbidity. Specific tests: nutrients, nitrogenous, phosphorous, toxic compounds, nuisance matter. The water act (India), reasons for water analysis.

Soil Pollution and Waste Management **5 Hrs**

Causes and impact of soil pollution. Pesticides and its environmental effects. Methods of pest control. Disposal techniques. Waste management approach. Industrial waste management, incineration of waste. Causes and remedies of Radiation and noise pollution.

Reference Books:

1. *Environmental Chemistry*, K. De, New Age International Pvt., Ltd, New Delhi (2006).
2. *Environmental Pollution Analysis*, S. M. Khopkar, Wiley Eastern Ltd, New Delhi (2015).
3. *Environmental Chemistry*, S.E. Manahan, CRC Press (2005).
4. *Environmental Chemistry*, H. Kaur, Pragathi Edition (2010).
5. *Principles of Inorganic Chemistry*, B. R. Puri, L. R. Sharma, K. C. Kalia, Vallabh Publications, Delhi (2017).
6. *Environmental Chemistry Pollution and Remedial Perspective*, V. Salker, Narosa publishing house (2017).

FOURTH SEMESTER

G502.4: Chemistry Paper IV

Learning Outcomes:

After studying the course, the students shall be able to:

- Understand the concept of system, variables, heat, work and laws of thermodynamics.
- Understand the concepts of entropy, reversible and irreversible processes.
- Know IUPAC nomenclature and theories of coordination compounds.
- Learn d-orbital splitting in tetrahedral, octahedral, square planar complexes.
- Familiarise with the applications of common reagents in organic synthesis and mechanisms of some important named reactions.
- Describe and explain photochemical and photophysical processes using Jablonski diagram and their quantum yield expressions.

UNIT I

Thermodynamics **12 Hrs**

First Law of Thermodynamics - statement, definition of internal energy and enthalpy. Heat Capacity, heat capacities at constant volume and pressure and their relationship. Joule's Law; Joule-Thomson coefficient and inversion temperature. Bond dissociation energy and its calculation from thermochemical data, temperature dependence of enthalpy. Kirchhoff's equation - explanation and derivation. Second law of thermodynamics (definition), efficiency (definition); Carnot's theorem, Carnot's cycle. Derivation of an expression for efficiency of Carnot's engine. Thermodynamic scale of temperature, concept of entropy, to prove that entropy is a state function. Statement of zeroth law of thermodynamics.

Entropy change in reversible process and irreversible process. entropy change for an ideal gas as a function of V & T, entropy as a function of P & T. Entropy change in physical changes - fusion, evaporation, sublimation and transition and on mixing of ideal gases. Entropy as a criterion of spontaneity and equilibrium. Third Law of thermodynamics - significance, unattainability of absolute zero. Gibbs and Helmholtz functions. Elementary account of Gibbs free energy and Helmholtz free energy. A & G as criteria for thermodynamic equilibrium and spontaneity. Variation of G with P, V and T. Problems. Maxwell relations.

UNIT II

Coordination Compounds **12 Hrs**

Nomenclature including bridging ligands; Isomerism in coordination compounds - ionization isomerism, hydrate isomerism, coordinate isomerism, linkage isomerism. Geometrical isomerism and optical isomerism (coordination numbers 4 and 6).

Effective atomic number calculations, stability of complexes and factors affecting stability of complexes.

Postulates of Valence Bond Theory (VBT); Examples for sp^3, dsp^2, dsp^3, d^2sp^3 and sp^3d^2 hybridization - $[Ni(CO)_4]$, $[Ni(CN)_4]^{2-}$, $[Cu(NH_3)_4]^{2+,}$ $[Fe(CO)_5]$, $[Fe(CN)_6]^{3-}$, $[Co(NH_3)_6]^{3+}$ and $[CoF_6]^{3-}$. Explanation for magnetic properties. Limitations of VBT.

Crystal field theory (CFT) - important concepts of CFT, Crystal field splitting in octahedral, tetrahedral and square planar complexes; Jahn-Teller distortion and crystal field stabilization energy (CFSE). Calculation of CFSE; weak and strong field ligands, spectrochemical series, explanation for stability, geometry, magnetic and spectral properties. Factors affecting the crystal field splitting. Limitations of CFT. Ligand field theory.

UNIT III

Reagents in Organic Synthesis 12 Hrs

Reagents for reduction: Reduction of specific functional groups– alkenes, alkynes, aldehydes, ketones, carboxylic acids and its derivatives, nitro and aromatic compounds.

Catalytic hydrogenation (homogeneous and heterogeneous) – Lindlar and Rosenmund catalysts, Wilkinson's catalyst. Metal hydride reductions ($LiAlH_4$, $NaBH_4$, DIBAL-H and B_2H_6), Dissolving metal reductions (Birch reduction – reduction of aromatic compounds, alkynes). Wolf-Kishner reduction and Clemensen reduction. Meerwein-Pondorf-Varley reduction (Mechanism not required).

Reagents for oxidation: Oxidation of C–C double bonds, alcohols, glycols, ketones and aldehydes, aromatic compounds, allylic oxidation. Oxidation with chromium and manganese reagents (CrO_3, $K_2Cr_2O_7$, PCC, Collin's reagent, Jones reagent, MnO_2, $KMnO_4$), ozone, peroxides and peracids, lead tetra acetate, periodic acid, OsO_4, SeO_2 and NBS. Oppenauer oxidation (Mechanism not required)

UNIT IV

Photochemistry 12 Hrs

Interaction of radiation matter; Differences between thermal and photochemical reactions. Laws of photochemistry: Grothus-Draper law, Stark - Einstein law, primary and secondary reactions, Quantum yield - reasons for low and high quantum yield, Examples for high quantum yield with explanation (decomposition of HI, combination H_2 and Cl_2 reaction), Examples for low quantum yield with explanation (combination of H_2 and Br_2). Photosensitized reactions with examples - Photosynthesis in plants, dissociation of H_2, Isomerization of 2-butene and butadiene. Photo-physical processes - Jablonski diagram depicting various processes occurring

in the excited state, qualitative description of fluorescence, phosphorescence, non-radiative processes (internal conversion, intersystem crossing). Types of fluorescence-sensitized and resonance fluorescence (examples), explanation of phosphorescence with examples. Chemiluminescence. Photochemical reactions: Norrish Type I and II. Lasers – Basic principles; population inversion, application.

Reference Books:

1. *Physical Chemistry*, Atkins P. W. and De Paula J., 11th Ed. (2017), Oxford University Press.
2. *Principles of Physical Chemistry*, Puri, Sharma and Pathania (2019), Vishal Publishing Company.
3. *A Textbook of Inorganic Chemistry* Puri and Sharma 2000, 33rd Ed. (2017), Milestone Publishers.
4. *Concise Inorganic Chemistry*, J. D. Lee, 5th Ed. (1999), Blackwell Science Ltd.
5. *Organic Chemistry*, R. T. Morrison, R. N. Boyd and S. K. Bhattacharjee, 7th Ed. (2010), Pearson Education India.
6. *Organic Reaction Mechanism*, V. K. AhIuwalia and R. K. Parashar, 4th Ed. (2010), Narosa Publishing House.
7. *Fundamentals of Photochemistry*, K. K. Rohatgi-Mukherjee., 3rd Ed. (2017), New Age Publishers.
8. *Physical Chemistry,* K. J. Laidler and J. M. Meiser, B. C. Sanctuary, 4th Ed. (2003), Houghton Mifflin College.
9. *Industrial Chemistry*, B. K. Sharma, 17th Ed. (2014), Krishnan Prakashan.
10. *Riegel's Handbook of Industrial Chemistry*, J. A. Kent, 10th Ed. CBS Publishers.

G 502.4P: Chemistry Practical IV

I. PART A: Physical Chemistry (10 Weeks x 3 Hrs)

1) The percentage of NaCl present in water - phenol system.
2) Determination of composition of a binary liquid mixture (alcohol & toluene) by Refractometry.
3) The molecular weight of a non - volatile solute by Walker - Lumsden method.
4) The density and surface tension of a liquid.
5) Determination of density and viscosity of a liquid.
6) The percentage composition of a given mixture of glycerol and water by viscometry.
7) The rate constant of decomposition of hydrogen peroxide.
8) Rate constant for acid hydrolysis of an ester and comparison of catalytic strengths of HCl and H_2SO_4.
9) Preparation of arsenious sulphide sol and comparison of the precipitating powers of mono-, bi- and trivalent anions.
10) Estimation of sugar by refractometric method.
11) Determination of molar mass of polymer by viscosity method.
12) Effect of surfactants on the surface tension of water.
13) Determination of degree of dissociation of an electrolyte by ebullioscopic method
14) Determination of Na and K by Flame Photometry.

II. PART B: Preparation of Organic Compounds (2 Weeks x 3 Hrs)

1) Preparation of benzoic acid from benzaldehyde / toluene
2) Preparation of Acetanilide from aniline.
3) Preparation of *p* - bromoacetanilide from acetanilide.
4) Preparation of *m*-dinitrobenzene from nitrobenzene.
5) Nitration of acetanilide.
6) Use of Flash evaporator for the recovery of solvent (Calculation of theoretical yield using density / mass concept).

G 502.4E: Chemistry in Everyday Life

UNIT I

Cosmetics and Toiletries Industry **10 Hrs**

Raw materials: Surfactants – structure, types (anionic, cationic, nonionic and zwitterionic) hydrophilic lipophilic balance (HLB); Thickeners, foam stabilizers, natural oils, emulsifiers, humectants (definition, types and examples), plasticizers.

Hair-care products – Structure of hair keratin, major components of shampoo, hair dyes (mechanism and composition), Health & Environmental concerns.

Skin care products – skin structure, sunscreens, fairness creams, moisturizers, Health & environmental concerns.

Nail polish – formulation, manufacture and safety concerns.

Perfumes – Perfumes and odours in nature, synthetic perfumes, ingredients, chemoreception.

Polymers in Everyday Life **5 Hrs**

Natural and synthetic polymers – Properties, classification and structures, polymers and the environment, recycling of polymers.

Natural polymers – cellulose, starch, polysaccharides, proteins, polyisoprene.

Synthetic polymers – Rubber, Adhesive, paints, silicones and plastics.

UNIT II

Drugs and Medicines **15 Hrs**

General principles of drug action; classification on the basis of origin and therapeutic use; different routes of drug administration; mechanism of drug action.

Drug-receptor interactions – Covalent, ionic, hydrogen bonded, Vander Waals and hydrophobic/hydrophilic interactions.

Chemistry of Prodrugs – Concept; applications; some important prodrug concepts (to improve chemical stability, increased water solubility, decrease toxicity).

General anaesthetics – Introduction and classification, Examples (nitrous oxide, chloroform).

Local Anaesthetics – Definition, properties of ideal local anaesthetics; Examples (Benzocaine, lidocaine).

Sedatives and hypnotics – Classification (Barbiturates and non-barbiturates); Chemistry of Barbiturates – Examples, structure-activity relationship, mechanism of action and uses of Barbiturates.

Non-steroidal Anti-inflammatory Drugs (NSAIDs) – Definition, general structure and Classification – Salicylates (Aspirin, Salol) and Propionic acid (Ibuprofen).

Reference Books:

1. *Chemistry and technology of the cosmetics and toiletries industry*, D. F. Williams, W. H. Schmitt (1992), Kluwer Academic Publishers.
2. *The chemistry of fragrances: From Perfumer to Consumer*, Charles Sell, 2nd Ed. (2015), Royal Society of Chemistry.
3. *Medicinal Chemistry*, Ashutosh Kar, 7th Ed. (2018), New Age Publishers.
4. *Principles of organic medicinal chemistry*, R. R. Nadendla (2005), New Age Intl Publishers.
5. *Essentials of pharmaceutical chemistry*, Donald Cairns, 4th Revised Ed. (2012), Pharmaceutical Press.

FIFTH SEMESTER

G 502.5a: Chemistry Paper V

Learning outcomes:

After studying the course, the students shall be able to:

- Define and understand various colligative properties and to differentiate between different liquid mixtures.
- Explain the basic definitions and terms in a phase diagram.
- Define magnetic behavior of different metal complexes and explain geometry of the complex based on magnetic moment data.
- Predict mechanism of electrophilic substitution reactions in heterocyclic compounds.
- Compare the basicity of heterocyclic compound containing nitrogen.
- Understand significance of metalloporphyrins and its functions in biological system.

UNIT I

Dilute Solutions and Colligative Properties **5 Hrs**

Ideal and non-ideal solutions - thermodynamic properties (ΔG, ΔH and ΔS) of ideal solutions, Activity and Activity coefficients, colligative properties – Definition and an elementary account of the four colligative properties. Raoult's Law of relative lowering of vapour pressure. Osmosis - Laws of osmotic pressure.

Elevation in boiling point and depression in freezing point. Thermodynamic derivation of relation between molecular weight and elevation in boiling point and depression in freezing point. Experimental determination of molecular weight by Walker-Lumsden method and Beckmann's method. van't Hoff factor, Abnormal molar mass, Degree of dissociation and association of solutes. Problems.

Binary Mixtures **3 Hrs**

Ideal liquid mixtures - Raoult's law, Vapour pressure vs composition (mole-fraction) curves. Azeotropes - HCl-H_2O and Ethanol-Water system; Fractional distillation, Partially miscible liquids - phenol-water, triethanol-water and nicotine-water systems. Lower and upper consolute temperature; Effect of impurity on consolute temperature. Immiscible liquids - steam distillation.

Phase Equilibrium **5 Hrs**

Phase rule-Statement (mathematical expression) and meaning of the terms. Explanation for the terms phase, component and degrees of freedom with suitable examples for each. Derivation of phase rule from thermodynamic consideration. Explanation of phase equilibria of one component system (water and sulphur system) using phase diagram. Two component system - classification with examples, simple eutectic system (lead-silver system) - phase diagram and explanation, desilverisation of lead (Pattinson's Process). Compound formation with incongruent melting point (NaCl + water system) - phase diagram and explanation. Solid solutions - compound formation with congruent melting point (Mg-Zn system) phase diagram and explanation. Freezing mixtures (acetone-dry ice). Solid solution formation.

UNIT II

Applications of metal complexes and complexation **3 Hrs**

Applications of complexes and complex formation in metallurgy (gold, silver, nickel, aluminium), volumetric analysis (in the determination of hardness of water, masking and demasking agents), qualitative analysis (detection of Fe^{2+}, $Fe^{3}+$, $Cu^{2+,}$ Cd^{2+}) and gravimetric analysis (Ni and Mg).

Oxidation and Reduction **5 hrs**

Redox couple, redox potentials, standard reduction potential, Electrochemical series, Use of redox potential data. Latimer diagram (chlorine in acidic and basic medium); applications. Frost diagram of manganese and nitrogen; Conversion of Latimer to Frost diagram. Applications of Frost diagram. Redox stability in water based on Pourbaix diagram.

Magnetic Properties of Transition Metal Complexes **5 Hrs**

Origin of magnetism; Common terms used in magneto-chemistry - magnetic induction, magnetic flux density, magnetic moment and magnetic susceptibility. Different types of magnetic behaviour. Method to determine magnetism. Guoy method of determining magnetic susceptibility. Variation of magnetic susceptibility with temperature. Curie temperature and Neel temperature. Calculation of magnetic moment for the complexes using spin only formula. Orbital contribution to magnetic moment. Application of magnetic moment data of 3d metal complexes.

UNIT III

Heterocyclic Compounds **10 Hrs**

Introduction: Types and nomenclature, Molecular orbital picture and explanation for aromatic character of pyrrole, furan, thiophene, pyridine. Comparison of aromaticity of these compounds. Methods of synthesis of pyrrole (Paal-Knorr, from acetylene), furan (Paal-Knorr, Feist-Benary), thiophene (Paal-Knorr, from Furan) and pyridine (Hantzsch, from acetylene). Chemical reactions with emphasis on the mechanism of electrophilic substitution (nitration, sulfonation, halogenations, Friedel Craft's reaction). Mechanism of nucleophilic substitution reactions in pyridine derivatives (reaction with sodamide). Comparison of basicity of pyridine, piperidine and pyrrole. Introduction to condensed five and six- numbered heterocycles. Preparation and reactions of indole, quinoline and isoquinoline with special reference to Fisher indole synthesis, Skraup synthesis and Bischler-Napieralski synthesis. Mechanism of electrophilic substitution, reactions of indole, quinoline and isoquinoline (nitration, sulfonation, halogenation, Friedel-Crafts reaction).

Bioinorganic Chemistry **3 Hrs**

Essential and trace elements in biological processes. Metalloporphyrins with reference to haemoglobin and myoglobin, skeletal structures and functions. Biological role of alkali and alkaline earth metals - Ca^{2+}, Mg^{2+}, Na^{+}, $K^{+,}$ Fe^{+2}, Cu^{+2}, Zn^{+2}. Mechanism of Na^{+}/K^{+} pump. Explanation for co-operative effect and Bohr Effect. Effect of excess intake of metals.

Reference Books:

1. *Textbook of Physical Chemistry*, P. L. Soni, O. P. Dharmarha and U. N. Dash, 2016, Sultan Chand & Sons.
2. *Atkin's Physical Chemistry*, Peter Atkins & Julio de Paula, Indian Edition 2006, Oxford Publication.
3. *A Textbook of Inorganic Chemistry*, Puri and Sharma 2000, 33rd Ed. (2017), Milestone Publishers.
4. *Concise Inorganic Chemistry*, J. D. Lee, 5th Ed. (1999), Blackwell Science Ltd.
5. *Organic Chemistry*, R. T. Morrison, R. N. Boyd and S. K. Bhattacharjee, 7th Ed. (2010), Pearson Education India.
6. *Heterocyclic Chemistry*, J.A. Joule and G. F. Smith, 5th Ed. (2010), Wiley-Blackwell.
7. *Principles of Bioinorganic Chemistry,* Lippard, S.J. & Berg (1994), University Science.

FIFTH SEMESTER

G502.5b: Chemistry Paper VI

Learning outcomes:

After completion of the course, the learner shall be able to:

- Understand the basic concepts of quantum mechanics and to derive expression for Schrodinger wave equation.
- Familiarize with the basics of rotational spectra and its application to determine bond length and moment of inertia.
- Learn the basics of electronics spectroscopy and able to apply Woodward-Fieser rules for calculating absorption maximum in dienes.
- Explain general characteristics of inorganic polymers of silicon, phosphorous, boranes.
- Explain the structures of biomolecules (carbohydrates, proteins, enzymes, lipids and hormones) and their role in biological processes.
- Understand the interconversion of the carbohydrate and plan their synthesis.
- Summarize the functions of proteins and recognize the importance of the three-dimensional shape of a protein on its function.
- Explain protein denaturation and the effect of heat on protein structure and function.

UNIT I

Quantum Mechanics **7 Hrs**

Comparison of classical mechanics with quantum mechanics. Qualitative explanation of Black-body and black body radiation, Planck's radiation law, Photoelectric effect, Dual nature of matter and radiation, Heisenberg's uncertainty principle, Compton effect. Derivation of expression for de-Broglie wavelength of matter waves. Sinusoidal wave equation, Postulates of quantum mechanics. Setting up of Schrödinger wave equation. Application of Schrödinger wave equation to a particle in one dimensional box (no derivation) Setting up of Schrödinger wave equation for H-atom (no separation of variables or solution). Eigen functions and Eigen values. Concept of operators (Laplacian and Hamiltonian), quantum numbers and their importance; Problems.

Rotational Spectroscopy **6 Hrs**

Rigid rotor and Non-rigid rotor; expression for moment of inertia of diatomic molecule - derivation. Derivation of the expression for rotational energy. Rotational energy level diagram, selection rules. Frequency and wavenumber of lines in the rotational spectra. Intensity of rotational spectral lines (explanation by taking population of energy level and degeneracy only elementary account). Isotopic effect - explanation by taking ^{12}CO and ^{13}CO. Non-rigid rotor (qualitative description). Application of rotational spectra to determine bond length and moment of inertia. Problems.

UNIT II

Electronic Spectroscopy **6 Hrs**

Introduction to spectroscopy. Electromagnetic radiation - Wave theory of electromagnetic radiation; Quantum theory of electromagnetic radiation. Electromagnetic spectrum.

Absorption laws (Beer-Lambert law with limitations), Derivation of Beer-Lambert law, molar absorptivity; Instrumentation and applications of Colorimetry and spectrophotometry. Concept of potential energy curves for bonding and anti-bonding molecular orbitals, qualitative description of selection rules (Forbidden and allowed transitions). Formation of bands, Franck-Condon principle, types of electronic transitions, effect of conjugation with examples. Concept and effect of addition of chromophore and auxochrome. Absorption and intensity shifts - Bathochromic, hypsochromic, hyperchromic and hypochromic shifts. Woodward-Fieser rules for calculating absorption maximum in dienes.

Electronic spectra of transition metal complexes **4 Hrs**

Introduction, microstates, types of electronic transitions, spectroscopic ground states for d^1-d^9 system. Selection rules for d-d transition, relaxation of selection rules. Russell-Saunders coupling. Spectrochemical series; Orgel energy level diagram for d^1 and d^9 system. Discussion of the electronic spectrum of $[Ti(H_2O)_6]^{3+}$ and $[Cu(H_2O)_6]^{2+}$ complex ions.

Inorganic Polymers **3 Hrs**

General characteristics of inorganic polymers. Silicones - linear and cross linked. Preparation and applications of silicones. Phosphazenes - examples, preparation and applications. Production and structural features of Borazine. Boron nitride - Structural features and preparation. Production and structural features of sulfur nitride $(SN)_x$ and silicon carbide.

UNIT III

Carbohydrates **4 Hrs**

Classification. Monosaccharides: interconversions of glucose and fructose, chain lengthening of aldoses (Kiliani-Fischer method), Chain shortening (Ruff degradation); Conversion of glucose and mannose – epimerisation; Reduction, reaction with hydroxylamine, and semicarbazide; osazone formation – Mechanism; Amadori rearrangement; Formation of glycosides, ethers (methyl), esters (acetates). Configuration of glucose; Lobry de Bruyn-van Ekenstein rearrangement. Determination of ring size of monosaccharides (methylation and periodic acid method). Mechanism of mutarotation.

Amino Acids, Peptides and Proteins **4 Hrs**

Amino acids: Classification, structure and stereochemistry of amino acids, Acid–base behaviour, isoelectric point and electrophoresis – explanation. Preparation of α-amino acids from α-halogenated acids, from ethyl malonate; Strecker synthesis, Koops synthesis and Gabriel

synthesis. Reactions due to -COOH groups – with bases, esterification and reduction. Reactions due to NH_2 groups – with acid, acylation, nitrous acid, DNFB. Action of heat.

Peptides and Proteins: Formation of peptides and peptide bond, polypeptides, classification of proteins. Peptide structure determination – end group analysis, selective hydrolysis of peptides, classical peptide synthesis, solid phase peptide synthesis, levels of protein structure - primary, secondary, tertiary and quaternary structures; Denaturation of proteins.

Lipids **3 Hrs**

Introduction, Classification. Fatty acids – definition, classification as saturated and unsaturated with examples and structure (lauric, myristic, palmitic, stearic, oleic, linoleic and linolenic acids). Essential fatty acids – definition with examples. Triglycerides – Structure of simple and mixed glycerides. Biological importance of triglycerides. Phosphoglycerides – types, structure and biological importance of lecithin, cephalin, phosphatidylserine, phosphatidylinositol.

Vitamins and Hormones **2 Hrs**

Definition, Classification with example and their importance. Synthesis of vitamin C from D-glucose. Synthesis of vitamin A from β-ionone. Synthesis of Adrenaline from catechol. Synthesis of thyroxine from *p*-nitroaniline.

Reference Books:

1. *Introductory Quantum Chemistry*, A. K. Chandra, 4th Ed. (2017), Tata McGraw-Hill Education.
2. *A Textbook of Inorganic Chemistry*, Puri and Sharma 2000, 33rd Ed. (2017), Milestone Publishers.
3. *Elementary Organic Spectroscopy*, Y. R. Sharma, 5th Ed. (2013), S. Chand Publication.
4. *Fundamentals of Molecular Spectroscopy*, C. N. Banwell, E. McCash, 4th Ed. (1994), Tata McGraw-Hill.
5. *Biochemistry*, J. M. Berg, J. L. Tymoczko, and L. Stryer, 7th Ed. (2011). Palgrave MacMillan.
6. *Organic Chemistry*, S. M. Mukherji, S. P. Singh, R. K. Kapoor, R. Dass (2017), New Age Publications.

G 502.5P - Chemistry Practical V

1) **Inorganic Gravimetric Exercises** **(6 Weeks x 4 Hrs)**

Determination of Percentage purity of the compound involving the estimation of:

a. Barium as barium sulphate.
b. Iron as ferric oxide.
c. Copper as cuprous thiocyanate.
d. Nickel as nickel dimethylglyoximate.
e. Chloride/Silver as AgCl.
f. Magnesium as oxinate.

2) **Separation of Compounds** **(1 Week x 4 Hrs)**

Separation and estimation of Mg(II) and Fe(III) ions by solvent extraction method.

3) **Effluent Analysis of Water** **(1 Week x 4 Hrs)**

a. Determination of COD.
b. Determination of DO, pH and conductivity.

4) **Preparation of Inorganic Complexes** **(2 Weeks x 4 Hrs)**

a. Preparation of tetraamminecopper(II) sulphate
b. Preparation of sodium tris(oxalato)ferrate(III).
c. Preparation of hexamminecobalt(III) chloride.

5) **Instrumental Analysis** **(3 Weeks x 4 Hrs)**

a. Colorimetric determination of copper.
b. Determination of pH of buffer solution using a pH meter and evaluation of pKa of acids.
c. Determination of solubility of sparingly soluble compound by conductometry.
d. Potentiometric determination of solubility of silver halide and the standard electrode potential using quinhydrone electrode.

SIXTH SEMESTER

G502.6a: Chemistry Paper VII

Learning Outcomes:

After learning this course students shall be able to:

- Describe molecular vibrations with the interaction of matter and electromagnetic waves and identify vibrational degrees of freedom.
- Explain the basic concepts in infrared and Raman spectroscopy.
- Understand the principle, instrumentation and applications of mass spectroscopy.
- Predict thermodynamic and kinetic stabilities of metal complexes and mechanism of substitution in square planar complexes.
- Understand bonding and applications of organometallic complexes.
- Classify basic symmetry groups and operations in simple molecules.
- Understand the concept of enolates and active methylene compounds and their role in organic synthesis.
- Understand description of various types of nano materials, host-guest chemistry, self-assembled structures, nano-structured materials, and their applications.
- Design multistep organic synthesis by retrosynthetic approach.

UNIT I

Vibrational Spectroscopy **7 Hrs**

Molecular vibrations, vibrational degrees of freedom, absorption of IR – conditions with examples (IR active and IR inactive); Hooke's law, Energy levels of a simple harmonic oscillator, selection rules, Instrumentation, sampling techniques and measurement of IR spectrum intensity and position of IR bands. Applications of IR - calculation of moment of inertia, bond length, force constant, and dissociation energy; effect of anharmonic motion; Fingerprint region and functional group region. Characteristic absorptions of various functional groups and interpretation of IR spectra of simple organic compounds –1-Hexyne, benzaldehyde, aniline, ethanol, benzoic acid, toluene, benzonitrile.

Raman Spectroscopy **2 Hrs**

Classical and Quantum theory of Raman effect - Explanation for Raman frequency, Raman Effect, Raman spectrum, Rayleigh's line, stokes' line and antistokes' line.

Concept of polarizability. Type of molecules giving Raman spectra, mutual exclusion principle. Applications of Raman spectroscopy. Advantages of Raman spectroscopy over IR spectroscopy.

Mass spectrometry **4 Hrs**

Principle and instrumentation of mass spectrometer. Applications in the determination of molecular mass and isotopic abundance; Nitrogen rule, even electron rule, McLafferty

rearrangement. Differentiation between 2-methylbutanal and 3-methylbutanal by McLafferty rearrangement.

UNIT II

Thermodynamic and Kinetic Aspects of Metal Complexes **4 Hrs**

Thermodynamic and kinetic stability of metal complexes, stepwise and overall stability constants. Factors affecting stability of metal complexes, Methods of determination of stability constants (spectrophotometric method). Substitution reactions of square planar complexes - trans effect, theories and applications of trans effect.

Organometallic Chemistry **5 Hrs**

Definition, Nomenclature and classification of organometallic compounds. Structure, preparation, properties, bonding and applications of alkyls and aryls of Li, Al, Hg, Grignard reagents. Industrial application of organometallic compounds – Hydrogenation of alkenes - Wilkinsons' catalyst, Fischer-Tropsch synthesis.

Metal carbonyls - Mononuclear carbonyls, 18 electron rule, nature of bonding in metal, evidences in support of back bonding. Preparation and structure of Nickel tetracarbonyl, $Co_2(CO)_8$.

Symmetry and Point Groups **4 Hrs**

Symmetry elements and associated symmetry operations. Types of symmetry elements - axis of symmetry, plane of symmetry, centre of symmetry, identity, rotation reflection axes. Classification of molecules based on symmetry elements - Schoenflies notation, taking the examples of H_2O, NH_3, BF_3 and HCl. Flow chart for assigning point group.

UNIT III

Supramolecular Chemistry **3 Hrs**

Introduction – Definition, basics of Supramolecular Chemistry, Classification of supramolecules, Host and guest compounds, Driving forces for the formation of supramolecular structures, Applications.

Nano Chemistry **3 Hrs**

Introduction, nanostructures, types with examples, quantum structures, synthesis – sol-gel method; Properties of carbon nano structures. Inorganic nanotubes and nanowires. Nanocomposites and nanofibres. Applications of nanotechnology in catalysis, biology; Nanofilters; nanoswitches. Surface characterization technique - principle of SEM, Advantages of SEM.

Organic Synthesis *via* Enolates **4 Hrs**

Acidity of α-hydrogens. Alkylation of diethyl malonate and ethyl acetoacetate. Synthesis of ethyl acetoacetate, Claisen condensation with mechanism. Keto-enol tautomerism of ethyl acetoacetate. Reactions supporting keto and enol forms.

Uses of malonic ester (to synthesize alkyl acetic acid, dicarboxylic acids, β-keto acids, α, β-unsaturated acids) and acetoacetic ester (for synthesis of carboxylic acids, diketones and dicarboxylic acids, α-β unsaturated acids and methyl ketones). Synthesis of 4-methyluracil and antipyrine.

Retrosynthesis **3 Hrs**

Introduction to multistep synthesis; designing a synthesis – Synthesis of ketone, alkyl halide and alcohol from alkyne; Retrosynthetic analysis, synthon, synthetic equivalent, target molecule, functional group addition (FGA), functional group interconversion (FGI), Disconnection.

Reference books:

1. *Instrumental methods of Chemical analysis*, G. R. Chatwal, Sham Anand (2011), Himalaya Publishing House.
2. *Spectrometric Identification of Organic Compounds,* R. M. Silverstein, F. X. Webster, D. J. Kiemle, 8th Ed (2014), John Wiley & Sons.
3. *A Textbook of Inorganic Chemistry*, Puri and Sharma 2000, 33rd Ed. (2017), Milestone Publishers.
4. *Organometallic chemistry: A Unified Approach*, R. C. Mehrotra and A. Singh (1991), New Age Publishers.
5. *Group Theory and Symmetry in Chemistry,* Gurudeep Raj, A. Bhagi, V. Jain (2017), Krishna Prakashan Media Ltd.
6. *Chemical Applications of Group Theory*, F. A. Cotton, 3rd Ed (2008), Wiley.
7. *The Chemistry of Nanomaterials: Synthesis, Properties and Applications,* C. N. R. Rao, A. Müller, A. K. Cheetham (Eds), Wiley-VCH (2004).
8. *Introduction to Supramolecular Chemistry*, Asim K. Das and Mahua Das, CBS (2020).
9. *Bioorganic, Bioinorganic and Supramolecular Chemistry*, P. S. Kalsi and J. P. Kalsi, New Academic Science Ltd (2011).
10. *Organic Chemistry*, Paula Y. Bruice, 8th Ed. (2016), Pearson Education Publishers.
11. *Organic synthesis: The disconnection approach*, Stuart Warren and Paul Wyatt, 2nd Ed (2009), Wiley Publications.

SIXTH SEMESTER

G502.6b: Chemistry Paper VIII

Learning outcomes:

After completion of the course, the learner shall be able to:

- Understand basic principle of electrochemistry and its applications.
- Learn different types of galvanic cells, Nernst equation, calculations of thermodynamic properties and applications of conductometric and potentiometric titrations.
- Learn principles and application of Green chemistry in industrial processes.
- Understand the importance and theory behind biopolymers and biodegradable polymers.
- Understand the basics of NMR spectroscopy and apply this knowledge to elucidate the structure of simple organic molecules.
- Learn structures of some alkaloids and terpenes and their extraction process from plants.

UNIT I

Electrochemistry **13 Hrs**

Specific conductance, Equivalent conductance and its determination, Kohlrausch's law and its applications, Application of conductivity measurements: determination of degree of dissociation, determination of Ka of acids, determination of solubility product of a sparingly soluble salt. Conductometric titrations weak acid-strong base, strong acid-weak base, weak acid-weak base, strong acid-strong base and mixture of acids against strong base. Debye-Huckel theory, Debye-Huckel-Onsager's equation for strong electrolytes (no derivation). Transport number, definition, determination of transport number by Hittorf's method and Moving boundary method.

Activity, activity coefficient. Reference electrode: calomel electrode. Indicator electrode, metal – metal ion electrode, quinhydrone electrode, Inert electrode, EMF of a cell and its measurements. Computation of cell EMF. Relation between G and K for a cell reaction, decomposition potential and its applications and hydrogen overvoltage. Concentration cell with and without transference, Liquid Junction potential, Application of concentration cells- determination of valency of ions and solubility product, potentiometric titrations Redox and acid base. Determination of pH using quinhydrone electrode and SbO/Sb_2O_3 electrodes. Problems.

UNIT II

Sustainable Chemistry

Green Chemistry **4 Hrs**

Introduction, the need of green chemistry; Principles of green chemistry; Designing a green synthesis – Green reactions, Concept of atom economy for simple organic reactions. Calculation of atom economy for organic reactions.

Applications in industry: Green starting materials - D-glucose to adipic acid; Green reagents - dimethyl carbonate; Green solvents - Supercritical CO_2 and ionic liquids; Green catalyst - biocatalysts. Green synthesis of methyl methacrylate, furfural and paracetamol.

Biopolymers and Bioplastics **4 Hrs**

Biopolymers- definition and examples – cellulose, starch and lignins; Bioplastics - definition and examples - starch based, cellulose based plastics, aliphatic polyesters (PLA, PHB), bio-derived polyethylene and genetically modified bioplastics. Environmental impact of bioplastics and biodegradation.

Biodegradable and Conducting Polymers **5 Hrs**

Biodegradable polymer – Introduction; Polyhydroxyalkanoates (P3HB and P3HB-*co*-3HV) and polyurethanes - Preparation, Structure and properties, mechanism of breakdown; Applications and uses. Conducting polymers **-** Introduction, definition and examples - polyaniline, polyacetylene. Mechanism of conduction. Qualitative treatment of doping, Properties- elasticity with high electrical conductivities, Engineering and biological applications. conduction mechanism, polyacetylene, polyparaphenylene and polypyrole, applications.

UNIT III

NMR Spectroscopy and Applications **7 Hrs**

Proton magnetic resonance ('H NMR) Spectroscopy, instrumentation, solvents used, TMS as Internal standard scales, nuclear shielding and deshielding, calculation of chemical shift and molecular structure. Factors affecting chemical shift (inductive, anisotropic, hydrogen bonding). Spin-spin splitting and coupling constants, number of signals, areas of signals, interpretation of PMR spectra of simple organic molecules such as ethyl bromide, ethanol, acetaldehyde, 1,1,2- tribromoethane and ethyl acetate.

Dyes and Colouring Agents **3 Hrs**

Dyes-Witt's theory and molecular orbital theory of colour and constitution. Classification based on structure and application. Synthesis of Methyl orange, Congo red, Malachite green, Crystal violet, Phenolphthalein, Fluorescein, Alizarin and Indigo. Action of methyl orange and phenolphthalein as indicators.

Chemistry of Natural Products **3 Hrs**

Alkaloids: Classification of alkaloids with examples – Pyridine, piperidine, Quinoline, Isoquinoline and indole alkaloids, extraction of alkaloids from plants. General properties– formation of salts and exhaustive methylation, physical properties and physiological activity. structural elucidation of nicotine including synthesis. Structural formulae of atropine and cocaine

Terpenes: Isoprene rule, Classification, isolation of terpenes, structural elucidation of citral including synthesis. Structural formulae of geraniol, menthol, α-pinene and camphor.

Reference books:

1. *Textbook of Physical Chemistry*, S. Glasstone, 2nd Ed. 1982, McMillan Publishers.
2. *Advanced Physical Chemistry*, Gurudeep Raj, 4th Ed (2016), Krishna Prakashan Media.
3. *Organic Spectroscopy*, William Kemp, 3rd Ed. (2019), McMillan.
4. *Elementary Organic Spectroscopy: Principles and Chemical Applications*, Y. R. Sharma (2010), New Age.
5. New Trends in Green Chemistry, V.K. Ahluwalia, M. Kidwai (2004), Springer Science.
6. *Organic Chemistry of Natural Products (Vol - I and II)*, Gurudeep R. Chatwal, M. Arora, (2009), Himalaya Publishing House.
7. *Organic Chemistry*, R. T. Morrison, R. N. Boyd and S. K. Bhattacharjee, 7th Ed. (2010), Pearson Education India.
8. *A Textbook of Chemistry*, Raj K. Bansal (2015), New Age International.
9. *Advanced Organic Chemistry*, Arun Bahl, B. S. Bahl, 5th Ed (2012), S. Chand.
10. *Biopolymers*, R.M. Johnson, L.Y. Mwaikambo and N. Tucker (2010).
11. *Handbook of Bioplastics & Biocomposites for Engineering Applications*, Srikanth Pilla (2011), John Pillai & Sons.

G502.6P: Chemistry Practical VI

PART A (Compulsory for All Students) **(4 Weeks x 4 Hrs)**

1) Conductometric determination of two acid mixture (acetic acid and hydrochloric acid).
2) Conductometric determination of three acid mixture - Trichloroacetic acid and acetic acid or monochloroacetic acid and acetic acid.
3) Potentiometric titration of ferrous ammonium sulphate using potassium dichromate as titrant and calculation of the redox potential of Fe^{2+}/ Fe^{3+} system on the hydrogen scale.
4) Spectrophotometric determination of ferrous ions using 1,10-phenanthroline.
5) Spectrophotometric determination of glucose by DNS method.
6) Conductometric determination of vitamin C in the tablets.

PART B: For Students without Project Work **(9 Weeks x 4 Hrs)**

1) Flame photometric determination of Na, Li and Ca in pharmaceutical formulation.
2) Potentiometric determination of dissociation constant of a weak acid. Analysis of alloys – Gun metal.
3) Analysis of ores – haematite.
4) Conductometric determination of equivalent conductance of sodium chloride.
5) Conductometric determination of ionisation constant of a weak acid.
6) Polarimetric determination of rate of inversion of cane sugar.
7) Determination of nitrogen in organic compounds by Kjeldahl's method.
8) Determination of adulteration in food stuffs.
9) Determination of chloride or sulphate by nephelometric method.

PROJECT WORK **(9 Weeks X 4 Hours)**

In addition to experiments of Part A of G502.6P, student will take experimental project work related to the elective chosen by the student. The work will be supervised and certified by a teacher in the department. The experimental work will be undertaken in the departmental laboratory and a project report should be submitted at the end of the semester for evaluation.

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