Four-Year B.Sc. (Honours and Honours with Research) Courses of Studies (Under Curriculum & Credit framework)

NEP-2020 (wef 2024)

SYLLABUS

FOR

CHEMISTRY

Raja Narendra Lal Khan Women's College (Autonomous)

Semester-I

Course	Paper Code	Name of the Subject	Brief Description	Credit
Major	CHEM-MJ-101-T	Fundamental Chemistry-IT	Extra nuclear structure of atoms and Periodicity, Basics of Organic Chemistry Bonding and Physical Properties, Stereochemistry – I Thermodynamics–I, Chemical Kinetics-I	03
	CHEM-MJ-101-P	Fundamental Chemistry- IP	Acid-Base Titration, Oxidation-Reduction Titrimetry.	01
Minor-1	CHEM-MI-I-T	Chemistry MINOR-I Fundamental Chemistry-IT	Extra nuclear structure of atoms and Periodicity, Basics of Organic Chemistry Bonding and Physical Properties, Stereochemistry – I, Thermodynamics –I, Chemical Kinetics-I.	03
	CHEM-MI-I-P	Chemistry MINOR-I-P Fundamental Chemistry-I-P	Acid-Base Titration, Oxidation-Reduction Titrimetry.	01
Skill Enhancement Course	CHEM-H-SEC-101-T	Chemistry of Cosmetics, Perfumes and Pesticides	Introduction to cosmetics, perfumes and pesticides Basic laboratory practices.	02
	CHEM-H-SEC-101-P	Chemistry of Cosmetics, Perfumes and Pesticides	Introduction to cosmetics, perfumes and pesticides Basic laboratory practices.	01

CHEMISTRY MAJOR

PAPER: CHEM-MJ-101-T

(Credit: Theory-03, Practical–01)

Fundamental Chemistry-I

Course objectives and expected outcome: This course also deals with the fundamentals of Thermodynamics including thermodynamic systems and properties, relationships among the thermos-physical properties, the laws of thermodynamics and applications of these basic laws in thermodynamic systems.

After successful completion of this course the students will be able to:

1. Upon successful completion students should be able to apply the fundamental principles of measurement, matter, atomic theory, chemical periodicity
2. Explain the concepts of work, power, and heat in thermodynamics;determine work and heat sign conventions; determine work involved with moving boundary systems (graphical and analytical methods).
3. Explain the first law of thermodynamics for a closed system.
4. Determine thermodynamic properties of pure substances.
5. Chemical kinetics is the study of the rates and the mechanism of chemical reactions. Commonly the measure of how fast the products are formed and the reactants consumed is given by the rate values
6. Upon successful completion students should be able to apply the fundamental principles of measurement, matter, atomic theory, chemical periodicity
7. Working through this course, students are expected to apply their knowledge to problem-solve, deduce structures, Bonding geometries of carbon compounds and representation of molecules.

Theory: (45Hrs)

Module: I

Extra nuclear structure of atoms: (8 Hrs)

Wave-Particle duality; de Broglie hypothesis. Heisenberg's uncertainty principle. Introducing Schrödinger equation. Hydrogen and hydrogen like systems (detailed solution not required). Concept of Atomic Orbital; shapes of s, p and d orbitals. Radial and angular distribution curves. Extension to multi electronic systems. Aufbau principle and its limitations; Pauli's exclusion principle; Hund'srules and multiplicity. Effective nuclear charge. Shielding and penetration; Slater's rule.

Chemical Periodicity: (7 Hrs)

The general idea about modern periodic table, atomic and ionic radii, ionization energy, electron affinity and electro negativity –definition, trends of variation in periodic table and their application in explaining and predicting the chemical behavior of elements and compounds. Electronegativity scales (Pauling's, Mulliken's and Allred-Rochow's scales). Inert pair effect.

Module: II

Basics of Organic Chemistry Bonding and Physical Properties: (10 Hrs)

Valence Bond Theory

Nomenclature of Organic Compounds, Concept of hybridisation, shapes and structures of molecules, double bond equivalent (DBE), Resonance (including hyper conjugation) and Resonance energy.

Electronic displacement:

Inductive effect, bond polarization and bond polarizability; steric effect, steric inhibition of resonance.

MO Theory

Qualitative idea about molecular orbitals, bonding and anti-bonding interactions, idea about σ, σ*, π, π *, n – MOs; concept of HOMO, LUMO and SOMO; sketch and energy levels of π MOs of i) acyclic p orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems) cyclic p orbital system (neutral systems: [4],[6]annulenes; charged systems: 3-,4-,5-7 membered ring systems); Hückel's rules for aromaticity up to [8] annulene; concept of anti-aromaticity; non-aromatic molecules.

Physical properties

Melting point/boiling point and solubility of common organic compounds in terms of covalent & non-covalent intermolecular forces; polarity of molecules and dipole moments.

Stereochemistry–I: (5Hrs)

Bonding geometries of carbon compounds and representation of molecules: tetrahedral nature of carbon and concept of asymmetry; Fischer, saw horse,flying wedge and Newman projection formulae and their inter translations. Concept of chirality and symmetry: symmetry elements, molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of stereogenicity, chiral centres and number of stereoisomers: systems involving 1/2-chiral centre(s).

Module: III

Thermodynamics-I:
Zeroth Law & First Law of Thermodynamics (9Hrs)

Concept of systems (open, closed and isolated) and surroundings. State of a system; Intensive and extensive variables. Partial derivatives. Exact and in exact differentials. Path function and State function. Concept of heat and work. Zeroth law of thermodynamics. Concept of thermodynamic reversibility. Concept of internal energy and 1^{st} law of thermodynamics. Enthalpy and heat capacity, Relations between C_p and C_v. Isothermal and Adiabatic processes;

Thermochemistry: Calculations of ΔU, ΔH, q and w involving ideal gases in different processes. Enthalpy of reaction. Hess's law. Enthalpy of formation and combustion. Kirchhoff's equation.

Chemical Kinetics-I: **(6Hrs)**

Concept of order and molecularity. Rate laws for zero, 1st and 2nd order reactions and in general for any nth order reaction. Determination of order of a reaction by half-life and differential methods. Rate determining step and steady state approximation. Opposing, Consecutive and parallel reactions (first order steps only). Temperature dependence of rate constant and Arrhenius equation.

Recommended Text Books:

1. Lee, J.D. Concise Inorganic Chemistry, 5thEd., Wiley India Pvt.Ltd.,2008.
2. Atkins, Overton, Rourke, Weller, Armstrong; Shriver &Atkins' Inorganic Chemistry, 5thEd., Oxford University Press (2010).
3. Finar,I.L. Organic Chemistry (Volume1), 6th Edition, Pearson Education,2002
4. Sykes, P. A guide book to Mechanism in Organic Chemistry, Pearson Education,2003.
5. Nasipuri, D. Stereochemistry of Organic Compounds, 4th Edition, New Age International Pvt Ltd, 2020
6. Levine,I.N. Physical Chemistry, 6th Edition McGraw-Hill India,2011
7. Castellan,G.W. Physical Chemistry,Narosa ,2004
8. Atkins, P. W. & Paula, J. de, Atkins'Physical Chemistry, 11th Edition, Oxford University Press,2018
9. G.L.Miessler, D.A.Tarr, Inorganic Chemistry,3rdEdition,Pearson India,2008

Practical: (30Hrs)

Course objectives and expected outcome: Facilitate the learner to make solutions of various molar concentrations. This may include: The concept of the mole; Converting moles to grams; Converting grams to moles; Defining concentration; Dilution of Solutions; Making different molar concentrations. They will also experience in different type of titration like acid-base, oxidation-reduction titration.

PAPER: CHEM-101-P

(1) Calibration and use of apparatus.

(2) Preparation of primary standard solutions (Oxalic Acid and $K_2Cr_2O_7$)

Acid-Base Titrations:

(3) Standardization of NaOH standard oxalic acid solution.

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

(5) Estimation of acetic acid in commercial Vinegar.

Oxidation-Reduction Titrimetry:

(6) Standardization of $KMnO_4$standard oxalic acid solution.

(7) Estimation of Fe(II) using standardized $KMnO_4$solution.

(8) Estimation of Fe(III) using standard $K_2Cr_2O_7$solution.

(9) Estimation of Fe(II)and Fe(III)in a given mixture using standard $K_2Cr_2O_7$solution.

Reference Books:

1. Mendham, J.,A.I.Vogel's Quantitative Chemical Analysis 6th Ed.,Pearson,2009.
2. Practical Work book Chemistry (Honours), UGBOS, Chemistry, University of Calcutta,2015.
3. An Advanced Course In Practical Chemistry Book by Nad, Mahapatra, Ghosal.

CHEMISTRY MINOR

PAPER: CHEM-MI-I

(Credit: Theory-03, Practical–01),

Chemistry Minor-I

Course objectives and expected outcome: This course also deals with the fundamentals of Thermodynamics including thermodynamic systems and properties, relationships among the thermos-physical properties, the laws of thermodynamics and applications of these basic laws in thermodynamic systems.

After successful completion of this course the students will be able to:

1. Explain fundamental concepts relevant to thermodynamics.
2. Explain the concepts of work, power, and heat in thermodynamics;determine work and heat sign conventions; determine work involved with moving boundary systems (graphical and analytical methods).
3. Explain the first law of thermodynamics for a closed system.
4. Determine thermodynamic properties of pure substances.
5. Chemical kinetics is the study of the rates and the mechanism of chemical reactions. Commonly the measure of how fast the products are formed and the reactants consumed is given by the rate values
6. Upon successful completion students should be able to apply the fundamental principles of measurement, matter, atomic theory, chemical periodicity
7. Working through this course, students are expected toapply their knowledge to problem-solve, deduce structures, Bonding geometries of carbon compounds and representation of molecules.

Module: I

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Wave-Particle duality; de Broglie hypothesis. Heisenberg's uncertainty principle. Introducing Schrödinger equation. Hydrogen and hydrogen like systems (detailed solution not required). Concept of Atomic Orbital; shapes of s, p and d orbitals. Radial and angular distribution curves. Extension to multi electronic systems. Aufbau principle and its limitations; Pauli's exclusion principle; Hund's rules and multiplicity. Effective nuclear charge. Shielding and penetration; Slater's rule

Chemical Periodicity: **(7 Hrs)**

The general idea about modern periodic table, atomic and ionic radii, ionization energy, electron affinity and electro negativity definition, trends of variation in periodic table and their application in explaining and predicting the chemical behavior of elements and compounds. Electronegativity scales (Pauling's,Mulliken's and Allred-Rochow's scales). Inert pair effect.

Module: II

Basics of Organic Chemistry Bonding and Physical Properties: (10 Hrs)

Valence Bond Theory

Nomenclature of Organic Compounds, Concept of hybridisation, shapes and structures of molecules, double bond equivalent (DBE), Resonance (including hyperconjugation) and Resonance energy.

Electronic displacements

Inductive effect, bond polarization and bond polarizability; stericeffect, steric inhibition of resonance.

MO Theory

Qualitative idea about molecular orbitals, bonding and antibonding interactions, idea about σ, σ*, π, π *, n– MOs; concept of HOMO, LUMO and SOMO; sketch and energy levels of π MO's of acyclic orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems), cyclic p orbital system (neutral systems: [4], [6] annulenes; charged systems: 3-,4-,5-7 membered ring systems); Hückel's rules for aromaticity up to [8] annulene; concept of anti-aromaticity; non-aromatic molecules.

Module:III

Thermodynamics-I: **(9 Hrs)**

Concept of systems (open, closed and isolated) and surroundings. State of a system; Intensive and extensive variables. Partial derivatives. Exact and inexact differentials. Path function and State function. Concept of heat and work. zeroth law of thermodynamics. Concept of thermodynamic reversibility. Concept of internal energy and 1^{st} law of thermodynamics. Enthalpy and heat capacity, Relations between C_P and C_V. Isothermal and Adiabatic processes.

Thermochemistry: Calculations of ΔU, ΔH, q and w involving ideal gases in different processes. Enthalpy of reaction. Hess's law. Enthalpy of formation and combustion. Kirchhoff's equation.

Chemical Kinetics-I: **(6 Hrs)**

Concept of order and molecularity. Rate laws for zero, 1^{st} and 2^{nd} order reactions and in general for any n^{th} order reaction. Determination of order of a reaction by half-life, ratio variation and differential methods. Rate determining step and steady state approximation. Opposing, Consecutive and parallel

reactions (first order steps only). Temperature dependence of rate constant and Arrhenius equation.

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Practical:(30 Hrs)

Course objectives and expected outcome: Facilitate the learner to make solutions of various molar concentrations. This may include: The concept of the mole; Converting moles to grams; Converting grams to moles; Defining concentration; Dilution of Solutions; Making different molar concentrations. They will also experience in different type of titration like acid-base, oxidation-reduction titration.

PAPER: CEM-I-P

(1) Calibration and use of apparatus.

(2) Preparation of primary standard solutions (Oxalic Acid and $K_2Cr_2O_7$)

Acid-Base Titrations:

(3) Standardization of NaOH standard oxalic acid solution.

(4) Estimation of Carbonate and bicarbonate present together in a mixture

(5) Estimation of acetic acid in commercial Vinegar.

Oxidation-Reduction Titrimetry:

(6) Standardization of $KMnO_4$standard Oxalic Acid solution.

(7) Estimation of Fe(II)using standardized $KMnO_4$solution.

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Reference Books:

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3. An Advanced Course in Practical Chemistry. Ghoshal, Mahapatra and Nad.

SKILL ENHANCEMENT COURSE

PAPER: CEM-SEC-101

(Credit: Theory-02, Practical–01)

SEC-101T: CHEMISTRY OF COSMETICS, PERFUMES AND PESTICIDES
Credit 02 (30 Hrs)

Course objectives and expected outcome: Facilitate the learner to understand about the preparation of cosmetic products and some essential oils.

Course Contents:
Chemistry of Cosmetics and Perfumes:

A general study including preparation and uses of the following: Hair dye, hair spray, shampoo, suntan lotions, face powder, lipsticks, talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants and artificial flavors. Essential oils and their importance in cosmetic industries with reference to Eugenol, Geraniol, sandalwood oil, eucalyptus, rose oil, 2 phenyl ethyl alcohol, Jasmone, Civetone, Muscone.

Chemistry of Pesticides:

General introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides, structure activity relationship, synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene,); Organophosphates (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor).

SEC-101-P: Practical Credit 01 (15 Hrs)

Course objectives and expected outcome: Facilitate the learner to understand about the preparation of cosmetic products and some essential oils.

1. Preparation of talcum powder.
2. Preparation of shampoo.
3. Preparation of enamels.
4. Preparation of hair remover.
5. Preparation of face cream.
6. Preparation of nail polish and nail polish remover.
7. To calculate acidity/alkalinity in given sample of pesticide formulations as per BIS specifications.

SEMESTER – II

Course	Paper Code	Name of the Subject	Brief Description	Credit
Major	CHEM-MJ-201-T	Fundamental Chemistry-II	Kinetic Theory and Gaseous state, Chemical Bonding – I, Stereochemistry – II, General Treatment of Reaction Mechanism-I	03
	CHEM-MJ-201-P	Fundamental Chemistry-IIP	Iodo-/ IodimetricTitrations , Estimation of metal content in some selective samples.	01
Minor -II	CHEM-MI-2-T	Chemistry MINOR-II	Kinetic Theory and Gaseous state, Chemical Bonding–I, Stereochemistry – II, General Treatment of Reaction Mechanism-I.	03
	CHEM-MI-2-P	Chemistry MINOR-II	Iodo-/Iodimetric Titrations, Estimation of metal content in some selective samples.	01
Skill Enhancement Course	CHEM-H-SEC-201-T	Pharmaceutical Chemistry	Drugs & Pharmaceuticals, Fermentation	02
	CHEM-H-SEC-201-P	Pharmaceutical Chemistry	Preparation of drug molecules	01

CHEMISTRY MAJOR

PAPER: CHEM-MJ-201-T

(Credit: Theory-03, Practical–01)

Fundamental Chemistry-II

Course objectives and expected outcome: The kinetic theory of gases explains the three macroscopic properties of a gas in terms of the microscopic nature of atoms and molecules making up the gas. Usually, the physical properties of solids and liquids can be described by their size, shape, mass, volume etc. However, when we talk about gases, they have no definite shape, size while mass and volume are not directly measurable. The Kinetic theory of gases is useful and can be applied in this case. With the help of the kinetic theory of gases, the physical properties of any gas can be defined generally in terms of three measurable macroscopic properties. Upon successful completion students should be able to apply the fundamental principles of measurement, matter, atomic theory, chemical periodicity, general chemical reactivity and solution chemistry to subsequent courses in science. Bonding geometries of carbon compounds and representation of molecules, concept of chirality, optical activity of chiral compounds and symmetry, and synthesize simple organic molecules using the studied reactions. Relationships between organic chemistry and other disciplines are noted.

Theory:(45Hrs)

Module: I

Kinetic Theory and Gaseous state: (8 Hrs)

Concept of pressure and temperature from kinetic theory of gas. Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules);Wall collision and rate of effusion Calculation of number of molecules having energy $\geq \varepsilon$, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

Real gas and Virial equation: (7Hrs)

Deviation of gases from ideal behavior; Compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; its derivation and application in explaining real gas behavior; Existence of critical state, Critical constants in terms of vander Waals constants; Law of corresponding states; Virial equation of state; van der Waals equation expressed in the Virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard-Jones potential - elementary idea.

Module: II

Chemical Bonding– I: **(15Hrs)**

i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its application and limitations. Packing of ions in crystals. Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy. Defects in solids (elementary idea). Solubility energetic of dissolution process.

ii) Covalent bond: Polarizing power and polarizabilty, ionic potential, Fajan's rules, Lewis structures, formal charge, Valence Bond Theory,the hydrogen molecule(Heitler –London approach),directional character of covalent bonds, hybridizations, equivalent and non-equivalent hybrid orbitals, Bent's rules, dipole moments, VSEPR theory, shapes of molecules and ions containing lone pairs (examples from main group chemistry) and multiple bonding (σ and π bond approach).

Module: III

Course objectives and expected outcome: Facilitate the learner to know about stereochemistry, reaction thermodynamics, concept of organic acids and bases, tautomerism and reaction kinetics.

Stereochemistry–II: **(8Hrs)**

Chirotopicity and its relationship with stereogenicity; concept of pseudo asymmetry for ABA type systems. Relative and absolute configuration: *R/S* descriptors; *erythro/threo* and *meso* nomenclature of compounds; *E/Z* descriptors for C=C, combination of *R/S*- and *E/Z* isomerisms. Optical activity of chiral compounds: optical rotation, and specific rotation; racemic compounds, racemisation (through cationic, anionic intermediates); resolution of acids and bases *via* diastereomeric salt formation; optical purity and enantiomeric excess.

General Treatment of Reaction Mechanism –I: **(7Hrs)**

Reactive intermediates

Carbocations (carbenium and carbonium ions), non-classical carbocations, carbanions, carbon radicals: generation And stability, structure and electrophilic /nucleophilic behavior of reactive intermediates (elementary idea).

Reaction thermodynamics

Free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change *via* B D E, inter molecular & intra molecular reactions.

Reaction kinetics

Rate constant and free energy of activation; free energy profiles for one-step, and two-step reactions; catalyzed reactions, principle of microscopic reversibility; Hammond's postulate.

Preliminary idea about Substitution Reaction

Free-radical substitution reaction: halogenation of alkanes, mechanism (with evidence) and stereochemical features; reactivity-selectivity principle in the light of Hammond's postulate.

Recommended Text Books:

1. Lee, J.D. Concise Inorganic Chemistry,5th Ed., WileyIndiaPvt.Ltd.,2008.
2. Atkins,Overton, Rourke, Weller, Armstrong; Shriver &Atkins'InorganicChemistry,5th Ed.,OxfordUniversityPress(2010).
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9. G. L. Miessler, D. A. Tarr, Inorganic Chemistry, 3rd Edition, Pearson India, 2002.

Practical: (30Hrs)

Course objectives and expected outcome: Facilitate the learner to understand about iodometric titration and estimation

PAPER: CHEM-MJ-201-P

(1) Standardization of $Na_2S_2O_3$solution against standard $K_2Cr_2O_7$solution.

Iodo-/IodimetricTitrations

(2) Estimation of Vitamin C

(3) Estimation of (i) arsenite and (ii) antimony iodimetrically

(4) Estimation of available chlorine in bleaching powder.

Estimation of metal content in some selective samples

(5) Estimation of Cu in brass.

(6) Estimation of Cr and Mn in Steel.

(7) Estimation of Fe in cement.

Reference Books:

1. Mendham, J.A.I.Vogel's Quantitative Chemical Analysis 6thEd.,Pearson,2009.

Practical Work book Chemistry (Honours), UGBOS, Chemistry,University of Calcutta,2015

CHEMISTRY MINOR

PAPER: CHEM-MI-2-T

(Credit: Theory-03, Practical–01)

Chemistry Minor-II

Course objectives and expected outcome: The kinetic theory of gases explains the three macroscopic properties of a gas in terms of the microscopic nature of atoms and molecules making up the gas. Usually, the physical properties of solids and liquids can be described by their size, shape, mass, volume etc. However, when we talk about gases, they have no definite shape, size while mass and volume are not directly measurable. The Kinetic theory of gases is useful and can be applied in this case. With the help of the kinetic theory of gases, the physical properties of any gas can be defined generally in terms of three measurable macroscopic properties. Upon successful completion students should be able to apply the fundamental principles of measurement, matter, atomic theory, chemical periodicity, general chemical reactivity and solution chemistry to subsequent courses in science. Bonding geometries of carbon compounds and representation of molecules, concept of chirality, optical activity of chiral compounds and symmetry, and synthesize simple organic molecules using the studied reactions. Relationships between organic chemistry and other disciplines are noted.

Theory: (45Hrs)

Module: I

Kinetic Theory and Gaseous state: **(8Hrs)**

Concept of pressure and temperature from kinetic theory of gas. Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; Collision of gas molecules; Collisiondiameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules);Wall collision and rate of effusion Calculation of number of molecules having energy $\geq \varepsilon$, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases.

Real gas and Virial equation: (7Hrs)

Deviation of gases from ideal behavior; compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; its derivation and application in explaining real gas behavior, other equations of state; Existence of critical state, Critical constants in terms of vander Waals constants; Law of corresponding states; virial equation of state; vander Waals equation expressed in virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard-Jones potential elementary idea).

Module: II

Chemical Bonding– I: (15Hrs)

i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its application and limitations.Packingofionsincrystals.Born-LandeequationwithderivationandimportanceofKapustinskiiexpressionforlattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy. Defects in solids (elementary idea). Solubility energetic of dissolution process.

ii) Covalent bond: Polarizing power and polarizabilty, ionic potential, Fajan'srules, Lewis structures, formal charge, Valence Bond Theory. The hydrogen molecule (Heitler –London approach), directional character of covalent bonds, hybridizations, equivalent and non-equivalent hybrid orbitals, Bent's rules, dipole moments, VSEPR theory, shapes of molecules and ions containing lone pairs (examples from main group chemistry) and multiple bonding (σ and π bond approach).

Module: III

Stereochemistry–II: (8Hrs)

Chirotopicity and its relationship with stereogenicity; concept of pseudoasymmetry for ABA type systems. Relative and absolute configuration: *R/S* descriptors; *erythro/threo*and *meso*nomenclature ofcompounds; *E/Z* descriptors for C=C, combination of *R/S*- and *E/Z* isomerisms. Optical activity of chiral compounds: optical rotation, and specific rotation; racemic compounds, racemisation (through cationic, anionic intermediates); resolution of acids and bases *via* diastereomeric salt formation; optical purity and enantiomeric excess.

General Treatment of Reaction Mechanism –I: (7 Hrs)

Reactive intermediates

Carbocations (carbenium and carbonium ions), non-classical carbocations, carbanions, carbon radicals: generation And stability, structure and electrophilic/nucleophilic behavior of reactive intermediates (elementary idea).

Reaction thermodynamics

Free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change *via* BDE, intermolecular & intramolecular reactions.

Reaction kinetics

Rate constant and free energy of activation; free energy profiles for one-step, and two-step reactions; catalyzed reactions, principle of microscopic reversibility; Hammond's postulate.

Preliminary idea about Substitution reaction

Free-radical substitution reaction: halogenation of alkanes, mechanism (with evidence) and stereochemical features; reactivity-selectivity principle in the light of Hammond's postulate.

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Practical: (30Hrs)

PAPER:CHEM-MI-2-P

Course objectives and expected outcome: Facilitate the learner to understand about iodometric titration and estimation

Iodo-/IodimetricTitrations

(1) Standardization of $Na_2S_2O_3$solution against standard $K_2Cr_2O_7$solution.

(2) Estimation of Vitamin C

(3) Estimation of (i) arsenite and(ii)antimony iodimetrically

(4) Estimation of available chlorine in bleaching powder.

Estimation of metal content in some selective samples

(5) Estimation of Cu in brass.

(6) Estimation of Cr and Mn in Steel.

(7) Estimation of Fe in cement.

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SKILL ENHANCEMENT COURSE

PAPER: CEM-SEC-201

(Credit: Theory-02, Practical–01)

SEC-201T: Pharmaceutica Chemistry **(Credits 02) (30 Hrs)**

Course objectives and expected outcome: Facilitate the learner to understand about the structures, properties and functions of drugs and pharmaceuticals and to gain the idea about fermentation.

Drugs&Pharmaceuticals

Drug discovery, design and development; Basic Retrosynthetic approach. Synthesis of there presentative drugs of the following classes: analgesics agents, anti pyretic agents, anti-inflammatory agents (Aspirin,paracetamol, lbuprofen); antibiotics (Chloramphenicol);antibacterial and antifungal agents (Sulphonamides; Sulphanethoxazol, Sulphacetamide, Trimethoprim); antiviral agents (Acyclovir), Central Nervous System agents (Pheno barbital,Diazepam), Cardio vascular(Glyceryltrinitrate),antilaprosy (Dapsone), HIV-AIDS related drugs(AZT-Zidovudine).

Fermentation
Aerobic and an aerobic fermentation. Production of (i) Ethyl alcohol and citric acid, (ii)Antibiotics;Penicillin, Cephalosporin,ChloromycetinandStreptomycin,(iii)Lysine,Glutamicacid, Vitamin B2, Vitamin B12and Vitamin C.

SEC-201-P: Pharmaceuticals Chemistry - 01 (15 Hrs)

Course objectives and expected outcome: Facilitate the learner to understand about the structures, properties and functions of drugs and pharmaceuticals.

Practical:

1. Preparation of Aspirin and its analysis.
2. Preparation of magnesium bisilicate(Antacid).

SEMESTER – III

Course	Paper Code	Name of the Subject	Brief Description	Credit
Major	CHEM-MJ-301-T	Physical Chemistry-I	Thermodynamics -II, Applications of Thermodynamics–I, Electrochemistry-I.	03
	CHEM-MJ-301-P	Physical Chemistry-I	Chemical Kinetics (Analytical), Enthlpy of neutralization and enthalpy of solubility	01
	CHEM-MJ-302-T	Organic Chemistry–I	Substitution Reactions, Stereochemistry II, General Treatment of Reaction Mechanism II	03
	CHEM-MJ-302-P	Organic Chemistry–I	Identification of a Pure Organic Compound, Separation	01
Minor -I	CHEM-MI-IT	Chemistry MINOR-I	Extra nuclear structure of atoms and Periodicity, Basics of Organic Chemistry Bonding and Physical Properties, Stereochemistry – I, Thermodynamics –I, Chemical Kinetics-I.	03
	CHEM-MI-I-P	Chemistry MINOR-I	Acid-Base Titration, Oxidation-Reduction Titrimetry.	01
Skill Enhancement Course	CHEM-H-SEC-301-T	Fuel Chemistry	Coal Petroleum, Lubricants and Petrochemicals	02
	CHEM-H-SEC-301-P	Fuel Chemistry	Project on energy science	01

CHEMISTRY MAJOR

PAPER: CHEM-MJ-301

(Credit: Theory-03, Practical–01)

Theory:(45Hrs)

PHYSICAL CHEMISTRY-I

Course objectives and expected outcome: The kinetic theory of gases explains the three macroscopic properties of a gas in terms of the microscopic nature of atoms and molecules making up the gas. Usually, the physical properties of solids and liquids can be described by their size, shape, mass, volume etc. However, when we talk about gases, they have no definite shape, size while mass and volume are not directly measurable. The Kinetic theory of gases is useful and can be applied in this case. With the help of the kinetic theory of gases, the physical properties of any gas can be defined generally in terms of three measurable macroscopic properties. This course also deals with the fundamentals of Thermodynamics including thermodynamic systems and properties, relationships among the thermos-physical properties, the laws of thermodynamics and applications of these basic laws in thermodynamic systems.

After successful completion of this course the students will be able to: Explain fundamental concepts relevant to thermodynamics. Explain the concepts of work, power, and heat in thermodynamics; determine work and heat sign conventions; determine work involved with moving boundary systems (graphical and analytical methods). Explain the first law of thermodynamics for a closed system. Perform energy analysis of refrigeration and heat pump thermodynamic cycles. Determine thermodynamic properties of pure substances. Apply the first law of thermodynamics for a control volume, including with turbines, compressors, nozzles, diffusers, heat exchangers, and throttling devices. Explain the second law of thermodynamics, including why it is necessary, how it is defined (Kelvin- Planck and Clausius), the nature of irreversibility, and the Carnot cycle. Explain the concept of entropy, including the Clausius Inequality.

Module: I

Thermodynamics-II: **(20 Hrs)**

Second Law

Need for a Second law; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Carnot engine and refrigerator; Kelvin – Planck and Clausius statements and equivalence of the two statements with entropic formulation; Carnot's theorem; Values of §dQ/T and Clausius inequality; Physical concept of Entropy; Entropy is a measure of the microscopic disorder of the system. Entropy changes of systems and Surroundings for various processes and transformations; Entropy and unavailable work; Temperature – Entropy diagram. Useful work and The Gibbs and Helmholtz function. Changes at constant T,P. Application to electric work. Criteria for spontaneity and equilibrium. Gibbs- Helmholtz equation, The Gibbs Function and useful work in biological systems. Gibbs free energy and spontaneous phase transition. Maxwell's relations; Joule-Thomson experiment and its consequences; inversion temperature; Joule-Thomson coefficient for a van der Waals gas; General heat capacity relations

Systems of Variable Compositions

State functions for system of variable compositions. Criteria of equilibrium and spontaneity in systems of variable composition. Partial molar quantities, dependence of thermodynamic parameters on composition;

Chemical potential as an escaping tendency. Gibbs-Duhem equation, Entropy and Gibbs function for mixing of ideal gases, the chemical potential of ideal mixtures. The Fugacity function of a pure real gas. Calculation of the fugacity of a vander Waals gas using compressibility factor. Definitions of Activities and activity coefficients. Choice of standard states. Dependence of Activity on pressure and temperature.

Module: II

Applications of Thermodynamics–I: (8 Hrs)

Chemical Equilibrium

Thermodynamic conditions for equilibrium, degree of advancement; van't Hoff's reaction isotherm (deduction from chemical potential); Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; Van't Hoff's reaction isobar and isochors from different standard states; Le Chatelier's principle and its derivation, variation of equilibrium constant under different conditions Nernst's distribution law; Application- (eg. dimerization of benzene in benzoic acid). Solvent Extraction.

Module: III

ELECTROCHEMISTRY-I:

(i) Conductance (9Hrs)

Ion conductance; Conductance and measurement of conductance, cell constant, specific conductance and molar conductance; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye –Huckel theory of Ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Debye-Huckel limiting law-brief qualitative description. Estimation of activity coefficient for electrolytes using Debye-Huckel limiting law. Ostwald's dilution law; Ionic mobility; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations. Transport number, Principles of Hittorf'sand Moving-boundary method.

(ii) Ionic Equilibrium (8Hrs)

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 Salt hydrolysis- calculation of hydrolysis constant, degree of hydrolysis and pH for different salts (exact Treatment). Determination of hydrolysis constant conductometrically. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action. Theory of acid–base indicators; selection of indicators and their limitations

Recommended Text Books:

1. Levine, I.N. Physical Chemistry,6th EditionMcGraw-HillIndia,2011
2. Castellan, G.W.Physical Chemistry,Narosa,2004
3. Atkins, P.W.&Paula,J.de,Atkins'Physical Chemistry,11th Edition, Oxford University Press, 2018.

Reference Books:

1. Denbigh, K. The Principles of Chemical Equilibrium, Cambridge University Press
2. Zemansky, M.W.& Dittman, R.H, Heat and Thermodynamics, Special Indian Edition,8th Edition,Tata-McGraw-Hil,2017
3. Klotz, Irving M, Rosenberg, Robert M, Chemical Thermodynamics, Wiley India,2013

Practical:(30Lectures)

Course objectives and expected outcome: The course provides training in advanced physical chemistry laboratory techniques. The experiments are guided by demonstrators and are designed both to illustrate the applications of theory covered in the Chemical Physics and lecture courses, and to introduce typical instrumentation. On successful completion of the course students will be able to:

1. Developed expertise relevant to the professional practice of chemistry.
2. Developed an understanding of the breadth and concepts of physical chemistry.
3. An appreciation of the role of physical chemistry in the chemical sciences.
4. Developed an understanding of the role of the chemist in tasks employing physical chemistry.
5. An understanding of methods employed for problems involving in physical chemistry.

PAPER: CHEM-MJ-301-P

Experiment-1. Determination of heat of solution of oxalic acid from solubility measurement.

Experiment-2. Determination of the rate constant for the decomposition of H_2O_2using $FeCl_3$as catalyst.

Experiment-3. Determination of the rate constant for the first order acid catalyzed hydrolysis of an ester.

Experiment-4. Determination of heat of neutralization of a strong acid by a strong base.

Reference Books:

1. Practical Work book Chemistry (Honours),UG BOS, Chemistry, University of Calcutta,2015.
2. An Advanced Course in Practical Course in Practical Chemistry, Ghosal. Mahaptra. Nad.

Paper CEM-MJ-302-T -: ORGANIC CHEMISTRY-I Credit (3Th+1Pr)

Course objectives and expected outcome: Facilitate the learner to understand about substitution reactions in aliphatic as well as aromatic compounds. Enable the learner to know about stereochemistry, reaction thermodynamics, concept of organic acids and bases, tautomerism and reaction kinetics.

Unit-I

Substitution Reactions (8Hrs)

Nucleophilic substitution reactions: substitution at sp^3 center: mechanisms (with evidence), relative rates & stereochemical features: S_N1, S_N2, S_N2', S_N1' (allylic rearrangement) and S_Ni; effects of solvent, substrate structure, leaving group and nucleophiles (including ambient nucleophiles, cyanide & nitrite); substitutions involving NGP; role of crown ethers and phase transfer catalysts; [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides].

Unit-II

Aromatic Substitution (9Hrs)

Electrophilic aromatic substitution: mechanisms and evidences in favour of it; orientation and reactivity; reactions: nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reaction; one-carbon electrophiles (reactions: chloromethylation, Gatterman-Koch, Gatterman, Houben-Hoesch, Vilsmeier-Haack, Reimer-Tiemann, Kolbe-Schmidt); *Ipso* substitituion.

Nucleophilic aromatic substitution: addition-elimination mechanism and evidences in favour of it; S_N1 mechanism; cine substitution (benzyne mechanism), structure of benzyne.

Unit-III

Stereochemistry II (20Hrs)

Chirality arising out of stereoaxis: stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in allenes, spiro compounds, alkylidene cycloalkanes and biphenyls; related configurational descriptors (R_a/S_a and *P/M*); atropisomerism; racemisation of chiral biphenyls; *buttressing* effect.

Concept of prostereoisomerism: prostereogeniccentre; concept of (*pro*)^n-*chirality*: topicity of ligands and faces (elementary idea); *pro-R/pro-S, pro-E/pro-Z* and *Re/Si* descriptors; *pro-r* and *pro-s* descriptors of ligands on pro pseudo asymmetric centre.

Conformation: conformational nomenclature: eclipsed, staggered, *gauche*, *syn* and *anti*; dihedral angle, torsion angle; Klyne-Prelog terminology; *P/M* descriptors; energy barrier of rotation, concept of torsional and steric strains; relative stability of conformers on the basis of steric effect, dipole-dipole interaction and H-bonding; *butane gauche* interaction; conformational analysis of ethane, propane, *n*-butane, 2-methylbutane and 2,3-dimethylbutane; haloalkane, 1,2-dihaloalkanes and 1,2-diols (up to four carbons); 1,2-halohydrin; conformation of conjugated systems (*s-cis* and *s-trans*).

Unit-IV

General Treatment of Reaction Mechanism II (8Hr)

Concept of organic acids and bases: effect of structure, substituent and solvent on acidity and basicity; proton sponge; gas-phase acidity and basicity; comparison between nucleophlicity and basicity; HSAB principle; application of thermodynamic principles in acid-base equilibria.

Tautomerism: prototropy (keto-enol, nitro - *aci*-nitro, nitroso-oximino, diazo-amino and enamine-imine systems); valence tautomerism and ring-chain tautomerism; composition of the equilibrium in different systems (simple carbonyl; 1,2- and 1,3-dicarbonyl systems, phenols and related systems), factors affecting keto-enol tautomerism; application of thermodynamic principles in tautomeric equilibria.

CHEM-MJ-302 P – ORGANIC CHEMISTRY-I Practical (30 Hrs)

Course objectives and expected outcome: Facilitate the learner to separate the components based upon solubility, by using common laboratory reagents, to purify the separated components by crystallization and determination of its melting point, to identify the pure organic compounds.

1. Separation, based upon solubility, by using common laboratory reagents like water (cold,hot), dil. HCl, dil. NaOH, dil. $NaHCO_3$, *etc*., of components of a binary solid mixture; purification of **any one** of the separated components by crystallization and determination of its melting point. The composition of the mixture may be of the following types: Benzoic acid/*p*-Toluidine; *p*-Nitrobenzoic acid/*p*-Aminobenzoic acid; *p*-Nitrotolune/*p*-Anisidine; *etc*.

2. **Identification of a Pure Organic Compound**

Solid compounds: oxalic acid, tartaric acid, citric acid, succinic acid, resorcinol, urea, glucose, cane sugar, benzoic acid and salicylic acid.

Liquid Compounds: formic acid, acetic acid, methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and nitrobenzene

Reference Books

1. Clayden, J., Greeves, N. & Warren, S. *Organic Chemistry*, Second edition, Oxford University Press, 2012.
2. Keeler, J., Wothers, P. *Chemical Structure and Reactivity – An Integrated approach*, Oxford University Press.
3. Sykes, P. *A guidebook to Mechanism in Organic Chemistry*, Pearson Education, 2003.
4. Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Limited.
5. Carey, F. A., Guiliano, R. M. *Organic Chemistry*, Eighth edition, McGraw Hill Education, 2012.
6. Eliel, E. L. & Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London, 1994.
7. Nasipuri, D. *Stereochemistry of Organic Compounds*, Wiley Eastern Limited.
8. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education)
10. Fleming, I. *Molecular Orbitals and Organic Chemical Reactions*, Reference/Student Edition, Wiley, 2009.
11. James, J., Peach, J. M. *Stereochemistry at a Glance*, Blackwell Publishing, 2003.
12. Robinson, M. J. T., *Stereochemistry*, Oxford Chemistry Primer, Oxford University Press, 2005.

SEC-301-T: FUEL CHEMISTRY (30 Hrs) Credits 02

Course Contents:

Course objectives and expected outcome: Facilitate the learner to Review of energy sources (renewable and non-renewable), Petroleum and Petrochemical Industry,Petrochemicals, Lubricants.

Review of energy sources (renewable and non-renewable). Classification of fuels and their calorific value.

Coal: Uses of coal (fuel and nonfuel) in various industries, its composition, carbonization of coal. Coal gas, producer gas and water gas—composition and uses. Fractionation of coal tar, uses of coal tar bases chemicals, requisites of a good metallurgical coke, Coal gasification (Hydro gasification and Catalytic gasification), Coal liquefaction and Solvent Refining.

Petroleum and Petrochemical Industry: Composition of crude petroleum, Refining and different types of petroleum products and their applications. Fractional Distillation (Principle and process), Cracking (Thermal and catalytic cracking), Reforming Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels.

Petrochemicals: Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and its derivatives Xylene**.**

Lubricants: Classification of lubricants, lubricating oils (conducting and non-conducting) Solid and semi solid lubricants, synthetic lubricants. Properties of lubricants (viscosity index, cloud point, pore point) and their determination.

SEC-301-P: FUEL CHEMISTRY (15 Hrs) Credits 01
Project on energy science

SEMESTER – IV

Course	Paper Code	Name of the Subject	Brief Description	Credit
Major	CHEM-MJ-401-T	Inorganic Chemistry–I	Chemical Bonding –II, Acid-base Reactions	03
	CHEM-MJ-401-P	Inorganic Chemistry–I	Acid-base titration and Oxidation and reduction titration	01
	CHEM-MJ-402-T	Organic Chemistry– II	Chemistry of alkenes and alkynes, Carbonyl and Related Compounds and elimination reactions	03
	CHEM-MJ-402-P	Organic Chemistry– II	Organic Preparations	01
	CHEM-MJ-403-T	Physical Chemistry-II	Transport processes and Liquid State, Application of Thermodynamics– II, Electrochemistry-II.	03
	CHEM-MJ-403-P	Physical Chemistry-II	Surface Tension, Viscosity, Conductometry.	01
Minor -II	CHEM-MI-2-T	Minor-2T	Chemistry MINOR-II	03
	CHEM-MI-2-P	Minor-2P	Chemistry MINOR-II	01

CHEM-MJ-401-T: INORGANIC CHEMISTRY-ICredit (3Th+1Pr)

Course objectives and expected outcome: Students get the overall and details idea on chemical bonding through MO concept and know some weak forces in chemistry. They also get knowledge on acid base.

Unit-I

Chemical Bonding-II **30hrs**

1. Molecular orbital concept of bonding (The approximations of the theory, Linear combination of atomic orbitals (LCAO)) (elementary pictorial approach): sigma and pi-bonds and delta interaction, multiple bonding. Orbital designations: gerade, ungerade, HOMO, LUMO. Orbital mixing, MO diagrams of H_2, Li_2, Be_2, B_2, C_2, N_2, O_2, F_2, and their ions wherever possible; Heteronuclear molecular orbitals: CO, NO, NO^+, CN^-, HF, BeH_2, CO_2 and H_2O. Bond properties: bond orders, bond lengths.

2. **Metallic Bond:** Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

3. **Weak Chemical Forces**: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Intermolecular forces: Hydrogen bonding (theories of hydrogen bonding, valence bond treatment), receptor-guest interactions, Halogen bonds. Effects of chemical force, melting and boiling points.

Unit-II

Acid-Base reactions **15 hrs**

Acid-Base concept: Arrhenius concept, theory of solvent system (in H_2O, NH_3, SO_2 and HF), Bronsted-Lowry's concept, relative strength of acids, Pauling's rules. Lux-Flood concept, Lewis concept, group characteristics of Lewis acids, solvent levelling and differentiating effects. Thermodynamic acidity parameters, Drago-Wayland equation. Super acids, Gas phase acidity and proton affinity; HSAB principle. Acid-base equilibria in aqueous solution (Proton transfer equilibria in water), pH, buffer. Acid-base neutralisation curves; indicator, choice of indicators.

Reference Books

1. Lee, J. D. *Concise Inorganic Chemistry,*5th Ed., Wiley India Pvt. Ltd., 2008.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry* Oxford, 1970.
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Atkin, P. *Shriver & Atkins' Inorganic Chemistry,* 5th Ed., Oxford University Press (2010).
5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., *Basic Inorganic Chemistry 3rd Ed.;* Wiley

CHEM-MJ-401-P – INORGANIC CHEMISTRY-I (30Hrs)

Course objectives and expected outcome: Facilitate the learner to make solutions of various molar concentrations. This may include: The concept of the mole; Converting moles to grams; Converting grams to moles; Defining concentration; Dilution of Solutions; Making different molar concentrations. They will also experience in different type of titration like acid-base, oxidation-reduction titration.

Acid Base Titration:

1. Estimation of carbonate and hydroxide present together in mixture
2. Estimation of free alkali present in different soaps/detergents.

Oxidation-Reduction Titrimetric

3. Estimation of Fe(III) and Mn(II) in a mixture using standardized $KMnO_4$ solution
4. Estimation of Fe(III) and Cu(II) in a mixture using $K_2Cr_2O_7$.
5. Estimation of Fe(III) and Cr(III) in a mixture using $K_2Cr_2O_7$.

Reference Books

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis* 6th Ed., Pearson, 2009.
2. An Advanced Course in Practical Chemistry., Ghosal. Mahapatra .Nad. New Central Book Agency.
3. Chemistry in Laboratory., Ghosh. Das Sarma. Majumdar. Manna. Santra Publications.

CHEM-MJ-402-T: ORGANIC CHEMISTRY-II Credit (3Th+1Pr)

Course objectives and expected outcome: Facilitate the learner to know about different kind of organic reactions like substitution and elimination. They should also gain detailed knowledge about different reactions of carbonyl chemistry.

Unit-I

Chemistry of alkenes and alkynes (15 Hrs)

Addition to C=C: mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenations, iodolactonisation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation,

epoxidation, *syn* and *anti*-hydroxylation, ozonolysis, addition of singlet and triplet carbenes; electrophilic addition to diene (conjugated dienes and allene); radical addition: HBr addition; mechanism of allylic and benzylic bromination in competition with brominations across C=C; use of NBS; Birch reduction of benzenoid aromatics; interconversion of *E* - and *Z* - alkenes; contra-thermodynamic isomerization of internal alkenes.

Addition to C≡C (in comparison to C=C): mechanism, reactivity, regioselectivity (Markownikoff and anti-Markownikoff addition) and stereoselectivity; reactions: hydrogenation, halogenations, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, dissolving metal reduction of alkynes (Birch); reactions of terminal alkynes by exploring its acidity; interconversion of terminal and non-terminal alkynes.

Unit-II

Carbonyl and Related Compounds (25Hrs)

Addition to C=O: structure, reactivity and preparation of carbonyl compounds; mechanism (with evidence), reactivity, equilibrium and kinetic control; Burgi-Dunitz trajectory in nucleophilic additions; formation of hydrates, cyanohydrins and bisulphite adduct; nucleophilic addition-elimination reactions with alcohols, thiols and nitrogen- based nucleophiles; reactions: benzoin condensation, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig and Corey-Chaykovsky reaction; Rupe rearrangement, oxidations and reductions: Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, MPV, Oppenauer, Bouveault-Blanc, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols.

Exploitation of acidity of α-H of C=O: formation of enols and enolates; kinetic and thermodynamic enolates; reactions (mechanism with evidence): halogenation of carbonyl compounds under acidic and basic conditions, Hell-Volhard-Zelinsky (H. V. Z.) reaction, nitrosation, SeO_2 (Riley) oxidation; condensations (mechanism with evidence): Aldol, Tollens', Knoevenagel, Claisen-Schmidt, Claisen ester including Dieckmann, Stobbe; Mannich reaction, Perkin reaction, Favorskii rearrangement; alkylation of active methylene compounds; preparation and synthetic applications of diethyl malonate and ethyl acetoacetate; specific enol equivalents (lithium enolates, enamines, aza-enolates and silyl enol ethers) in connection with alkylation, acylation and aldol type reaction.

Nucleophilic addition to α, β-unsaturated carbonyl system: general principle and mechanism (with evidence); direct and conjugate addition, addition of enolates (Michael reaction), Stetter reaction, Robinson annulation.

Substitution at sp² carbon (C=O system): mechanism (with evidence): $B_{AC}2$, $A_{AC}2$, $A_{AC}1$, $A_{AL}1$ (in connection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

Unit-III

Elimination reactions (5Hrs)

Elimination reactions: E1, E2, E1cB and Ei (pyrolytic *syn* eliminations); formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity; comparison between substitution and elimination; importance of Bredt's rule relating to the formation of C=C.

Reference Books

1. Clayden, J., Greeves, N., Warren, S. *Organic Chemistry*, Second edition, Oxford University Press 2012.
2. Sykes, P. *A guidebook to Mechanism in Organic Chemistry*, Pearson Education, 2003.
3. Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Limited.
4. Carey, F. A. & Guiliano, R. M. *Organic Chemistry*, Eighth edition, McGraw Hill Education, 2012.
5. Loudon, G. M. *Organic Chemistry*, Fourth edition, Oxford University Press, 2008.
6. Eliel, E. L. & Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London, 1994.
7. Nasipuri, D. *Stereochemistry of Organic Compounds*, Wiley Eastern Limited.
8. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
9. Finar, I. L. *Organic Chemistry (Volume 1)* Pearson Education.
10. Graham Solomons, T.W., Fryhle, C. B. *Organic Chemistry*, John Wiley & Sons, Inc.
11. James, J., Peach, J. M. *Stereochemistry at a Glance*, Blackwell Publishing, 2003.
12. Robinson, M. J. T., *Stereochemistry*, Oxford Chemistry Primer, Oxford University Press, 2005.
13. Maskill, H., *Mechanisms of Organic Reactions*, Oxford Chemistry Primer, Oxford University Press.

CHEM-MJ-402-P: Organic Chemistry II Practical (30 Hrs)

Course objectives and expected out come: Facilitate the learner to calculate percentage yield based upon isolated yield (crude) and theoretical yield of prepared organic compounds by different significant reaction of organic chemistry and calculation of melting point of the corresponding compound.

Organic Preparations

A. The following reactions are to be performed, noting the yield of the crude product:

1. Nitration of aromatic compounds
2. Condensation reactions
3. Hydrolysis of amides/imides/esters
4. Acetylation of phenols/aromatic amines
5. Benzoylation of phenols/aromatic amines
6. Side chain oxidation of aromatic compounds
7. Diazo coupling reactions of aromatic amines
8. Bromination of anilides using green approach (Bromate-Bromide method)
9. Redox reaction including solid-phase method
10. Green 'multi-component-coupling' reaction
11. Selective reduction of *m*-dinitrobenzene to *m*-nitroaniline

Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

B. Purification of the crude product is to be made by crystallisation from water/alcohol, crystallization after charcoal treatment, or sublimation, whichever is applicable.

C. Melting point of the purified product is to be note.

CHEMISTRY MAJOR

PAPER: CHEM-MJ-403-T, (Credit: Theory-03, Practical–01)

PHYSICAL CHEMISTRY-II (45 Hrs)

Course objectives and expected out come: Facilitate the learner to understand of liquid and their physical properties like viscosity, surface tension and diffusion process. Idea about dilute solution and colligative properties, Gibbs phase rule, phase diagram, azeotrope, eutectic point. Evaluation of thermodynamics parameters from electrochemical cell reactions and applications of electromotive force measurement.

Module: I

Transport processes and Liquid State:

Diffusion and Viscosity: (6Hrs)

Diffusion

Fick's law, Flux, force, phenomenological coefficients & their inter-relationship (general form), different examples of transport properties

Viscosity

General features of fluid flow (streamline flow and turbulent flow); Newton's equation, viscosity

coefficient; Poiseuille's equation (with derivation); principle of determination of viscosity coefficient of liquids by falling sphere method and using Ostwald's viscometer. Temperature variation of viscosity of liquids and comparison with that of gases. Relation between viscosity coefficient of a gas and mean free path.

Surface tension and energy **(5 Hrs)**

Surface tension, surface energy, excess pressure, capillary rise and surface tension; Work of cohesion and adhesion, spreading of liquid over other surface; Vapour pressure over curved surface; Temperature dependence of surface tension

Module: II

ELECTROCHEMISTRY-II: **(14Hrs)**

Electromotive Force:

Rules of oxidation/reduction of ions based on half-cell potentials, Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Thermodynamic derivation of Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and
(iii) p^H values, using hydrogen, quinone-hydroquinone and glass electrodes. Concentration cells with and without transference, liquid junction potential; Potentiometric Titration.

Module: III

Application of Thermodynamics–II: **(20 Hrs)**

Colligative properties

Vapour pressure of solution; Ideal solution, ideally dilute solution and colligative properties; Raoult's law. Thermodynamic derivations (using chemical potential) relating (i) Elevation of boiling point of an ideally dilute solution containing a non-volatile non electrolyte solute, (ii) Depression of freezing point of an ideally dilute solution containing a non –volatile non electrolyte solute (iii) Osmotic pressure of an ideally dilute solution containing an on volatile non electrolyte solute with the molality/molar concentration of solute in solution. Applications in calculating molar masses of normal, dissociated and associated solutes in solution; abnormal colligative properties.

Phase Equilibrium:

Definitions of phase, component and degrees of freedom; Phase rule and its derivations; Definition of phase diagram; Phase diagram for water, CO_2, Sulphur. First order phase transition and Clapeyron equation; Clausius- Clapeyron equation - derivation and use; Ehrenfest Classification of phase transition.

Binary solutions: Liquid vapour equilibrium for two component systems. Ideal solution at fixed temperature and pressure;Lever Rule. Principle of fractional distillation; Duhem-Margules equation; Henry's law; Konowaloff's rule; Positive and negative deviations from ideal behaviour; Azeotropic solution; Liquid-liquid phase diagram using phenol- water system; Solid-liquid phase diagram; Eutectic mixture

Three component systems, water-chloroform-acetic acid system, tri angular plots.

Recommended Text Books:

1. Levine, I.N. Physical Chemistry, 6th Edition McGraw-Hill India,2011
2. Castellan,G.W. Physical Chemistry, Narosa,2004
3. Atkins, P.W.& Paula, J.de, Atkins' Physical Chemistry,11th Edition, Oxford UniversityPress,20

Practical: (30Hrs)

Course objectives and expected out come: Facilitate the practical understand of Ostwald viscometer, Stalagmometer and critical solution temperature and critical compositions.

PAPER: CHEM-403-P

1. Surface tension measurements using Stalagmometer:

a) Determine the surface tension of a given solution by drop weight method using a stalagmometer.

b) Study the variation of surface tension of acetic acid solutions with concentration and hence determine graphically the concentration of an unknown solution of acetic acid.

2. Viscosity measurement using Ostwald's viscometer:

a) Determination of viscosity of aqueous solutions of (i) polymer (ii)ethanol and (iii) sugar at room temperature.

b) Study the variation of viscosity of sucrose solution with the concentration of solute and hence determine graphically the concentration of an unknown solution.

3. Determination of critical solution temperature and critical composition between partially miscible liquid pair.

Reference Books:

1. Practical Work book Chemistry (Honours),UGBOS, Chemistry, University of Calcutta,2015.
2. An Advanced Course in Practical Chemistry., Ghosal, Mahapatra, Nad.

SEMESTER – V

Course	Paper Code	Name of the Subject	Brief Description	Credit
Major	CHEM-MJ-501-T	Inorganic Chemistry–II	Redox Reactions and precipitation reactions, Chemistry of *s* and *p* Block Elements	03
	CHEM-MJ-501-P	Inorganic Chemistry–II	Quantitative analysis, Spectrophotometry	01
	CHEM-MJ-502-T	Organic Chemistry– III	Organometallics, Nitrogen compounds, Rearrangements, Cyclic Stereochemistry	03
	CHEM-MJ-502-P	Organic Chemistry– III	Qualitative Analysis of Single Solid Organic Compounds	01
	CHEM-MJ-503-T	Physical Chemistry-III	Foundation of Quantum Mechanics, Exactly Solvable Systems, Surface Chemistry and Electrical properties.	03
	CHEM-MJ-503-P	Physical Chemistry-III	Conduct metric and Potentiometric titration	01
	CHEM-MJ-504-T	Inorganic Chemistry–III	NobleGases,Radioactivity,General Principles of Metallurgy, Coordination Chemistry-I	03
	CHEM-MJ-504-P	Inorganic Chemistry–III	Analysis of Ores and Minerals Inorganic Preparations	01
Minor -III	CHEM-MI-3-T	Minor-2T	Electrochemistry, d block elements, carbonyl and Grignard reagents.	03
	CHEM-MI-3-P	Minor-2P	Identification of Pure Single organic Compound	01

CHEM-MJ-501-T: INORGANIC CHEMISTRY-II Credit (3Th+1Pr)

Course objectives and expected outcome: Students will be able to gain idea about redox reaction and the chemistry of s and p block elements.

Unit-I

Redox Reactions and precipitation reactions **15hrs**

Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential. Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential diagram (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples). Theoretical principles involved in analysis of cations and anions and Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides. Interferring anions (fluoride, borate, oxalate and phosphate) and need to remove them after group II.

Unit-II

Chemistry of *s* and *p* Block Elements **30 hrs**

Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Beryllium hydrides and halides. Boric acid and borates, boron nitrides, borohydrides (diborane) and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, phosphorus, sulphur and chlorine. Peroxo acids of sulphur, sulphur-nitrogen compounds, interhalogen compounds, polyhalide ions, pseudohalogens, fluorocarbons and basic properties of halogens.

Reference Books

1. Lee, J. D. *Concise Inorganic Chemistry*,5th Ed., Wiley India Pvt. Ltd., 2008.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry* Oxford, 1970.
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Atkin, P. *Shriver & Atkins' Inorganic Chemistry,* 5th Ed., Oxford University Press (2010).
5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., *Basic Inorganic Chemistry 3rd Ed.;* Wiley India.
6. Sharpe, A.G., *Inorganic Chemistry*, 4th Indian Reprint (Pearson Education) 2005.
7. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. *Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed.*, Harper Collins 1993, Pearson,2006.
8. Atkins, P.W. & Paula, J. *Physical Chemistry*, Oxford Press, 2006.
9. Mingos, D.M.P., *Essential trends in inorganic chemistry*. Oxford University Press (1998).
10. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
11. Burgess, J., *Ions in solution: basic principles of chemical interactions.* Ellis Horwood (1999).

CHEM-MJ-501-P – INORGANIC CHEMISTRY-II(30Hrs)

Course objectives and expected outcome: They will also experience in volumetric of titration like oxidation-reduction titration from metal ions mixtures. They also measure 10Dq and λ_{Max}.

Quantitative analysis

1. Volumetric estimation of Mn(II)/Fe(III)

2. Volumetric estimation of Cr(VI)/ Fe(III)

3. Volumetric estimation of Cu(II)/ Fe(III)

Spectrophotometry

1. Measurement of 10 Dq by Spectrophotometric method
2. Determination of λ_{Max} of $[Mn(acac)_3]$ and $[Fe(acac)_3]$ complexes .

Reference Books

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. An Advanced Course in Practical Chemistry., Ghosal. Mahapatra .Nad. New Central Book Agency.
3. Chemistry in Laboratory., Ghosh. Das Sarma. Majumdar. Manna. Santra Publications.

CHEM-MJ-502-T: Organic Chemistry-III Credit (3Th+1Pr)

Course objectives and expected outcome: Facilitate the learner to understand about substitution reactions in aliphatic as well as aromatic compounds. They will know about carbonyl and related compounds, organometallics and will gain knowledge about Elementary ideas of stereochemistry of cyclohexane.

Unit-I

Organometallics 7Hrs

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard and organolithium to carbonyl compounds; substitution on -COX; directed ortho metalation of arenes using organolithiums, conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky reaction; Blaise reaction; concept of *umpolung* and base-nucleophile dichotomy in case of organometallic reagents.

Unit-II

Nitrogen compounds 12Hr

Amines: Aliphatic & Aromatic: preparation, separation (Hinsberg's method) and identification of primary, secondary and tertiary amines; reaction (with mechanism): Eschweiler–Clarke methylation,diazo coupling reaction, Mannich reaction; formation and reactions of phenylene diamines, diazomethane and diazoacetic ester.

Nitro compounds (aliphatic and aromatic): preparation and reaction (with mechanism): reduction under different conditions; Nef carbonyl synthesis, Henry reaction and conjugate addition of nitroalkane anion.

Alkylnitrile and isonitrile: preparation and reaction (with mechanism): Thorpe nitrile condensation, von Richter reaction. *Diazonium salts and their related compounds*: reactions (with mechanism) involving replacement of diazo group; reactions: Gomberg, Meerwein, Japp-Klingermann.

Unit-III

Rearrangements 18Hrs

Mechanism with evidence and stereochemical features for the following

Rearrangement to electron-deficient carbon: Wagner-Meerwein rearrangement, pinacol rearrangement, dienone-phenol; Wolff rearrangement in Arndt-Eistert synthesis, benzil-benzilic acid rearrangement, Demjanov

rearrangement, Tiffeneau–Demjanov rearrangement.

Rearrangement to electron-deficient nitrogen: rearrangements: Hofmann, Curtius, Lossen, Schmidt and Beckmann.

Rearrangement to electron-deficient oxygen: Baeyer-Villiger oxidation, cumene hydroperoxide-phenol rearrangement and Dakin reaction.

Aromatic rearrangements: Migration from oxygen to ring carbon: Fries rearrangement and Claisen rearrangement.

Migration from nitrogen to ring carbon: Hofmann-Martius rearrangement**,** Fischer-Hepp rearrangement, *N*-azo to *C*-azo rearrangement, Bamberger rearrangement, Orton rearrangement and benzidine rearrangement.

Rearrangement reactions by green approach: Fries rearrangement, Claisen rearrangement, Beckmann rearrangement, Baeyer-Villiger oxidation.

Unit-IV

Cyclic Stereochemistry 8Hrs

Alicyclic compounds: concept of I-strain; conformational analysis: cyclohexane, mono and disubstituted cyclohexane; symmetry properties and optical activity; topomerisation; ring-size and ease of cyclisation; conformation & reactivity in cyclohexane system: consideration of steric and stereoelectronic requirements; elimination (E2, E1), nucleophilic substitution (S_N^1, S_N^2, S_N^i, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic syn elimination and fragmentation reactions.

Suggested Readings:

1. Clayden, J., Greeves, N., Warren, S. *Organic Chemistry*, Second edition, Oxford University Press 2012.
2. Sykes, P. *A guidebook to Mechanism in Organic Chemistry*, Pearson Education, 2003.
3. Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Limited.
4. Carey, F. A., Guiliano, R. M. *Organic Chemistry*, Eighth edition, McGraw Hill Education, 2012.
5. Loudon, G. M. *Organic Chemistry*, Fourth edition, Oxford University Press, 2008.
6. Norman, R.O. C., Coxon, J. M. *Principles of Organic Synthesis*, Third Edition, Nelson Thornes, 2003.
7. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Finar, I. L. *Organic Chemistry (Volume 1)*, Pearson Education.
9. Graham Solomons, T.W., Fryhle, C. B. *Organic Chemistry*, John Wiley & Sons, Inc.
10. March, J. *Advanced Organic Chemistry*, Fourth edition, Wiley.
11. Jenkins, P. R., *Organometallic Reagents in Synthesis*, Oxford Chemistry Primer, Oxford University Press.
12. Ward, R. S., *Bifunctional Compounds*, Oxford Chemistry Primer, Oxford University Press.
13. Ahluwalia, V. K. *Strategies for Green Organic Synthesis*, ANE Books Pvt. Ltd.

CHEM-MJ-502-P: Organic Chemistry-III Practical (30Hrs)

Course objectives and expected outcome: Facilitate the learner to understand about qualitative analysis of single solid Organic compounds having different functional groups.

Experiment -1: Qualitative Analysis of Single Solid Organic Compounds

a) Detection of special elements (N, S, Cl, Br) by Lassaigne's test
b) Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
c) Detection of the following functional groups by systematic chemical tests: aromatic amino ($-NH_2$), aromatic nitro ($-NO_2$), amido ($-CONH_2$, including imide), phenolic –OH, carboxylic acid (-COOH), carbonyl (-CHO and >C=O); only one test for each functional group is to be reported.
d) Melting point of the given compound
e) Preparation, purification and melting point determination of a crystalline derivative of the given compound
f) Identification of the compound through literature survey.

Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special

elements and the functional groups with relevant derivatisation in known and unknown (**at leastsix)** organic compounds.

CHEM-MJ-503-T: PHYSICAL CHEMISTRY-III Credit (3Th+1Pr)

Course objectives and expected outcome: Facilitate the learner to understand dipole moment, polarization, different types of adsorption isotherm, electro-kinetic phenomena, types of colloids. quantum chemistry (science of microscopic world).

Unit-I:Electrical Properties of molecules 5 (Hrs)

Dipole moment and polarizability: Polarizability of atoms and molecules, dielectric constant and polarisation, molar polarisation for polar and non-polar molecules; Clausius-Mosotti equation and Debye equation(both without derivation)and their application; Determination of dipole moments.

Unit-II: Surface Chemistry (10 Hrs)

1. Adsorption: Physical and chemical adsorption; Freundlich and Langmuir adsorption isotherms; multilayer adsorption and BET isotherm (no derivation required);Gibbs adsorption isotherm and surface excess; Heterogenous catalysis (single reactant); Zero order and fractional order reactions;
2. Colloids: Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, Coagulation and Schultz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electro kinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrins method; Stability of colloids and zeta potential; Micelle formation.

Unit-III:Quantum Chemistry (30 Hrs)

Foundation of Quantum Mechanics

Beginning of Quantum Mechanics: Wave-particle duality, light as particles: photoelectric and Compton effects; electrons as waves and the de Broglie hypothesis; Uncertainty relations(without proof)

Wave function: Schrodinger time-independent equation; nature of the equation, acceptability conditions imposed on the wave functions and probability interpretations of wave function

Concept of Operators: Elementary concepts of operators, eigen functions and eigen values; Linear operators;Commutation of operators, commutator and uncertainty relation; Expectation value; Hermitian operator;Postulates of Quantum Mechanics

Particle in a box:Setting up of Schrodinger equation for one-dimensional box and its solution; Comparison with free particle eigen functions and eigen values. Properties of PB wave functions (normalization, orthogonality, probability distribution); Expectation values ofx, x^2, p_x and $p_x^2$and their significance in relation to the uncertainty principle; Extension of the problem to two and three dimensions and the concept of degenerate energy levels

Simple Harmonic Oscillator: setting up of the Schrodinger stationary quation, energy expression (without derivation), expression of wave function for n = 0 and n = 1 (without derivation) and their characteristic features

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component; Rigid rotator model of rotation of diatomic molecule; Schrödinger equation, transformation to spherical polar coordinates; Separation of variables. Spherical harmonics; Discussion of solution

Qualitative treatment of hydrogen atom and hydrogen-like ions: Setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy(only final energy expression); Average and most probable distances of electron from nucleus; Setting up of Schrödinger equation for many-electron atoms (He, Li)

Suggested Readings:

1. Castellan,G.W. *Physical Chemistry*,Narosa
2. Atkins, P.W.& Paula,J.de *Atkins', Physical Chemistry*,Oxford University Press
3. McQuarrie,D.A.&Simons,J.D.*Physical Chemistry:A Molecular Approach*,Viva Press
4. Levine,I.N.*Physical Chemistry*,Tata McGraw-Hill
5. Moore,W.J.*Physical Chemistry*,Orient Longman
6. Mortimer,R.G.*Physical Chemistry*,Elsevier
7. Engel,T.&Reid,P.*Physical Chemistry*,Pearson
8. Levine,I.N.*Quantum Chemistry*,PHI
9. Atkins,P.W.*Molecular Quantum Mechanics*,Oxford
10. Engel,T.&Reid,P.*PhysicalChemistry*,Pearson
11. Maron,S.H.,Prutton,C.F.,*Principles of Physical Chemistry*,McMillan
12. Klotz,I.M.,Rosenberg,R.M.*ChemicalThermodynamics:Basic Concepts and Methods* Wiley
13. Rastogi,R.P.&Misra,R.R.AnIntroductiontoChemicalThermodynamics,Vikas
14. Glasstone,S.An Introduction to Electrochemistry, East-West Press.

CHEM-MJ-503-P: Physical Chemistry-III

Course objectives and expected outcome: The course provides training in advanced physical chemistry laboratory techniques. The experiments are guided by demonstrators and are designed both to illustrate the applications of theory covered in the Chemical Physics and lecture courses, and to introduce typical instrumentation. On successful completion of the course students will be able to:

1. Developed expertise relevant to the professional practice of chemistry.
2. Developed an understanding of conductometer and potentiometer.
3. Developed skills in the conductometric titration and potentiometric titration.

Experiment-1: Conductometric Experiments:

(A) Conductometric titration of an acid (Mixture Strong and Weak mono basic acid, and Dibasic acid) against strong base.

(B) Study of kinetics saponification reaction conductometrically

Experiment 2: Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$solution

Experiment 3: Determination of K_{sp} for AgCl by potentiometric titration of $AgNO_3$ solution against standard KCl solution.

CHEM-MJ-504-T: INORGANIC CHEMISTRY-III Credit (3Th+1Pr)

Course objectives and expected outcome: Students will be able to gain idea about the general principles of metallurgy, noble gases, and Coordination Chemistry.

Unit-I

Noble Gases: **6 hrs**

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2 and XeF_4). Xenon-oxygen compounds. Molecular shapes of noble gas compounds (VSEPR theory).

Unit-II

Radioactivity **14L**

Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers. Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Separation and uses of isotopes. Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures.

Unit-III

General Principles of Metallurgy **10 hrs**

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond's process, Zone refining.

Unit-IV

Coordination Chemistry-I **15 hrs**

Coordinate bonding: double and complex salts. Werner's theory of coordination complexes, Classification of ligands, Ambidentate ligands, chelates, Coordination numbers, IUPAC nomenclature of coordination complexes (up to two metal centers), Isomerism in coordination compounds, constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes.

Reference Books

1. Lee, J. D. *Concise Inorganic Chemistry,*5th Ed., Wiley India Pvt. Ltd., 2008.
2. Douglas, B.E. and McDaniel, D.H. *Concepts & Models of Inorganic Chemistry*
Oxford, 1970.
3. Day, M.C. and Selbin, J. *Theoretical Inorganic Chemistry*, ACS Publications, 1962.
4. Atkin, P. *Shriver & Atkins' Inorganic Chemistry,* 5th Ed., Oxford University Press (2010).
5. Cotton, F.A., Wilkinson, G. and Gaus, P.L., *Basic Inorganic Chemistry 3rd Ed.;* Wiley India.
6. Sharpe, A.G., *Inorganic Chemistry*, 4th Indian Reprint (Pearson Education) 2005.
7. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. *Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed.*, Harper Collins 1993, Pearson,2006.
8. Atkins, P.W. & Paula, J. *Physical Chemistry*, Oxford Press, 2006.
9. Mingos, D.M.P., *Essential trends in inorganic chemistry*. Oxford University Press (1998).
10. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
11. Burgess, J., *Ions in solution: basic principles of chemical interactions.* Ellis Horwood (1999).

CHEM-504-P – INORGANIC CHEMISTRY-III (30Hrs)

Course objectives and expected outcome: Student estimate different metal ions from ores. They also prepare different metal complexes.

Analysis of Ores and Minerals

A. Quantitative estimation of manganese in pyrolusite

B. Quantitative estimation of $CaCO_3$ and $CaCO_3$ in dolomite

Inorganic preparations

1. $[Cu(CH_3CN)_4]PF_6/ClO_4$

2. *Cis* and *trans* $K[Cr(C_2O_4)_2(H_2O)_2]$

3. Potassium diaquadioxalatochromate(III)

4. Tetraamminecarbonatocobalt (III) ion

5. Potassium tris(oxalato)ferrate(III)

6. Tris-(ethylenediamine) nickel(II) chloride.

7. $[Mn(acac)_3]$ and $Fe(acac)_3]$ (acac= acetylacetonate)

Suggested Readings:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis* 6th Ed., Pearson, 2009.
2. *Inorganic Synthesis*, Vol. 1-10.
3.An Advanced Course in Practical Chemistry., Ghosal. Mahapatra .Nad. New Central Book Agency.
4.Chemistry in Laboratory., Ghosh. Das Sarma. Majumdar. Manna. Santra Publications.

CHEMISTRY MINOR

PAPER: CHEM-MI-3T, (Credit: Theory-03, Practical–01)
Theory:(45Hrs)

Minor-III

Course objectives and expected outcome: Facilitate the learner to know about the transport phenomenon with respect to conductance and electrical properties molecules. Facilitate the learner to understand about coordination chemistry, transition metals, and color complex. Facilitate the learner to understand about substitution reactions in aliphatic as well as aromatic compounds. They will know about carbonyl and related compounds.

Module: I

Electrochemistry (Conductance & Ionic Equilibrium) (15 Hrs)

Conductance and transport number: Ion conductance; Conductance and measurement of conductance, cell constant, specific conductance and molar conductance; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye – Huckel theory of Ion atmosphere (qualitative)- asymmetric effect, relaxation effect and electrophoretic effect; Ostwald's dilution law; Ionic mobility; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations.

Ionic equilibria: Chemical potential of an ion in solution; Activity and activity coefficients of ions in solution; Debye-Huckel limiting law-brief qualitative description of the postulates involved, qualitative idea of the model, the equation (without derivation) for ion-ion atmosphere interaction potential. Estimation of activity coefficient for electrolytes using Debye-Huckel limiting law; Derivation of mean ionic activity coefficient from the expression of ion-atmosphere interaction potential; Applications of the equation and its limitations

Module: II

Co-ordination Chemistry and d-block elements (15Hrs)

Coordinate bonding: double and complex salts. Werner's theory of coordination complexes, Classification of ligands, Ambidentate ligands, chelates, Coordination numbers, IUPAC nomenclature of coordination complexes (upto two metal centers), Isomerism in coordination compounds, constitutional and stereoisomerism, Geometrical and optical isomerism in square planar and octahedral complexes. General

comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, coordination chemistry.

Module: III

Carbonyl Grignard (12Hrs)

Addition to C=O: structure, reactivity and preparation of carbonyl compounds; mechanism (with evidence),reactivity, equilibrium and kinetic control; Burgi-Dunitz trajectory in nucleophilic additions; formation of hydrates, cyanohydrins and bisulphite adduct; nucleophilic addition-elimination reactions with alcohols, thiols and nitrogen-based nucleophiles; reactions: benzoin condensation, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig and Corey-Chaykovsky reaction; Rupe rearrangement, oxidations and reductions: Clemmensen, Wolff-Kishner,$LiAlH_4$,$NaBH_4$,MPV,Oppenauer,Bouveault-Blanc, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetra acetate oxidation of 1,2-diols.

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions (mechanism withevidence); addition of Grignard and organolithium to carbonyl compounds; substitution on -COX;directed ortho metalation of arenes using organolithiums, conjugate addition by Gilman cuprates;Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky reaction; Blaise reaction; conceptof *umpolung* and base-nucleophile dichotomy in case of organometallic reagents.

Recommended Text Books:

1. Finar, I .L. Organic Chemistry (Volume1), 6th Edition, Pearson Education,2002
2. Sykes, P. A guide book to Mechanism in Organic Chemistry, Pearson Education, 2003.
3. Morrison, R. N. & Boyd, R. N. and Bhattacharjee, Organic Chemistry, 7th Edition, Pearson Education,2010

Practical:(30Hrs)

PAPER : CHEM-MI-3P

Course objectives and expected outcome**:** Facilitate the learner to separate the components based upon solubility, by using common laboratory reagents, to purify the separated components by crystallization and determination of its melting point, to identify the pure organic compounds.

Identification of Pure Single organic Compound.

Solid compounds:

Oxalic acid, tartaric acid, citric acid, succinic acid, resorcinol, urea, glucose, cane sugar, benzoic acid and salicylic acid

Liquid Compounds:

Formic acid, acetic acid, ethyl alcohol, acetone, aniline, dimethyl aniline, benzaldehyde, chloroform and nitrobenzene.

Reference Books:

1. Practical Work book Chemistry (Honours), UGBOS, Chemistry, University of Calcutta, 2015.
2. Furniss, Hannaford, Smith, Tatcholl, Vogel's Text book of Practical Organic Chemistry, 5th Edition, Pearson India,20

SEMESTER – VI

Course	Paper Code	Name of the Subject	Brief Description	Credit
Major	CHEM-MJ-601-T	Inorganic Chemistry–IV	Coordination Chemistry-II, Magnetism and Colour, Inorganic Polymers	03
	CHEM-MJ-601-P	Inorganic Chemistry–IV	Complexometric titration & Quantitative analysis	01
	CHEM-MJ-602-T	Organic Chemistry– IV	Organic Synthesis, Spectroscopy and Dyes	03
	CHEM-MJ-602-P	Organic Chemistry– IV	Quantitative Estimations of organic compounds	01
	CHEM-MJ-603-T	Physical Chemistry-IV	Molecular Spectroscopy, Introduction to NMR Spectroscopy, Atomic Spectroscopy, Photochemistry.	03
	CHEM-MJ-603-P	Physical Chemistry-IV	Surface tension, spectrophotometrically determination	01
	CHEM-MJ-604-T	Organic Chemistry– V	Carbocycles and Heterocycles, Elementary Ideas of Pericyclic reactions, carbohydrate and biomolecules	03
	CHEM-MJ-604-P	Organic Chemistry– V	Chromatographic Separations, Spectroscopic Analysis of Organic Compounds	01
Minor -III	CHEM-MI-3-T	Minor-3-T	Electrochemistry, d block elements, carbonyl and Grignard reagents.	03
	CHEM-MI-3-P	Minor-3-P	Identification of Pure Single organic Compound	01

CHEM-MJ-601-T: INORGANIC CHEMISTRY-IV Credit (3Th+1Pr)

Course objectives and expected outcome: Students will be able to gain idea about VBT concept of coordination compound formation and overlap. Student can also calculate and compare the magnetic properties of coordinated complexes. Beside these students can get the idea about inorganic polymers.

Unit-I

Coordination Chemistry-II **20 hrs**

VB description and its limitations. Elementary Crystal Field Theory: splitting of dn configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series. Jahn- Teller distortion. Octahedral site stabilization energy (OSSE). Metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples).

Unit-II

Magnetism and Colour: **15 hrs**

Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for 3d1 to 3d9 ions. Racah parameter. Selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea).

Unit-III

Inorganic Polymers: **10 hrs**

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes.

Suggested Readings:

1. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. *Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed.*, Harper Collins 1993, Pearson,2006.
2. Greenwood, N.N. & Earnshaw A. *Chemistry of the Elements*, Butterworth- Heinemann, 1997.
3. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., *Advanced Inorganic Chemistry 6th Ed. 1999.*, Wiley.
4. Miessler, G. L. & Donald, A. Tarr. *Inorganic Chemistry* 4th Ed., Pearson, 2010.
5. Purecell, K.F. and Kotz, J.C., *An Introduction to Inorganic Chemistry*, Saunders: Philadelphia, 1980.
6. Mingos, D.M.P., *Essential trends in inorganic chemistry*. Oxford University Press (1998).

CHEM-MJ-601-P – INORGANIC CHEMISTRY-IV(30Hrs)

Course objectives and expected outcome: By this practical's students estimate different metal ion individually and from their mixture complex metrically. The also estimate different ions gravimetrically.

Complexometric titration

1. Zn(II)
2. Zn(II) in a Zn(II) and Cu(II) mixture.
3. Ca(II) and Mg(II) in a mixture.
4. Hardness of water.

Quantitative analysis

1. Gravimetric estimation of Zn(II) as $Zn(NH_4)(PO_4)$
2. Gravimetric estimation of Cu(II) as CuSCN
3. Gravimetric estimation of Ni(II) as $Ni(DMGH)_2$
4. Gravimetric estimation of Ba(II) as $BaSO_4$
5. Gravimetric estimation of Pb(II) as $(Pb)_3(PO_4)_2$
6. Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminium oxinate)

Suggested Readings:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis* 6th Ed., Pearson, 2009.
2. *Inorganic Synthesis*, Vol. 1-10.
3.An Advanced Course in Practical Chemistry., Ghosal. Mahapatra .Nad. New Central Book Agency.
4.Chemistry in Laboratory., Ghosh. Das Sarma. Majumdar. Manna. Santra Publications.

CHEM-MJ-602-T: ORGANIC CHEMISTRY-IV Credit (3Th+1Pr)

Course objectives and expected outcome: They will gain the knowledge about the synthesis, properties, spectroscopic characterization and utilities of carbon oxygen, Nitrogen containing organic compounds which are essential to our daily life.

Unit-I

The Logic of Organic Synthesis 20 Hrs

Retrosynthetic analysis: disconnections; synthons, donor and acceptor synthons; natural reactivity and *umpolung*; latent polarity in bifunctional compounds: consonant and dissonant polarity; illogical electrophiles and nucleophiles; synthetic equivalents; functional group interconversion and addition (FGI and FGA); C-C disconnections and synthesis: one-group and two-group (1,2- to 1,5-dioxygenated compounds), reconnection (1,6-dicarbonyl);protection-deprotection strategy (alcohol, amine, carbonyl, acid).
Strategy of ring synthesis: thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique.
Asymmetric synthesis: stereoselective and stereospecific reactions; diastereo selectivity and enantio selectivity (only definition); enantio selectivity: kinetically controlled MPV reduction; diastereoselectivity: addition of nucleophiles to C=O adjacent to a stereogeniccentre: Felkin-Anh and Zimmermann-Traxler models.

Unit-II

Organic Spectroscopy 25 Hrs

UV Spectroscopy: introduction;types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; Bathochromic and Hypsochromic shifts; intensity of absorptions (Hyper-/Hypochromic effects); application of Woodward's Rules for calculation of λ_{max} for the following systems: conjugated diene, α,β-unsaturated aldehydes and ketones (alicyclic, homo annular and hetero annular); extended conjugated systems (dienes, aldehydes and ketones); relative positions of λ_{max} considering conjugative effect, steric effect, solvent effect, effect of pH; effective chromophore concentration: keto-enol systems; benzenoid transitions.
IR Spectroscopy: introduction;modes of molecular vibrations(fundamental and non-fundamental); IR active molecules; application of Hooke's law, force constant; fingerprint region and its significance; effect of deuteration; overtone bands; vibrational coupling in IR; characteristic and diagnostic stretching frequencies of C-H, N-H, O-H, C-O, C-N, C-X, C=C (including skeletal vibrations of aromatic compounds), C=O, C=N, N=O, C≡C, C≡N; characteristic/diagnostic bending vibrations are included; factors affecting stretching frequencies: effect of conjugation, electronic effects, mass effect, bond multiplicity, ring-size, solvent effect, H-bonding on IR

absorptions; application in functional group analysis.

NMR Spectroscopy: introduction;nuclear spin;NMR active molecules;basic principles of Proton Magnetic Resonance; equivalent and non-equivalent protons; chemical shift and factors influencing it; ring current effect; significance of the terms: up-/downfield, shielded and deshielded protons; spin coupling and coupling constant (1st order spectra); relative intensities of *first-order*multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR ; elementary idea about *non-first-order* splitting; anisotropic effects in alkene, alkyne, aldehydes and aromatics; NMR peak area, integration; relative peak positions with coupling patterns of common organic compounds (both aliphatic and benzenoid-aromatic); rapid proton exchange; interpretation of NMR spectra of simple compounds.

Applications of IR, UV and NMR spectroscopy for identification of simple organic molecules.

Suggested Readings:

1. Finar, I. L. *Organic Chemistry (Volume 1)*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. *Organic Chemistry* (*Volume 2: Stereochemistry and the Chemistry of Natural Products*), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
3. Norman, R.O. C., Coxon, J. M. *Principles of Organic Synthesis*, Third Edition, Nelson Thornes, 2003.
4. Clayden, J., Greeves, N., Warren, S., *Organic Chemistry*, Second edition, Oxford University Press 2012.
5. Silverstein, R. M., Bassler, G. C., Morrill, T. C. *Spectrometric Identification of Organic Compounds*, John Wiley and Sons, INC, Fifth edition.
6. Kemp, W. *Organic Spectroscopy*, Palgrave.
7. Pavia, D. L. *et al. Introduction to Spectroscopy,* 5th Ed. Cengage Learning India Ed. (2015).
8. Dyer, J. *Application of Absorption Spectroscopy of Organic Compounds*, PHI Private Limited
9. March, J. *Advanced Organic Chemistry*, Fourth edition, Wiley.
10. Harwood, L. M., *Polar Rearrangements*, Oxford Chemistry Primer, Oxford University Press.
11. Bailey, Morgan, Organonitrogen Chemistry, Oxford Chemistry Primer, Oxford University Press.
12. Ahluwalia, V. K. *Strategies for Green Organic Synthesis*, ANE Books Pvt. Ltd.
13. Warren, S. *Organic Synthesis the Disconnection Approach*, John Wiley and Sons.
14. Warren, S., *Designing Organic Synthesis*, Wiley India, 2009.
15. Carruthers, W. *Modern methods of Organic Synthesis*, Cambridge University Press.
16. Willis, C. A., Wills, M., *Organic Synthesis*, Oxford Chemistry Primer, Oxford University Press.
17. Yates, P. Chemical Calculations. 2nd Ed. CRC Press (2007).
18. Harris, D.C.*QuantitativeChemicalAnalysis*.6th Ed.,Freeman(2007)Chapters3-5.
19. Levie, R.de, *Howtouse Excel in analytical chemistry and in general scientific data analysis*, CambridgeUniv.Press(2001)487pages.
20. Noggle, J.H. *Physical Chemistry on a Microcomputer*.Little Brown&Co.(1985).

CEM-MJ-602-P : Practical Organic Chemistry-IV Practical (30Hrs)

Course objectives and expected outcome: Acquire the knowledge about the quantitative estimation of different natural and artificial organic compounds

Quantitative Estimations:

Each student is required to perform all the experiments.

1. Estimation of glycine by Sörensen's formol method
2. Estimation of glucose by titration using Fehling's solution
3. Estimation of sucrose by titration using Fehling's solution
4. Estimation of vitamin-C (reduced)
5. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) method

6. Estimation of phenol by bromination (Bromate-Bromide) method
7. Estimation of formaldehyde (Formalin)
8. Estimation of acetic acid in commercial vinegar
9. Estimation of urea (hypobromite method)
10. Estimation of saponification value of oil/fat/ester.

CHEM-MJ-603-T: PHYSICAL CHEMISTRY-IVCredit (3Th+1Pr)

Course objectives and expected outcome: From this section students will gain knowledge about interaction of electromagnetic radiation with molecules and various types of spectra, Rotation spectroscopy, Vibrational spectroscopy, Raman spectroscopy, Nuclear Magnetic Resonance (NMR) spectroscopy, Electron Spin Resonance (ESR) spectroscopy, photochemistry, solid state and Surface phenomenon. This topic facilitates to detect, determine, or quantify the molecular and/or structural composition of a sample. Photochemical reaction kinetics and efficiency of photochemical reactions.

Unit-I:

Molecular Spectroscopy (28 Hrs)

1. Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation.
2. **Rotational spectroscopy**: Selection rules, intensities of spectral lines, determination of

Bond lengths of diatomic and linear tri atomic molecules, isotopic substitution

3. **Vibrational spectroscopy**: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies; Diatomic vibrating rotator, P, Q, R branches
4. **Raman spectroscopy**: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion
5. **Nuclear Magnetic Resonance (NMR) spectroscopy**: Principles of NMR spectroscopy, Larmor precession, chemical shift and low-resolution spectra, different scales, spin-spin coupling and high-resolution spectra, interpretation of PMR spectra of organic molecules
6. **Electron Spin Resonance (ESR) spectroscopy**: Its principle, hyperfine structure, ESR of simple radicals.

Unit-II:

Photochemistry (17 Hrs)

1. Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, Stark-Einstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields.
2. Photochemical Processes: Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; Fluorescence and phosphorescence, Jablonskii diagram.
3. Rate of Photochemical processes: Photochemical equilibrium and the differential rate of photochemical reactions, Photo stationary state; HI decomposition, H_2-Br_2 reaction, dimerisation of

anthracene; photo sensitized reactions, quenching; Role of photochemical reactions in biochemical processes, photo stationary states, chemiluminescence.

CHEM-MJ-603-P:Physical Practical IV: (30 Hrs)

Course objectives and expected outcome: The course provides training in advanced physical chemistry laboratory techniques. The experiments are guided by demonstrators and are designed both to illustrate the applications of theory covered in the Chemical Physics and lecture courses, and to introduce typical instrumentation. On successful completion of the course students will be able to:
Develop expertise in the professional practice of chemistry.

1. Developed an understanding of the breadth and concepts of pH, buffer solutions.
2. An appreciation of the role of components in phase equilibrium study. Developed an understanding of pH meter.

Experiment-1: Determination of pH of a buffer solution colour matching method.
Experiment 2: Determination of partition coefficient for the distribution of I_2 between water and CCl_4.
Experiment 3: Determination of K_{eq} for $KI + I_2 = KI_3$, using partition coefficient between water and CCl_4.
Experiment 4: pH-metric titration of acid (mono- and di-basic) against strong base.

Reference Books

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009) Mendham.
2. J.,A. I.Vogel ?s Quantitative Chemical Analysis 6th Ed., Pearson
Harris, D.C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
3. Palit, S.R., De, S.K. Practical Physical Chemistry Science Book Agency University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta
4. Levitt, B. P. edited Findlay ?s Practical Physical Chemistry Longman Group Ltd. Gurtu,
5. J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand &Co. Ltd.

CHEM-MJ-604-T Organic Chemistry V Credit (3Th+1Pr)

Course objectives and expected outcome:

- Acquire knowledge about synthesis and common chemical reaction of carbocyclic molecules (naphthalene, anthracene, phenanthrene) and hetrocyclic molecules (pyrrole, furan, thiophene, pyridine).
- Brief knowledge about a few chemical reactions and stereochemistry of alicyclic molecules.
- Gather brief knowledge about various pericyclic reactions and their FMO approach.

Some basic understanding of structure of different bio-molecules like carbohydrate, peptide, nucleic acid and their reactions.

Organic Chemistry V

Unit-I

Carbocycles and Heterocycles **12Hrs**

1. Polynuclear hydrocarbons and their derivatives: synthetic methods include Haworth, Bardhan-Sengupta, Bogert-Cook and other useful syntheses (with mechanistic details); fixation of double bonds and Fries rule; reactions (with mechanism) of naphthalene, anthracene, phenanthrene and their derivatives.
2. Heterocyclic compounds: 5- and 6-membered rings with one heteroatom; reactivity, orientation and important reactions (with mechanism) of furan, pyrrole, thiophene and pyridine; synthesis (including retrosynthetic approach and mechanistic details): pyrrole: Knorr synthesis, Paal-Knorr synthesis, Hantzsch; furan: Paal-Knorr synthesis, Feist-Benary synthesis and its variation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis; benzo-fused 5- and 6-membered rings with one heteroatom: reactivity, orientation and important reactions (with mechanistic details) of indole, quinoline and isoquinoline; synthesis (including retrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert; quinoline: Skraup, Doebner- Miller, Friedlander; isoquinoline: Bischler-Napieralski synthesis.

Unit-II

Elementary Ideas of Pericyclic reactions **8Hr**

Mechanism, stereochemistry, region-selectivity in case of

1. Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions.
2. Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions.
3. Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3]- and [1,5]-H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements.

Unit-III

Carbohydrates (14 Hrs)

1. Monosaccharides: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions (mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine-water oxidation, HNO_3 oxidation, selective oxidation of terminal $–CH_2OH$ of aldoses, reduction to alditols, Lobry de Bruyn-van Ekenstein rearrangement; stepping–up (Kiliani-Fischer method) and stepping–down (Ruff's & Wohl's methods) of aldoses; end-group-interchange of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose.
2. Disaccharides: Glycosidic linkages, concept of glycosidic bond formation by glycosyl donor-acceptor; structure of sucrose, inversion of cane sugar.

3. Polysaccharides: starch (structure and its use as an indicator in titrimetric analysis).

Unit-IV

Biomolecules

11 (Hrs)

1. Amino acids: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction, Dakin-West reaction; resolution of racemic amino acids.
2. Peptides: peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using N-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: C-terminal and N-terminal unit determination (Edman, Sanger & 'dansyl' methods); partial hydrolysis; specific cleavage of peptides: use of CNBr.
3. Nucleic acids: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; mechanism for acid catalysed hydrolysis of nucleosides (both pyrimidine and purine types); comparison of alkaline hydrolysis of DNA and RNA; elementary idea of double helical structure of DNA (Watson- Crick model); complimentary base–pairing in DNA.

Reference Books

1. Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Second edition, Oxford University Press 2012.
2. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London.
3. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
4. Sen Gupta, Subrata. Basic Stereochemistry of Organic molecules.
5. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
6. Fleming, I. Molecular Orbitals and Organic Chemical reactions, Reference/Student Edition, Wiley, 2009.
7. Fleming, I. Pericyclic Reactions, Oxford Chemistry Primer, Oxford University Press.
8. Gilchrist, T. L. & Storr, R. C. Organic Reactions and Orbital symmetry, Cambridge University Press.
9. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
10. Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd.
12. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press.
13. James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
14. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
15. Davis, B. G., Fairbanks, A. J., Carbohydrate Chemistry, Oxford Chemistry Primer, Oxford University Press.
16. Joule, J. A. Mills, K. Heterocyclic Chemistry, Blackwell Science.
17. Acheson, R.M. Introduction to the Chemistry of Heterocyclic compounds, John Wiely& Sons (1976).
18. Gilchrist, T. L. Heterocyclic Chemistry, 3rd edition, Pearson.

19. Bansal, R. K. Heterocyclic Chemistry, New Age International Publishers.
20. Davies, D. T., Heterocyclic Chemistry, Oxford Chemistry Primer, Oxford University Press.

CHEM-MJ-604-P Organic Chemistry V **Practical 30 Hr**

Course objectives and expected outcome:

- Acquire knowledge about different chromatographic separation technique (TLC, Column, Paper) of mixture of amino acids, dyes and sugars.
- IR and NMR spectroscopic analysis of different organic groups having specific functional group.

A. Chromatographic Separations

1. TLC separation of a mixture containing 2/3 amino acids
2. TLC separation of a mixture of dyes (fluorescein and methylene blue)
3. Column chromatographic separation of leaf pigments from spinach leaves
4. Column chromatographic separation of mixture of dyes
5. Paper chromatographic separation of a mixture containing 2/3 amino acids
6. Paper chromatographic separation of a mixture containing 2/3 sugars

B. Spectroscopic Analysis of Organic Compounds

1. Assignment of labeled peaks in the ^{1}H-NMR spectra of the known organic compounds explaining the relative δ-values and splitting pattern.

2. Assignment of labeled peaks in the IR spectrum of the same compound explaining the relative frequencies of the absorptions (C-H, O-H, N-H, C-O, C-N, C-X, C=C, C=O, N=O, C≡C, C≡N stretching frequencies; characteristic bending vibrations are included).

3. The students must record full spectral analysis of at least 15 (fifteen) compounds from the following list:

(i) 4-Bromoacetanilide (ii) 2-Bromo-4'-methylacetophenone (iii) Vanillin (iv) 2’-Methoxyacetophenone (v) 4-Aminobenzoic acid (vi) Salicylamide (vii) 2’-Hydroxyacetophenone(viii) 1,3-Dinitrobenzene (ix) Benzylacetate (x) trans-4-Nitrocinnamaldehyde (xi) Diethyl fumarate (xii) 4-Nitrobenzaldehyde (xiii) 4’-Methylacetanilide (xiv) Mesityl oxide (xv) 2-Hydroxybenzaldehyde (xvi) 4-Nitroaniline (xviii) 2-Hydroxy-3-nitrobenzaldehyde (xviii) 2,3-Dimethylbenzonitrile (xix) Pent-1-yn-3-ol (xx) 3-Nitrobenzaldehyde (xxi) 3-Ethoxy-4-hydroxybenzaldehyde (xxii) 2-Methoxybenzaldehyde (xxiii) Methyl 4-hydroxybenzoate (xxiv) Methyl 3-hydroxybenzoate (xxv) 3-Aminobenzoic acid (xxvi) Ethyl 3-aminobenzoate (xxvii) Ethyl 4-aminobenzoate (xxviii) 3-nitroanisole (xxix) 5-Methyl-2-nitroanisole (xxx) 3’-Methyl acetanilide.

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SEMESTER – VII

Course	Paper Code	Name of the Subject	Brief Description	Credit
Major	CHEM-MJ-701-T	Inorganic Chemistry–V	Chemistry of d- and f- block elements Transition Elements, Organometallic Chemistry –I, Symmetry and Group Theory-I	03
	CHEM-MJ-701-P	Inorganic Chemistry–V	Analysis of Metals and Alloys, Chromatography of metal ions, Equilibrium studies on inorganic reactions	01
	CHEM-MJ-702-T	Organic Chemistry– VI	Carbocycles and Heterocycles, Elementary Ideas of Pericyclic reactions, Carbohydrates	03
	CHEM-MJ-702-P	Organic Chemistry– VI	Chromatographic Separations	01
	CHEM-MJ-703-T	Physical Chemistry-V	Polymer Chemistry, Chemical Kinetics -II, Statistical Thermodynamics.	03
	CHEM-MJ-703-P	Physical Chemistry-V	Lamberts-Beers Law and Spectrophotometric study.	01
	CHEM-MJ-704-T	Physical Chemistry-VI	Solid state chemistry,	03
	CHEM-MJ-704-P	Physical Chemistry-VI	Computer programs based on numerical methods	01
Minor -IV	CHEM-MI-4-T	Minor-4-T	Industrial Chemistry and Environment	03
	CHEM-MI-4-P	Minor-4-P	Available chlorine in bleaching powder, BOD and COD	01

CHEM-MJ-701-T: INORGANIC CHEMISTRY-V **Credit (3Th+1Pr)**

Course objectives and expected outcome: Studentsgettheoreticalknowledgeaboutthed/f block elements with some physical& chemical properties,metal- carbon bond formation and their stability, Complex metric reaction kinetics and mechanism. Students get the idea of group theory.

Unit-I

Chemistry of d- and f- block elements Transition Elements: **10 hrs**

General comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, coordination chemistry.

Lanthanoids and Actinoids:

General Comparison on Electronic configuration, oxidation states, colour, spectral and magnetic properties; lanthanide contraction, separation of lanthanides (ion-exchange method only).

Unit-II

Organometallic Chemistry -I **20 hrs**

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. 18-electron and 16-electron rules (pictorial MO approach). Applications of 18-electron rule to metal carbonyls, nitrosyls, cyanides. General methods of preparation of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls. pi-acceptor behaviour of CO, synergic effect and use of IR data to explain extent of back bonding. Zeise‘s salt: Preparation, structure, evidences of synergic effect. Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation).

Unit-III

Symmetry and Group Theory-I **15 hrs**

Groups and their properties- the concept of groups; subgroups, classes and the related theorems; commutative (abelian) groups and cyclic groups and their examples; group multiplication tables and the rearrangement theorem. Symmetry elements and operations, products of symmetry operations, equivalent symmetry elements and equivalent atoms, symmetry in platonic solids, identification of point groups, Symmetry of C60 fullerenes, Crystallographic symmetry: 32 crystal classes, Hermann–Mauguin (HM) notations, optical activity and dipole-moment on the basis of point group symmetry; similarity transformation and the invariance of characters; block diagonalization; direct product of matrices and their characters etc. Matrix representation of symmetry operations, characters of symmetry operations in a representation, invariance of character under similarity transformation, the row / column orthogonality of characters, reducible and irreducible representations, the “Great Orthogonality Theorem” (without derivation) and its corollaries.

Reference Books

1. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.

2. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth- Heinemann. 1997.

3. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.

4. Atkin, P. Shriver &Atkins‘Inorganic Chemistry 5th Ed. Oxford University Press (2010).

5. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.

6. Sinha, S. P., Ed., Lanthanide and Actinide Research (Journal, Vol. 1, 1986).

7. Wulfsberg, G., Principles of Descriptive Inorganic Chemistry, Brooks/Cole: Monterey, CA, 1987.

CHEM-MJ-701-P – INORGANIC CHEMISTRY-V(30Hrs)

Course objectives and expected outcome: Student estimate metal ions from their ores. They also determine compositions of metal-dye complexes by mole-ratio methods/slope method/Job's method. They also get the idea on TLC/paper chromatography.

Analysis of Metals and Alloys

A. Quantitative estimation of Zn(II) and Cu(II) in brass sample by volumetry and gravimetry

B. Quantitative estimation of iron in cast iron and steel.

Equilibrium studies on inorganic reactions

A. Determination of composition of Fe(III)-sulfosalicylate complex in solution by Mole-Ratio method.

B. Determination of composition of Fe(II)-1,10-phenanthroline complex in solution by Mole- Ratio method.

C. Determination of composition of Fe(III)-sulfosalicylate complex in solution by Slope-Ratio method.

D. Determination of composition of Fe(II)-1,10-phenanthroline complex in solution by Slope- Ratio method.

E. Determination of composition of Fe(III)-sulfosalicylate complex in solution by Job‟s method of continuous variation.

F. Determination of composition of Fe(II)-1,10-phenanthroline complex in solution by Job‟s method of continuous variation.

Chromatography of metal ions

Principles invoved in chromatographic separations. Paper chromatographic separation of following metal ions:
1. Ni (II) and Co (II)

2. Fe (III) and Al (III)

Suggested Readings:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis* 6th Ed., Pearson, 2009. 2. *Inorganic Synthesis*, Vol. 1-10. 3.An Advanced Course in Practical Chemistry., Ghosal. Mahapatra .Nad. New Central Book Agency. 4.Chemistry in Laboratory., Ghosh. Das Sarma. Majumdar. Manna. Santra Publications.

CEM-MJ-702-T - Organic Chemistry VI **Credit (3Th+1Pr)**

Courseobjectivesandexpectedoutcome:

- Acquire knowledge about synthesis and common chemical reaction of carbocyclic molecules (naphthalene, anthracene, phenanthrene) and hetrocyclic molecules (pyrrole, furan, thiophene, pyridine).

- Brief knowledge about a few chemical reactions and stereochemistry of alicyclic molecules.
- Gatherbriefknowledgeaboutvariouspericyclicreactionsandtheir FMOapproach.
- Some basic understanding of structure of different bio-molecules like carbohydrate, peptide, nucleic acid and their reactions.

Unit-I

Carbocycles and Heterocycles **12Hrs**

Polynuclear hydrocarbons and their derivatives: synthetic methods include Haworth, Bardhan-Sengupta, Bogert-Cook and other useful syntheses (with mechanistic details); fixation of double bonds and Fries rule; reactions (with mechanism) of naphthalene, anthracene, phenanthrene and their derivatives.

Heterocyclic compounds: 5- and 6-membered rings with one heteroatom; reactivity, orientation and important reactions (with mechanism) of furan, pyrrole, thiophene and pyridine; synthesis (including retrosynthetic approach and mechanistic details): pyrrole: Knorr synthesis, Paal-Knorr synthesis, Hantzsch; furan: Paal-Knorr synthesis, Feist-Benary synthesis and its variation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis; benzo-fused 5- and 6-membered rings with one heteroatom: reactivity, orientation and important reactions (with mechanistic details) of indole, quinoline and isoquinoline; synthesis (including retrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert; quinoline: Skraup, Doebner- Miller, Friedlander; isoquinoline: Bischler-Napieralski synthesis.

Unit-II

Elementary Ideas of Pericyclic reactions **8Hr**

Mechanism, stereochemistry, region-selectivity in case of Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions.Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions.Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3]- and [1,5]-H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements.

Unit-III

Carbohydrates **14Hrs**

Monosaccharides: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions (mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine-water oxidation, HNO_3 oxidation, selective oxidation of terminal $–CH_2OH$ of aldoses, reduction to alditols, Lobry de Bruyn-van Ekenstein rearrangement; stepping–up (Kiliani-Fischer method) and stepping–down (Ruff's & Wohl's methods) of aldoses; end-group-interchange of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose.

Disaccharides: Glycosidic linkages, concept of glycosidic bond formation by glycosyl donor-acceptor; structure of sucrose, inversion of cane sugar.

Polysaccharides: starch (structure and its use as an indicator in titrimetric analysis).

Unit-IV

Biomolecules (11Hrs)

1. Amino acids: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction, Dakin-West reaction; resolution of racemic amino acids.
2. Peptides: peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using N-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: C-terminal and N-terminal unit determination (Edman, Sanger & 'dansyl' methods); partial hydrolysis; specific cleavage of peptides: use of CNBr.
3. Nucleic acids: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; mechanism for acid catalysed hydrolysis of nucleosides (both pyrimidine and purine types); comparison of alkaline hydrolysis of DNA and RNA; elementary idea of double helical structure of DNA (Watson-Crick model); complimentary base–pairing in DNA.

Reference Books

1. Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Second edition, Oxford University Press 2012.
2. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London.
3. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
4. Sen Gupta, Subrata. Basic Stereochemistry of Organic molecules.
5. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
6. Fleming, I. Molecular Orbitals and Organic Chemical reactions, Reference/Student Edition, Wiley, 2009.
7. Fleming, I. Pericyclic Reactions, Oxford Chemistry Primer, Oxford University Press.
8. Gilchrist, T. L. & Storr, R. C. Organic Reactions and Orbital symmetry, Cambridge University Press.
9. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).
10. Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd.
12. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press.

13. James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
14. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
15. Davis, B. G., Fairbanks, A. J., Carbohydrate Chemistry, Oxford Chemistry Primer, Oxford University Press.
16. Joule, J. A. Mills, K. Heterocyclic Chemistry, Blackwell Science.
17. Acheson, R.M. Introduction to the Chemistry of Heterocyclic compounds, John Wiely& Sons (1976).
18. Gilchrist, T. L. Heterocyclic Chemistry, 3rd edition, Pearson.
19. Bansal, R. K. Heterocyclic Chemistry, New Age International Publishers.
20. Davies, D. T., Heterocyclic Chemistry, Oxford Chemistry Primer, Oxford University Press.

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CHEM-MJ-702 –P. ORGANIC CHEMISTRY- VI **Practical (30Hr)**

Courseobjectivesandexpectedoutcome:

- Acquireknowledgeaboutdifferentextraction techniques and elementary knowledge about TLC and UV.
- Idea about Preparation of several organic compounds in one or two step reaction and yield calculation and boiling point measurement of different liquid organic compounds.

1. ExtractionofRenewablechemicals

Takeaparticularpartofaplantsuchasfruit,leaf,bark,heavywood,etc.

Weightit.Extractwitha particularsolvent. Removethevolatiles.Purify.Weigh theproduct.

Calculate %yield,Analyze theproductbyThinLayerChromatography,calculate$R_f$value.UV-VISspectralcharacterizations:Measureλ_{max},ϵ_{max}andexplain.Submittheproductwithproperlabel.

2. Preparation

Preparation of pure organic compound single-step or two step procedure and submission of crystallizedproduct:TablePreparation;Weighthecompound, calculatetheoreticalyield,preparethecompound,weightheproduct,calculate%yield,crystallize,checkM.P.,submit crystallizedproduct.

3. Determination of boiling point of common organic liquid compounds e.g., ethanol, cyclohexane, chloroform, ethyl methyl ketone, cyclohexanone, acetylacetone, anisole, crotonaldehyde, mesityl oxide, *etc*. [Boiling point of the chosen organic compounds should preferably be less than 160 °C]

Reference Books

1. Vogel, A. I. Elementary Practical Organic Chemistry, Part 1: Small scale Preparations, CBS Publishers and Distributors.

2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of

Calcutta, 2003.

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

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

5. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000). 6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.

CHEM-MJ-703-T: PHYSICAL CHEMISTRY-V **Credit (3Th+1Pr)**

Courseobjectivesandexpectedoutcome:

a. Acquireknowledgeaboutdifferent types of polymers and determination of molecular weight of polymers.
b. Idea about reaction kinetics effect of temperature on chemical reactions. Knowledge of catalyst on chemical reaction.
c. Idea about probability and statistics microstate, microstate, partition function. Classical and quantum statistics.

Unit-I

Macromolecules **15 (Hrs)**

Polymers: Classification of polymers, nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers; Criteria for synthetic polymer formation; Relationships between functionality, extent of reaction and degree of polymerization; Mechanism and kinetics of step growth and copolymerization; Conducting polymers.
Determination of molecular weight of polymers: (Mn, Mw, etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

Unit-II

Chemical Kinetics-II **(15 Hrs)**

Role of T and theories of reaction rate: Temperature dependence of rate constant; Arrhenius equation, energy of activation; Rate-determining step and steady-state approximation – explanation with suitable examples; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment).
Homogeneous catalysis: Homogeneous catalysis with reference to acid-base catalysis; Primary kinetic salt effect; Enzyme catalysis; Michaelis-Menten equation, Lineweaver-Burk plot, turn-over number Autocatalysis; periodic reactions. General principles and properties of catalysts, homogenous catalysis (catalytic steps and examples) and heterogenous catalysis (catalytic steps and examples) and their industrial applications, Deactivation or regeneration of catalysts. Phase transfer catalysts, application of zeolites as catalysts.

Unit-III

Statistical Thermodynamics (15 Hrs)

Configuration: Macrostates, microstates and configuration; calculation with harmonic oscillator; variation of W with E; equilibrium configuration Boltzmann distribution: Thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation); Applications to barometric distribution; Partition function, concept of ensemble - canonical ensemble and grand canonical ensembles Partition function: molecular partition function and thermodynamic properties, Maxwell's speed distribution; Gibbs' paradox..

Reference Books:

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
3. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
4. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
5. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta
6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

CHEM-MJ-703-P – PHYSICAL CHEMISTRY-V(30Hrs)

Courseobjectivesandexpectedoutcome: Thecourseprovidestraininginadvancedphysicalchemistry laboratory techniques.The experiments are guided by demonstrators and are designed both to illustrate the applications of theory covered in the Chemical Physics and lecture courses, and to introduce typical instrumentation. On successful completion of the course students will be able to:

1. Developedexpertiserelevanttotheprofessionalpracticeofchemistry.
2. Developedanunderstandingofthebreadthandconceptsofphysical chemistry.
3. Anappreciationoftheroleofphysicalchemistryinthechemicalsciences.
4. Developedanunderstandingoftheroleofthechemistintasksemployingphysicalchemistry.
5. Anunderstandingofmethodsemployedforproblemsolvinginphysicalchemistry.
6. Experienceinsomescientificmethodsemployedinbasicandappliedphysicalchemistry.
7. Developed skills in procedures and instrumental methods applied in analytical and practical tasks of physical chemistry.
8. Developedskillsinthescientificmethodofplanning,developing,conducting,reviewingand reporting experiments.
9. Developed some understandingoftheprofessionaland safetyresponsibilitiesresidingin workingwith chemical systems.

Experiment-1: VerificationofBeerandLambert'sLawforKMnO$_4$andK$_2$Cr$_2$O$_7$solution

Experiment-2: Studyofkineticsof K$_2$S$_2$O$_8$+ KIreaction,spectrophotometrically.

Experiment-3: DeterminationofpHofunknownbuffer,spectrophotometrically.

Experiment-4: SpectrophotometricdeterminationofCMC.

CHEM-MJ-704-T: PHYSICAL CHEMISTRY-VI Credit (3Th+1Pr)

Courseobjectivesandexpectedoutcome: Thecourseprovidestraininginadvancedphysicalchemistry laboratory techniques.The experiments are guided by demonstrators and are designed both to illustrate the applications of theory covered in the Chemical Physics and lecture courses, and to introduce typical instrumentation. On successful

completion of the course students will be able to:

1. Developedexpertiserelevantto crystallography and effect of temperature on solid crystal.
2. Knowledge of nanostructured materials and their role in chemical, biological sciences.
3. Anidea about mean, median, standard deviation and Pie chart, Bar chart, and Histogram .

Unit-I

Solid State Chemistry 18 hrs

Bravais Lattice and Laws of Crystallography: Types of solid, Bragg's law of diffraction; Laws of crystallography (Haüy's law and Steno's law); Permissible symmetry axes in crystals; Lattice, space lattice, unit cell, crystal planes, Bravais lattice. Packing of uniform hard sphere, close packed arrangements (fcc and hcp); Tetrahedral and octahedral voids. Void space in p-type, F-type and I-type cubic systems Crystal planes: Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of d_{hkl}; Relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation) Determination of crystal structure: Powder method; Structure of NaCl and KCl crystals.

Specific heat of solid: Coefficient of thermal expansion, thermal compressibility of solids; Dulong –Petit's law; Perfect Crystal model, Einstein's theory – derivation from partition function, limitations; Debye's T^3 law – analysis at the two extremes 3rd law: Absolute entropy, Plank's law, Calculation of entropy, Nernst heat theorem Adiabatic demagnetization: Approach to zero Kelvin, adiabatic cooling, demagnetization, adiabatic demagnetization – involved curves

Unit-II

Nanotechnology: (12 Hrs)

Introduction: Bulk vs Nano, Geometric structure, magic numbers, co-ordination number of small cluster.Synthesis of Nanomaterials: Physical methods, Chemical methods, Biological methods. Properties of Nanomaterials: Mechanical properties, structural properties, melting of nanoparticles, electrical conductivity, optical properties, magnetic properties.

Unit-III

Statistical Data Analysis: (15 Hrs)

Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. Presentation of experimental data and results, from the point of view of significant figures. Data analysis using spreadsheets - graphs and diagrams (Pie chart, Bar chart, and Histogram), summary statistics (Mean, Median, Mode, Standard deviation), calculation of correlation coefficient and performing a simple linear regression.

Reference Books:

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson

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

4. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency

5. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta

6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.

7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

CHEM-MJ-704-P – PHYSICAL CHEMISTRY-VI(30Hrs)

Courseobjectivesandexpectedoutcome: Thecourseprovidestraininginadvancedphysicalchemistry laboratory techniques.The experiments are guided by demonstrators and are designed both to illustrate the applications of theory covered in the Chemical Physics and lecture courses, and to introduce typical instrumentation. On successful completion of the course students will be able to:

1. Developedexpertiserelevanttothecomputer in chemistry.
2. Developedanunderstandingof scilab or C^{++} or Fortran.
3. Anappreciationoftheroleof thermodynamic parameter from computational study.

Computer programs based on numerical methods for
Programming 1: Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid)
Programming 2: Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations)
Programming 3: Numerical integration (e.g. entropy/ enthalpy changes from heat capacity data), probability distributions (gas kinetic theory) and mean values

SEMESTER – VIII

Course	Paper Code	Name of the Subject	Brief Description	Credit
Major	CHEM-MJ-801-T	Inorganic Chemistry– VI	Organometallic Chemistry – II, Group theory-II, Bioinorganic Chemistry	03
	CHEM-MJ-801-P	Inorganic Chemistry– VI	Qualitative semi micro analysis	01
	CHEM-MJ-802-T	Organic Chemistry– VII	Drugs, Pharmaceuticals, Dyes, Green chemistry, Retrosynthesis -II	03
	CHEM-MJ-802-P	Organic Chemistry– VII	Qualitative analysis of liquid sample	01
Minor -IV	CHEM-MI-4-T	Minor-4-T	Industrial Chemistry and Environment	03
	CHEM-MI-4-P	Minor-4-P	Available chlorine in bleaching powder, BOD and COD	01

CHEM-MJ-801-T: INORGANIC CHEMISTRY-VICredit (3Th+1Pr)

Course objectives and expected outcome: Student get the idea on heterogeneous organometallic catalytic cycle and some organometallic reaction mechanism. They also able the details idea on group theory. They get idea on bio-

inorganic chemistry.

Unit-I

Organometallic Chemistry -II **15 hrs**

Catalysis by Organometallic Compounds

A. Reactions of organometallic complexes: substitution, oxidative addition, reductive elimination and insertion reactions.

B. Study of the following industrial processes

1. Alkene hydrogenation (Wilkinson's Catalyst)
2. Hydroformylation
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Ziegler-Natta catalysis for olefin polymerization.

C. Reaction Kinetics and Mechanism

Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans- effect and its application in complex synthesis, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes.

Unit-II

Group theory-II **15 hrs**

Character tables (C_2v, C_3v, C4v, D_4), representation for cyclic groups, wave functions as bases for Irreducible Representations, the standard reduction formula; the direct product representation and its decomposition, identifying nonzero matrix elements, spectral transition probabilities, allowedness – forbiddenness of n-π* and π-π* transitions, symmetry of normal modes, normal mode analysis, selection rules for IR and Raman transitions. Projection operator (without derivation), use of the projection operator to form symmetry adapted linear combination (SALC) of simple system.

Unit-III

Bioinorganic Chemistry **15 hrs**

Elements of life: essential and beneficial elements, major, trace and ultra-trace elements. Basic chemical reactions in the biological systems and the role of metal ions (specially Na^+, K^+, Mg^{2+}, Ca^{2+}, $Fe^{3+/2+}$, $Cu^{2+/+}$, and $Zn^{2+)}$. Metal ion transport across biological membrane Na^+/ K^+-ion pump. Dioxygen molecule in life. Dioxygen management proteins: Haemoglobin, Myoglobin, Hemocyanine and Hemerythrin. Electron transfer proteins: Cytochromes and Ferredoxins. Hydrolytic enzymes: carbonate bicarbonate buffering system and carbonic anhydrase and carboxy anhydrase A. Biological nitrogen fixation, Photosynthesis: Photosystem-I and Photosystem-II. Toxic metal ions and their effects, chelation therapy (examples only), Pt and Au complexes as drugs (examples only), metal dependent diseases (examples only).

Reference Books

1. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.

2. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.

3. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth- Heinemann, 1997.

4. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.

5. Bertini, I., Gray, H. B., Lippard, S.J., Valentine, J. S., Viva, 2007.

6. Basolo, F, and Pearson, R.C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.

CHEM-801-P – INORGANIC CHEMISTRY-VI(30Hrs)

Course objectives and expectedoutcome: Facilitate the learner to experience inqualitative semimicroanalysisofmixturescontainingfourradicalsandtounderstandthechemistryofdifferent reactions and to assign the most probable composition.

Qualitative semi micro analysis

Qualitative semi micro analysis of mixtures containing four radicals. Emphasis to be given to the understanding of the chemistry of different reactions and to assign the most probable composition.

Cation Radicals: Na^{+}, K^{+}, Ca^{2+}, Sr^{2+}, Ba^{2+}, Al^{3+}, Cr^{3+}, Mn^{2+}/Mn^{4+}, Fe^{3+}, Co^{2+}/Co^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+},Bi^{3+}, Sn^{2+}/Sn^{4+}, As^{3+}/As^{5+}, Sb^{3+}/Sb^{5+}, NH^{4+}, Mg^{2+}.

AnionRadicals: F^{-}, Cl^{-}, Br-, BrO^{3-}, I^{-}, IO^{3-}, SCN^{-}, S^{2-}, SO_4^{2-}, NO_3^{-}, NO_2^{-},PO_4^{3-}, AsO_4^{3-}, BO_3^{3-}, CrO_4^{2-} ,$Cr_2O_7^{2-}$, $Fe(CN)_6^{4-}$, $Fe(CN)_6^{3-}$

Insoluble Materials: Al_2O_3(ig), Fe_2O_3(ig),Cr_2O_3(ig), SnO_2, $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$

Reference Books

1.Svehla & Sivasankar, Vogel's Qualitative Inorganic Analysis, 7th Ed., Pearson, 2012.

2.An Advanced Course in Practical Chemistry., Ghosal. Mahapatra .Nad. New Central Book Agency.
3.Chemistry in Laboratory., Ghosh. Das Sarma. Majumdar. Manna. Santra Publications.

CHEM-MJ-802-T – ORGANIC CHEMISTRY-VII **Credit (3Th+1Pr)**

Course objectives and expected outcome: Facilitate the learner to understand about the structures, properties and functions of drugs and pharmaceuticals and to gain the idea about

dyes as well as green approach of chemistry. They should gain knowledge about retrosynthesis of biologically important organic compounds.

Unit-I

(15 hrs)

Drugs &Pharmaceuticals

Drug discovery, design and development; Basic Retrosynthetic approach. Synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti-inflammatory agents (Aspirin, paracetamol, lbuprofen); antibiotics (Chloramphenicol); antibacterial and antifungal agents (Sulphonamides; Sulphanethoxazol, Sulphacetamide, Trimethoprim); antiviral agents (Acyclovir), Central Nervous System agents (Phenobarbital, Diazepam), Cardiovascular (Glyceryl trinitrate), antilaprosy (Dapsone), HIV-AIDS related drugs (AZT-Zidovudine).

Unit-II

Retrosynthesis-II **(15 hrs)**

Retrosynthetic analysis and synthesis; Analysis of selectivity and stereochemical problems; Functional group interconversion and protective group methodology; Modern methods for carbon-carbon, and carbon-heteroatom bond formations; Use of reagents and chemical transformation.

Unit-III

Elementary ideas of Green Chemistry*:* **(7 hrs)**

Twelve (12) principles of green chemistry; planning of green synthesis; common organic reactions and their counterparts: reactions: Aldol, Friedel-Crafts, Michael, Knoevenagel, Cannizzaro, benzoin condensation and Dieckmann condensation. Rearrangement reactions by green approach**:** Fries rearrangement, Claisen rearrangement, Beckmann rearrangement, Baeyer-Villiger oxidation.

Unit-IV

Dyes **(8Hrs)**

Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing; Synthesis and applications of: Azo dyes – Methyl Orange and Congo Red (mechanism of Diazo Coupling); Triphenyl Methane Dyes -Malachite Green, Rosaniline and Crystal Violet; Phthalein Dyes – Phenolphthalein and Fluorescein; Natural dyes –structure elucidation and synthesis of Alizarin and Indigotin; Edible Dyes with examples.

Reference Books:

1. Patrick, G. L. Introduction to Medicinal Chemistry, Oxford University Press, UK, 2013.
2. Singh, H. & Kapoor, V.K. Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi, 2012.
3. Foye, W.O., Lemke, T.L. & William, D.A.: Principles of Medicinal Chemistry, 4th ed., B.I. Waverly Pvt. Ltd. New Delhi.
4. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Finar, I. L. Organic Chemistry (Volume 1), Pearson Education.

6. Graham Solomons, T.W., Fryhle, C. B. Organic Chemistry,John Wiley & Sons, Inc.
7. March,J. Advanced Organic Chemistry, Fourth edition, Wiley.
8. Jenkins, P. R., Organometallic Reagents in Synthesis, Oxford Chemistry Primer, Oxford University Press.
9. Ward, R. S., Bifunctional Compounds, Oxford Chemistry Primer, Oxford University Press.
10. Ahluwalia, V. K. Strategies for Green Organic Synthesis, ANE Books Pvt. Ltd.
11. Clayden, J., Greeves, N., Warren, S. Organic Chemistry, Second edition, Oxford University Press 2012.
12. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
13. Smith,J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.
14. Carey, F. A., Guiliano, R. M. Organic Chemistry, Eighth edition, McGraw Hill Education, 2012.
15. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press, 2008.
16. Norman, R.O. C., Coxon, J. M. Principles of Organic Synthesis, Third Edition, Nelson Thornes

CHEM-MJ-802-P – ORGANIC CHEMISTRY-VII (30Hrs)

Courseobjectivesandexpectedoutcome: FacilitatethelearnertounderstandaboutQualitative Analysis of Liquid Organic Compounds having different functional groups with added understanding of TLC separation and NMR spectroscopic analysis.

1. Liquid Sample Qualitative analysis (color, odour, solubility etc.)
   (a) Detection of special elements (N, S, Cl, Br) by Lassaigne's test
   b) Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
   c) Detection of the following functional groups by systematic chemical tests: aromatic amino (NH_2), aromatic nitro ($-NO_2$), amido ($-CONH_2$, including imide), phenolic –OH, carboxylic acid (-COOH), carbonyl (-CHO and >C=O); only one test for each functional group is to be reported.
   d)Boiling point determination
   e) Preparation, purification and melting point determination of a crystalline derivative of the given compound
   f) Identification of the compound through literature survey.

2. Thin Layer Chromatography (TLC, preparation of TLC plates, analysis).

3. Assign ^1H- NMR,

Reference Books

1. Vogel, A. I. Elementary Practical Organic Chemistry, Part 1: Small scale Preparations, CBS Publishers and Distributors.

2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta, 2003.

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

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

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

6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.

CHEMISTRY -MI-IV

INDUSTRIAL CHEMISTRY AND ENVIRONMENT (Credits: Theory-03, Practicals-01)

Minor Paper-IV (Credit: Theory -03, Practical – 01) Theory: (45 Hrs)

Chemistry Minor Paper-IV

Courseobjectivesandexpectedoutcome:

Students learn about energy and environmental studies, energy resources, industrial gases, manufactureofhazardousinorganicmaterials,pollutions(air,water)andcontrollingprocess, biogeochemical cycles, biocatalyst synthesis and their applications to society.

Theory: (45 Hrs)

Module: I

Industrial Gases and Inorganic Chemicals

Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene.

Industrial Metallurgy

Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology.

Module: II

Environment and its segments

Ecosystems. Biogeochemical cycles of carbon, nitrogen and sulphur.

Air Pollution: Major regions of atmosphere. Chemical and photochemical reactions in atmosphere. Air pollutants: types, sources, particle size and chemical nature; Photochemical smog: its constituents and photochemistry. Environmental effects of ozone, Major sources of air pollution.

Pollution by SO_2, CO_2, CO, NO_x, H_2S and other foul-smelling gases. Methods of estimation of CO, NO_x, SO_x and control procedures. Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming,

Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.

WaterPollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems.

Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc. Sludge disposal. Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

Module: **III**

Energy & Environment

Sources of energy: Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.

Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

Biocatalysis

Introduction to biocatalysis: Importance in Green Chemistry and Chemical Industry.

Reference Books:

• E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.

• R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.

• J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.

• S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.

• K. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.

• S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi.

• S.E. Manahan, Environmental Chemistry, CRC Press (2005).

• G.T. Miller, Environmental Science 11th edition. Brooks/ Cole (2006).

• A. Mishra, Environmental Studies. Selective and Scientific Books, New Delhi (2005).

INDUSTRIAL CHEMISTRY AND ENVIRONMENT PRACTICAL: (30 Hrs)

Courseobjectivesandexpected outcome:

Students get practical knowledge to acquire oxygen demined, quantitativechlorine estimation,estimationoftotalalkalinityofwatersamplesandpreparationofboraxand boric acid.

1. Determination of dissolved oxygen in water.

2. Determination of Chemical Oxygen Demand (COD)

3. Determination of Biological Oxygen Demand (BOD)

4. Percentage of available chlorine in bleaching powder.

5. Measurement of chloride, sulphate and salinity of water samples by simple titration method ($AgNO_3$ and potassium chromate).

6. Estimation of total alkalinity of water samples (CO_3^{2-}, HCO_3^-) using double titration method.

7. Measurement of dissolved CO_2.

8. Study of some of the common bio-indicators of pollution.

9. Estimation of SPM in air samples.

10. Preparation of borax/ boric acid.

Reference Books:

• E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.

• R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.

• J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.

• S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.

• K. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.

• S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi.

DSE-1: Analytical Methods in Chemistry

DSE-1T: Analytical Methods in Chemistry (Credits 04)

Courseobjectivesandexpectedoutcome:

Acquire the knowledge about the idea of spectroscopic molecular structure determination, thermogravimetry and electrochemical analysis, qualitative and quantitative extraction and separation of molecules from chromatographic analysis.

Course Contents:

Unit-1 (15 Hrs)

Qualitative and quantitative aspects of analysis: Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals.

Optical methods of analysis: Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy

and selection rules, validity of Beer-Lambert's law. UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument; Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method. Infrared Spectrometry: Basic principles of instrumentation (choice of source, monochromator & detector) for single and double beam instrument; sampling techniques. Structural illustration through interpretation of data, Effect and importance of isotope substitution.

Unit-II (15 Hrs)

Thermal methods of analysis: Theory of thermogravimetry (TG), basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.
Electroanalytical methods: Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

Unit-III (15 Hrs)

Separation techniques: Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media. Chromatography: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange. Development of chromatograms: frontal, elution and displacement methods. Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

DSE-1P: Analytical Methods in Chemistry (lab) Credits 01

Course objectives and expected outcome:
Handsontrainingaboutthechromatographicseparationmetalextraction,ionexchangesoilanalysis, spectroscopic oxygen demand calculation.

Practical:

I. **Separation Techniques Chromatography:** (a) Separation of mixtures Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f values. (b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their R_f values. (c) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC II.
II. **Solvent Extractions:** To separate a mixture of Ni^{2+}& Fe^{2+} by complexation with DMG and extracting the Ni^{2+}-DMG complex in chloroform, and determine its concentration by spectrophotometry. Analysis of soil: (i) Determination of pH of soil. (ii) Estimation of calcium, magnesium, phosphate.

DSE-2T: Inorganic Materials of Industrial Importance (Credits 04)

Courseobjectivesandexpectedoutcome:

- Acquireknowledgeaboutsynthesis,applicationandcharacterizationofglass, cement and ceramic materials.
- Brief knowledge about a few components of batteries, their function, charging and discharging process.
- Gather brief knowledge about silicate industries, dyes and pigments and explosivematerials.
- Somebasicunderstandingofcatalysis.

Course Contents:
Unit-1 (20Hrs)

1. **Silicate Industries:** Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass. Ceramics: Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fibre.
2. **Fertilizers:** Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

Unit-II (25 Hrs)

1. **Surface Coatings:** Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Oil paint, Vehicle, modified oils, Pigments, toners and lakes pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, additives, Metallic coatings (electrolytic and electroless), metal spraying and anodizing.
2. **Batteries:** Primary and secondary batteries, battery components and their role, Characteristics of Battery. Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.
3. **Alloys:** Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation) and surface treatment (Ar and heat treatment, nitriding, carburizing). Composition and properties of different types of steels.

Suggested Readings:

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
2. R. M. Felder, R. W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.
4. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
5. P. C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.
6. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas Publications, New Delhi.
7. Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

DSE-2 P: Inorganic Materials of Industrial Importance (Credits 01)

Practicals knowledge about synthesis and application of fertilizers. Preparation of pigments, metallic coating and plastic materials.

Practical:

1. Determination of free acidity in ammonium sulphate fertilizer.
2. Estimation of Calcium in Calcium ammonium nitrate fertilizer.
3. Estimation of phosphoric acid in superphosphate fertilizer.
4. Electroless metallic coatings on ceramic and plastic material.
5. Determination of composition of dolomite (by complexometric titration).
6. Analysis of (Cu, Ni); (Cu, Zn) in alloy or synthetic samples.
7. Analysis of Cement. 8. Preparation of pigment (zinc oxide).

Suggested Readings:

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
2. 2. R. M. Felder, R. W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.
4. 4. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
5. 5. P. C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.
6. 6. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas 7
7. . Publications, New Delhi. 8. Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

DSE-3: Polymer Chemistry (Credits 04)

Courseobjectivesandexpectedoutcome:

Since ancient times, polymers have been part of our natural world. Current applications extend from adhesives, coatings, foams, and packaging materials to textile and industrial fibers, composites, electronic devices, biomedical devices, optical devices, and precursors for many newlydevelopedhigh-techceramics.Thelistisalmostendless.Thesemanifoldusesofpolymers have immensely helped to raise our living standards. Effect of temperature on polymerization, kinetics & mechanism. Kinetics and utility of copolymerization reaction. Evaluate the effect of reactivity ratio of monomers on the type of copolymer and copolymer composition to produce a copolymer of desired properties. Melting point also known as melt temperature is the critical temperature above which the crystalline regions in a semicrystalline plastic are able to flow.Rationalizebulkpropertiesandprocessesusingthermodynamicconsiderations.Electrochemical properties of polymers.

DSE-3T: 03 Credits (45 Hrs)

Unit-I (15 Hrs)

Introduction and history of polymeric materials: Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.

Functionality and its importance: Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bifunctional systems, Poly-functional systems.

Kinetics of Polymerization: Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization, polymerization techniques.

Unit-II (15 Hrs)

Crystallization and crystallinity: Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point.
Nature and structure of polymers: Structure Property relationships.
Glass transition temperature (Tg) and determination of Tg: Free volume theory, WLF equation, Factors affecting glass transition temperature (Tg).
Polymer Solution: Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures.

Unit-III (15 Hrs)

Properties of Polymer: (Physical, thermal, Flow & Mechanical Properties). Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydienes, Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly(p-phenylene sulphidepolypyrrole, polythiophene)].

Suggested Readings:
1. R.B. Seymour & C.E. Carraher: Polymer Chemistry: An Introduction, Marcel Dekker, Inc. New York, 1981.
2. G. Odian: Principles of Polymerization, 4th Ed. Wiley, 2004.
3. F.W. Billmeyer: Textbook of Polymer Science, 2nd Ed. Wiley Interscience, 1971.
4. P. Ghosh: Polymer Science & Technology, Tata McGraw-Hill Education, 1991.
5. R.W. Lenz: Organic Chemistry of Synthetic High Polymers. Interscience Publishers, New York, 1967.

DSE-3P: LAB Credits 01

Courseobjectivesandexpectedoutcome: Thecourseprovidestraininginadvancedphysicalchemistry laboratory techniques.The experiments are guided by demonstrators and are designed both to illustrate the applications of theory covered in the Chemical Physics and lecture courses, and to introduce typical instrumentation. On successful completion of the course students will be able to:

1. Developedexpertiserelevanttotheprofessionalpracticeofchemistry.
2. Developedanunderstandingofthebreadthandconceptsofpolymer chemistry.
3. Anappreciationoftheroleofphysicalchemistryinthechemicalsciences.
4. Developedanunderstandingoftheroleofthechemistintasksemployingpolymerchemistry.
5. An understanding of methods employed for problem solving in polymer chemistry.
6. Experience in some scientific methods employed in basic and applied polymer chemistry.
7. Developed skills in the scientific method of planning, developing, conducting, reviewing and reporting experiments.

Practical:

Polymer synthesis

1. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA). a) Purification of monomer b) Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bisisobutylonitrile (AIBN)
2. Preparation of nylon 66/6
3. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
4. Redox polymerization of acrylamide
5. Precipitation polymerization of acrylonitrile
6. Preparation of urea-formaldehyde resin
7. Preparations of novalac resin/ resold resin.
8. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

1. Determination of molecular weight by viscometry: (a) Polyacrylamide-aq.$NaNO_2$ solution (b) (Poly vinyl proplylidine (PVP) in water
2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.

Suggested Readings:

1. M.P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed., Oxford University Press, 1999.
2. H.R. Allcock, F.W. Lampe & J.E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003)
3. F.W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984)
4. J.R. Fried, Polymer Science and Technology, 2nd ed. Prentice-Hall (2003)
5. L. H. Sperling, Introduction to Physical Polymer Science, 4th ed. John Wiley & Sons (2005)