

DEPARTMENT OF CHEMISTRY

FACULTY OF NATURAL SCIENCES



JAMIA MILLIA ISLAMIA
(A Central University)

B.Sc. with CHEMISTRY
Effective from Academic Year 2019-2020

Syllabus of Courses Offered
Core, Elective and Ability Enhancement courses

COURSE OUTLINE					
Semester	Paper/ Practical	Paper No	Paper code	Paper Title	Total Credits
Semester-I	Theory (Core)	I-G	CHG-101	Inorganic Chemistry-I	03
	Practical (Core)		CHG-101L	Inorganic Chemistry Practical-I	01
Semester-II	Theory (Core)	II-G	CHG-202	Organic Chemistry-I	03
	Practical (Core)		CHG-202L	Organic Chemistry Practical-I	01
	Theory (Ability Enhancement)	III-G	CHG-205	Basic Analytical Chemistry	04
Semester-III	Theory (Core)	IV-G	CHG-301	Inorganic Chemistry-II	03
	Practical (Core)		CHG-301L	Inorganic Chemistry Practical-II	01
	Theory (Core)	V-G	CHG-303	Physical Chemistry-I	03
	Practical (Core)		CHG-303L	Physical Chemistry Practical-II	01
	Theory (Elective)	VI-G	CHG-304	Basic Chemistry	03
	Practical (Elective)		CHG-304-L	Basic Chemistry Practical	01
Semester-IV	Theory (Core)	VII-G	CHG-402	Organic chemistry-II	03
	Practical (Core)		CHG-402L	Organic Chemistry Practical-II	01
	Theory (Core)	VIII-G	CHG-403	Physical Chemistry-II	03
	Practical (Core)		CHG-403L	Physical Chemistry Practical-II	01
	Theory (Elective)	IX-G	CHG-404	General Chemistry	03
	Practical		CHG-404L	General Chemistry Practical	01
Semester-V	Theory (Core)	X-G	CHG-501	Inorganic Chemistry-III	03
	Practical (Core)		CHG-501L	Inorganic Chemistry Practical-III	01
	Theory (Core)	XI-G	CHG-502	Organic Chemistry-III	03
	Practical (Core)		CHG-502L	Organic Chemistry Practical-III	01
	Theory (Elective)	XII-G	CHG-504	Polymer Chemistry	03
	Practical (Elective)		CHG-504L	Polymer Chemistry Practical	01
Semester-VI	Theory (Core)	XIII-G	CHG-603	Physical Chemistry-IV	03
	Practical (Core)		CHG-603L	Physical Chemistry Practical-IV	01
	Theory (skill enhancement)	XIV-G	CHG-604	Green Chemistry	03
	Practical (skill enhancement)		CHG-604L	Green Chemistry Practical	01
	Total Credits				56

Paper code – 1st letter for semester, 2nd and 3rd for subject as mentioned below:-

01- Inorganic Chemistry, 02-Organic Chemistry, 03-Physical Chemistry, 04- Elective, 05-Ability Enhancement

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Semester-I

Paper/Practical	Paper No	Paper code	Total Credits
Inorganic Chemistry-I	CHG-101	I-G	03
Inorganic Chemistry Practical-I	CHG-101L		01
TOTAL CREDITS			04

SEMESTER-II

Paper/Practical	Paper No	Paper code	Total Credits
Organic Chemistry-I	CHG-202	II-G	03
Organic Chemistry Practical-I	CHG-202L		01
Basic Analytical Chemistry	CHG-205	III-G	04
TOTAL CREDITS			08

SEMESTER-III

Paper/Practical	Paper No	Paper code	Total Credits
Inorganic Chemistry-II	CHG-301	IV-G	03
Inorganic Chemistry Practical-II	CHG-301L		01
Physical Chemistry-I	CHG-303	V-G	03
Physical Chemistry Practical -I	CHG-303L		01
Basic Chemistry	CHG-304	VI-G	03
Basic Chemistry Practical	CHG-304L		01
TOTAL CREDITS			12

SEMESTER-IV

Paper/Practical	Paper No	Paper code	Total Credits
Organic Chemistry-II	CHG-402	VII-G	03
Organic Chemistry Practical-II	CHG-402L		01
Physical Chemistry-II	CHG-403	VIII-G	03
Physical Chemistry Practical -II	CHG-403L		01
General Chemistry	CHG-404	IX-G	03
General Chemistry Practical	CHG-404L		01
TOTAL CREDITS			12

SEMESTER-V

Paper/Practical	Paper No	Paper code	Total Credits
Inorganic Chemistry-III	CHG-501	X-G	03
Inorganic Chemistry Practical-III	CHG-501L		01
Organic Chemistry-III	CHG-502	XI-G	03
Organic Chemistry Practical -II	CHG-502L		01
Polymer Chemistry	CHG-504	XII-G	03
Polymer Chemistry Practical	CHG-504L		01
TOTAL CREDITS			12

SEMESTER-VI

Paper/Practical	Paper No	Paper code	Total Credits
Physical Chemistry-III	CHG-501	XIII-G	03
Physical Chemistry Practical-III	CHG-501L		01
Green Chemistry	CHG-604	XIV-G	03
Green Chemistry Practical -	CHG-604L		01
TOTAL CREDITS			08

CHG-101 Paper No: I-G	INORGANIC CHEMISTRY-I	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I - Atomic Structure

Bohr's theory and its limitations; Atomic spectrum of hydrogen atom; Wave mechanics: de Broglie equation; Heisenberg's Uncertainty Principle and its significance; Schrödinger's wave equation; significance of ψ and ψ^2 ; Quantum numbers and their significance; Sign of wave functions; Radial and angular wave functions for hydrogen atom; Radial and angular distribution curves; Shapes of *s*, *p*, *d* and *f* orbitals; Contour boundary and probability diagrams; Rules for filling electrons in various orbitals; Electronic configurations of the atoms; Stability of half-filled and completely filled orbitals; Concept of exchange energy; Pauli's Exclusion Principle; Hund's rule of maximum multiplicity; Aufbau's principle and its limitations; Variation of orbital energy with atomic number.

Unit II - Chemical Bonding and Molecular Structure

Ionic Bonding: General characteristics of ionic bonding; Energy considerations in ionic bonding; lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds; Statement of Born-Landé equation for calculation of lattice energy; Born-Haber cycle and its applications; polarizing power and polarizability; Fajan's rules; ionic character in covalent compounds; bond moment; dipole moment and percentage ionic character.

Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements; Concept of resonance and resonating structures in various inorganic and organic compounds; MO Approach: Rules for the LCAO method, bonding and anti-bonding MOs and their characteristics for *s-s*, *s-p* and *p-p* combinations of atomic orbitals; nonbonding combination of orbitals; MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of *s-p* mixing) and heteronuclear diatomic molecules such as CO, NO and NO⁺; Comparison of VB and MO approaches.

Unit III: Elements of Group I

Alkali Metals: Chemical properties of the metals: reaction with water, air, nitrogen; Compounds of alkali metals: oxides, hydroxides, peroxides, superoxides- preparation and properties; oxo salts: carbonates; bicarbonates; nitrates; halides; anomalous behaviour of Li.

Unit IV: Elements of Group II

Alkaline Earth metals: Comparative study of these elements with special reference to their hydrides, oxides, hydroxide and halides; Diagonal relationship; Complexes of s-block metals; complexes with crown ethers, biological significance.

Reference Books:

1. Basic Inorganic Chemistry by F.A. Cotton, G. Wilkinson & P.L. Gaus.
2. Concise Inorganic Chemistry by J.D. Lee.
3. Inorganic Chemistry by W.W. Portfield.
4. Inorganic Chemistry by D.E. Shriver, P.W. Atkins and C.H. Longford.
5. Inorganic Chemistry by A.G. Sharpe.

CHG-101L	INORGANIC CHEMISTRY PRACTICAL-I	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

A. Titrimetric Analysis

- i. Calibration and use of apparatus
- ii. Preparation of solutions of different Molarity/Normality of titrants.

B. Volumetric Analysis

- i. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
- ii. Estimation of oxalic acid by titrating it with KMnO_4 .
- iii. Estimation of water of crystallization in Mohr's salt by titrating with KMnO_4 .
- iv. Estimation of Fe(II) ions by titrating it with $\text{K}_2\text{Cr}_2\text{O}_7$ using internal indicator.
- v. Estimation of Cu(II) ions iodometrically using $\text{Na}_2\text{S}_2\text{O}_3$.

Any other experiment introduced during the year

Reference Books:

1. Mendham, J., A. I., Vogel's *Quantitative Chemical Analysis*, 6th Ed., Pearson, 2009.
2. Svehla, G., *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.

CHG-202 Paper No: II-G	ORGANIC CHEMISTRY-I	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I: Fundamentals of Organic Chemistry

Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis. Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals. Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values. Aromaticity: Benzenoids and Hückel's rule.

Unit II: Stereochemistry

Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds). Threo and erythro; D and L; cis- trans nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E / Z Nomenclature (for upto two C=C systems).

Unit III: Aliphatic Hydrocarbons

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure. Alkanes: Preparation: Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: Free radical Substitution: Halogenation. Alkenes: Preparation: Elimination reactions: Dehydration of alkenes and Dehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alk. KMnO₄) and trans-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, oxymercuration-demercuration, Hydroboration-oxidation. Alkynes: Preparation: Acetylene from CaC₂ and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides. Reactions: formation of metal acetylides, addition of bromine and alkaline KMnO₄, ozonolysis and oxidation with hot alk. KMnO₄.

Unit IV: Aromatic hydrocarbons

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure. Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid. Reactions: (Case benzene): Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation) (upto 4 carbons on benzene). Side chain oxidation of alkyl benzenes (upto 4 carbons on benzene).

Books Suggested:

1. Graham Solomon, T.W., Fryhle, C.B. & Snyder, S.A. Organic Chemistry, John Wiley & Sons (2014).
2. McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013.
3. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988).
4. Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S.
5. Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010.
6. Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.
7. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998)

CHG-202L	ORGANIC CHEMISTRY PRACTICAL -I	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

1. Detection of extra elements (N, S, Cl, Br, I) in organic compounds (containing upto two extra elements)
2. Separation of mixtures by Chromatography: Measure the R_f value in each case:
 - (a) Identify and separate the components of a given mixture of 2 amino acids (glycine, aspartic acid, glutamic acid, tyrosine or any other amino acid) by paper chromatography
 - (b) Identify and separate the sugars present in the given mixture by paper chromatography.

Books Suggested:

1. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.
2. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G.,
2. Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996

CHG-205 Paper No: III-G	BASIC ANALYTICAL CHEMISTRY	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I: Introduction

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; Analysis of soil: Composition of soil; Concept of pH and pH measurement; Complexometric titrations; Chelation, Chelating agents, use of indicators; Determination of pH of soil samples; Estimation of Calcium and Magnesium ions as carbonate by complexometric titration.

Unit II Analysis of Water

Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods; Determination of pH, acidity and alkalinity of a water sample; Determination of dissolved oxygen (DO), free chlorine and chloride ion of a water sample.

Unit III Analysis of Food Products

Nutritional value of foods; idea about food processing and food preservations and adulteration; Identification of adulterants in some common food items like coffee powder, asafoetida, chilli powder, turmeric powder, coriander powder and pulses, etc.; Chromatography: Definition, general introduction on principles of chromatography, paper chromatography, TLC etc. Paper chromatographic; Separation of mixture of metal ions (Fe^{3+} and Al^{3+}) and (Zn^{2+} and Cd^{2+}); Ion-exchange: Column, ion-exchange chromatography etc.

Unit IV Analysis of Cosmetics

Major and minor constituents and their function; Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc oxide and Calcium carbonate by complexometric titration. Applications (Any one): To study the uses of phenolphthalein in trap cases: (i) To analyze arson accelerants; (ii) To carry out analysis of gasoline. Instrumental demonstrations: Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry (i) Spectrophotometric determination of Iron in Vitamin / Dietary Tablets; (ii) Spectrophotometric Identification and Determination of Caffeine and Benzoic acid in Soft Drink.

Reference Books

1. Skoog, D.A.; West, D.M. & Holler, F.J., *Fundamentals of Analytical Chemistry*, 6th Ed., Saunders College Publishing, Fort Worth (1992).
2. Harris, D. C., *Quantitative Chemical Analysis*, W. H. Freeman. Dean, J. A., *Analytical Chemistry, Notebook*, McGraw Hill.
3. Cooper, T.G., *The Tools of Biochemistry*, John Wiley and Sons, N.Y., USA. (1977)
4. Vogel, A. I., *Vogel's Qualitative Inorganic Analysis*, 7th Ed., Prentice Hall.
5. Vogel, A. I., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Prentice Hall.
6. Robinson, J.W., *Undergraduate Instrumental Analysis*, 5th Ed., Marcel Dekker, Inc., New York (1995).

CHG-301 Paper No: IV-G	INORGANIC CHEMISTRY-II	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I: Elements of Group III

Comparative study of physical and chemical properties of these elements with special reference to their oxides, hydrides, halides and nitrides. Preparation and properties of boric acids and borax, borax bead test. Structure and bonding in diborane, an idea of three center-two electron bond in the light of molecular orbital theory, borazine, borohydrides.

Unit II: Elements of Group IV

Comparative study of physical and chemical properties of these elements with special references to their oxides, hydrides, sulphides and carbides, fluorocarbons, study of silicates (structural aspects only) and silicones. Allotropy, inert pair effect, metallic and non-metallic character, and catenation.

Unit III: Elements of Group V

Comparative study of the physical and chemical properties of these elements with special reference to their hydrides, oxides, halides, oxyhalides and sulphides, Oxoacids of nitrogen: nitrous acid, nitric acid, hyponitrous acid, hydrazoic acid, pernitric acid; oxoacids of phosphorus- orthophosphorous acid, metaphosphorous acid, hypophosphorous acid; orthophosphoric acid, di-, tri-, and tetrapolyphosphoric acids.

Unit IV: Elements of Group VI

Comparative study of physical and chemical properties of these elements with special reference to their hydrides, oxides, halides and oxyhalides. Detailed study of oxyacids, peroxyacids and thio-oxyacids of sulphur (with special emphasis on their structure). oxoacids of sulphur - thionic acid series, peroxyacid series, (with special emphasis on their structure and methods of preparation), allotropy.

Reference Books

1. Basic Inorganic Chemistry by F.A. Cotton, G. Wilkinson & P.L. Gaus.
2. Concise Inorganic Chemistry by J.D. Lee.
3. Inorganic Chemistry by W.W. Portfield.
4. Inorganic Chemistry by D.E. Shriver, P.W. Atkins and C.H. Longford.
5. Inorganic Chemistry by A.G. Sharpe.

CHG-301L	INORGANIC CHEMISTRY PRACTICAL -II	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

(A) Inorganic synthesis

- i. Potash alum and chrome alum
- ii. Tetraamminecopper(II) sulphate monohydrate, $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4 \cdot \text{H}_2\text{O}$
- iii. Potassium tris oxalate ferrete(III).

(B) Qualitative analysis

- i. Qualitative analysis of inorganic mixtures containing three anions and three cations including interfering radicals.

Reference Books

1. Mendham, J., A. I. Vogel's *Quantitative Chemical Analysis 6th Ed.*, Pearson, 2009.
2. Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.

CHG-303 Paper No: V-G	PHYSICAL CHEMISTRY-I	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I. Solutions

Ideal and non-ideal solutions, methods of expressing concentrations of solutions, activity and activity coefficient. Dilute solution, colligative properties, Raoult's law, relative lowering of vapour pressure, molecular weight determination. Osmosis, Law of osmotic pressure determination of molecular weight from osmotic pressure. Elevation of boiling point and depression of freezing point, Thermodynamic derivation of relation between molecular weight and elevation in boiling point and depression in freezing point. Abnormal molar mass, degree of dissociation and association of solutes.

Unit II. Phase Equilibrium

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation and its importance in phase equilibria. Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, FeCl₃-H₂O and Na-K only).

Unit III. Conductance

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch law of independent migration of ions. Transference number and its experimental determination using Hittorf and Moving boundary methods. Ionic mobility. Applications of conductance measurements: determination of degree of ionization of weak electrolyte, solubility and solubility products of sparingly soluble salts, ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acid base).

Unit IV. Electrochemistry

Electrolytic and Galvanic cells, reversible and irreversible cells, conventional representation of electrochemical cells, electromotive force and its measurement, electrical and electrochemical potentials, Nernst equation, types of half-cells and their reactions (gas-ion half cells, metal-metal ion half cells, metal- insoluble salt – anion half-cell, oxidation reduction half-cell, electrochemical series, calculation of cell e.m.f., thermodynamic quantities of cell reactions (ΔG , ΔH , and ΔS), reference electrodes, glass electrode, calomel electrode, determination of equilibrium constant, determination of pH of a solution, potentiometric titration. Concentration cells with transference and without transference.

Books Recommended:

1. Essentials of Physical Chemistry, B.S. Bahl, G.D. Tuli and Arun Bahl, S. Chand & Company Ltd.
2. A Text Book of Physical Chemistry, A.S. Negi and S.C. Anand, New Age International Publishers.
3. Physical Chemistry, G. M. Barrow, International Student Edition, McGraw Hill.
4. Physical Chemistry, P. W. Atkins, & J. de Paula, 10th Ed., Oxford University Press (2014).

CHG-303L	INORGANIC CHEMISTRY PRACTICAL -II	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

1. Phase Equilibrium

- a) Determination of the critical solution temperature and composition of the phenol water system and study of the effect of impurities on it.
- b) Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.

2. Conductance.

- a) To study changes in the conductance during titration with strong alkali in the following systems:
 - (i) Strong acid; (ii) Weak acid, and (iii) Mixture of strong acid and weak acid.
- b) To determine the ionization constant of a weak acid conductometrically.

3. Distribution.

- a) Determination of partition coefficient of iodine between water and carbon tetrachloride or toluene or chloroform.

4. Potentiometry

- a) Perform the following potentiometric titrations:
 - (i). Strong acid vs. strong base
 - (ii). Weak acid vs. strong base
 - (iii). Potassium dichromate vs. Mohr's salt

5. Any other experiment carried out in the class.

Reference Books

1. O.P. Pandey, D.N. Bajpai & S. Giri, Practical Chemistry, S. Chand & Company Ltd.
2. B. D. Khosla, V. C. Garg & A. Gulati, *Senior Practical Physical Chemistry*, S. Chand & Co.: New Delhi (2011).
3. C. W. Garland, J.W. Nibler, & D.P. Shoemaker, *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
4. A.M. Halpern & G.C. McBane, *Experimental Physical Chemistry 3rd Ed.*; W.H. Freeman & Co.: New York (2003).

CHG-304 Paper No: VI-G	BASIC CHEMISTRY	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I Atomic Structure and Periodic Properties

Idea of de Broglie matter waves, Heisenberg uncertainty principle, Atomic orbitals, Schrodinger wave equation, significance of ψ and ψ^2 , quantum numbers, radial and angular wave functions and probability distribution curves, shapes of s, p, d orbitals, Aufbau and Pauli exclusion principles, Hund's multiplicity rule. Electronic configurations of the elements, effective nuclear charge. Atomic and ionic radii, ionization energy, electron affinity and electronegativity – definition, methods of determination or evaluation, trends in periodic table and applications in predicting and explaining the chemical behavior.

Unit II Chemical Bonding

Definition and explanation of ionic bond, factors affecting the formation of ionic bond, Lattice energy and Born-Haber cycle. Polarizing power of ions, Fajan's rule. Covalent bond, Sigma and pi-bond, Valence bond theory of covalent bonding and its limitations, percentage ionic character in covalent bond from dipole moment and electronegativity difference. Weak Interactions-Hydrogen bonding, van der Waals forces. Concept of hybridization in inorganic compounds: Definition and explanation of sp, sp², sp³, dsp², hybridization by taking example of [Ni(CN)₄]²⁻, d²sp³ hybridization by taking example PCl₅, sp³d³ hybridization by taking example IF₇. MO theory, homonuclear and heteronuclear (CO and NO) diatomic molecules, multicenter bonding in electron deficient molecules, bond strength and bond energy. *VSEPR Theory*: Postulates, applications in explaining geometry and bond angle in molecules such as CH₄, NH₃, and H₂O. Limitations of VSEPR theory.

Unit III Reaction Mechanism of Organic Molecules

Localised and delocalised bonds, Vander Waals interactions, Inductive & field effects, Charge transfer complexes, Resonance, Hyper-conjugation, Hydrogen bonding Aromaticity. Curved arrow notation, drawing electron movements with arrows, half headed and double headed arrows, homolytic and heterolytic bond breaking. Types of reagents (electrophiles and nucleophiles). Types of organic reactions, energy considerations. Reactive intermediates (carbocations, carbanions, free radicals, carbenes with example). Methods of determination of reaction mechanism (product analysis, intermediates).

Unit IV Gaseous and Liquid States

Gaseous State: Gas Laws, Ideal Gas Equation, Dalton's Law of Partial Pressure, Graham's Law of Diffusion, Postulates of Kinetic Theory of Gases, Kinetic Gas Equation. Deviation from Ideal Behavior: Effect of Temperature and Pressure; Molecular Velocities: Root Mean Square, Average and Most Probable Velocities. Qualitative Discussion on Maxwell's Distribution of Molecular Velocities. Collision Properties: Collision Number, Mean Free Path, Collision Diameter and Collision Frequency. Liquefaction of Gases (based on Joule - Thomson effect); Critical Phenomena: PV Isotherms of Real Gases, Continuity of States, van der Waals Equation, Isotherms of van der Waals Equation, Relationship between Critical Constants and van der Waals Constants. *Liquid State*: Structure of Liquids (a qualitative description), Intermolecular Forces, Structural Differences between Solids, Liquids and Gases. Vapour pressure-Temperature Diagrams

Reference Books

1. Concise Inorganic Chemistry - J. D. Lee
2. Advanced Organic Chemistry – Bahl&Bahl.
3. Physical Chemistry, G. M. Barrow, International Student Edition, McGraw Hill.

CHG-304L	BASIC CHEMISTRY PRACTICAL	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

A. Qualitative Analysis

- i. Qualitative analysis of inorganic mixtures containing three anions and three cations excluding interfering radicals.
- ii. Synthesis of Potash Alum.

B. Organic Chemistry

- i. Checking the calibration of the thermometer.
- ii. Purification of organic compounds by crystallization using the following solvents:
 - a. Water
 - b. Alcohol
 - c. Alcohol-Water
- iii. Effect of impurities on the melting point – mixed melting point of two unknown organic compounds

C. Physical Chemistry

- i. Determination of the viscosity of pure liquids and binary mixtures.
- ii. Determination of the surface tension of pure liquids and binary mixtures.
- iii. Refractive index measurement of pure liquids.
- iv. Determination of Molecular weight of pure liquids by Victor Meyer method.
- v. Solubility curve of benzoic acid in water.

Reference Books

1. Vogel's Text Book of Inorganic Qualitative Analysis, 4 th edition, ELBS, London, 1974.
2. Senior Practical Physical Chemistry by B.D. Khosla, V.C. Garg and AdarshKhosla, R. Chand & Co. Delhi.
3. Experiments in Physical Chemistry, R.C. Das and B. Behra, Tata McGraw Hill.

CHG-402 Paper No: VII-G	ORGANIC CHEMISTRY-II	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I: Alkyl and Aryl Halides

Alkyl Halides Types of Nucleophilic Substitution (SN1, SN2 and SNi) reactions. Preparation: from alkenes and alcohols. Reactions: hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson's ether synthesis: Elimination vs substitution. Aryl Halides Preparation: (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer & Gattermann reactions. Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by -OH group) and effect of nitro substituent. Benzyne Mechanism: KNH₂/NH₃ (or NaNH₂/NH₃). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

Unit II: Alcohols

Alcohols: Preparation: Preparation of 1o, 2o and 3o alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters. Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. KMnO₄, acidic dichromate, conc. HNO₃). Oppenauer oxidation Diols: (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

Unit III: Phenols and Ethers

(Phenol case) Preparation: Cumenehydroperoxide method, from diazonium salts. Reactions: Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer-Tiemann Reaction, Gattermann-Koch Reaction, Houben-Hoesch Condensation, Schotten-Baumann Reaction. Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and LiAlH₄. Cleavage of ethers with HI.

Unit IV: Aldehydes and ketones (aliphatic and aromatic)

Formaldehyde, acetaldehyde, acetone and benzaldehyde) Preparation: from acid chlorides and from nitriles. Reactions – Reaction with HCN, ROH, NaHSO₃, NH₂-G derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemensen reduction and Wolff Kishner reduction. Meerwein-Ponndorf-Verley reduction.

Reference Books:

1. Graham Solomon, T.W., Fryhle, C.B. & Snyder, S.A. Organic Chemistry, John Wiley & Sons (2014).
2. McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013.
3. Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988).
4. Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S.
5. Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010.
Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.
6. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).

CHG-402L	ORGANIC CHEMISTRY PRACTICAL - II	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

1. Purification of organic compounds by crystallization (from water and alcohol) and distillation.
2. Criteria of Purity: Determination of melting and boiling points.
3. Preparations: Mechanism of various reactions involved to be discussed. Recrystallisation, determination of melting point and calculation of quantitative yields to be done.
 - (a) Bromination of Phenol/Aniline
 - (b) Benzoylation of amines/phenols
 - (c) Oxime and 2,4-dinitrophenylhydrazone of aldehyde/ketone

Reference Books

1. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry.
2. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry, Universities Press.

CHG-403 Paper No: VIII- G	PHYSICAL CHEMISTRY-II	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I. Kinetic Theory of Gases

Brief descriptions of Gas laws, Ideal gas equation, Dalton's law of partial pressure and Graham's law of diffusion. Postulates of kinetic theory of gases, Kinetic gas equation. Deviation from ideal behavior: Effect of temperature and pressure. Maxwell's distribution of molecular velocities: Root mean square, Average and Most probable velocities. Collision properties: Collision number, Mean free path, Collision diameter and Collision frequency. Liquefaction of gases. Critical Phenomena: PV isotherms of real gases, van der Waals equation, Isotherms of van der Waals equation, Relationship between critical constants and van der Waals constants, Law of corresponding states, Reduced equation of state.

Unit II. Liquids

Surface tension and its determination using stalagmometer. Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer. Effect of temperature on surface tension and coefficient of viscosity of a liquid.

Unit III. Solids

Crystalline and Amorphous solid, Symmetry of crystal systems, Space lattice and Unit cell, Summary of crystal systems, Applications of crystallographic studies; Packing fraction, Density, Coordination number and Number of atoms in unit cell. Law of rational indices, Inter-planer spacing. X-ray diffraction, Powder method and Bragg's equation. Determination of crystal structure of NaCl using powder method. Defects in crystals.

Unit IV. Chemical Kinetics

Chemical Kinetics and its Scope, Rate of a Reaction, Rate Laws, Rate Constant, Elementary and Complex Reactions, Molecularity, Order of Reactions. Factors Influencing the Rate of Reaction: Concentration, Temperature, Pressure, Catalyst. Mathematical Characteristics of Simple Chemical Reactions - Zero Order, First Order, Second Order, Pseudo Order, and their Half-life Expressions. Determination of Order of Reaction - Differential Method, Method of Integration, Half-life Method and Isolation Method. Activation Energy, Theories of Reaction Rates: Collision Theory of bimolecular reactions, Arrhenius Equation, Absolute Reaction Rate Theory.

Books Recommended:

1. Essentials of Physical Chemistry, B.S. Bahl, G.D. Tuli and Arun Bahl, S. Chand & Company Ltd.
2. A Text Book of Physical Chemistry, A.S. Negi and S.C. Anand, New Age International Publishers.
3. Physical Chemistry, G. M. Barrow, International Student Edition, McGraw Hill.
4. Physical Chemistry, P. W. Atkins, & J. de Paula, 10th Ed., Oxford University Press (2014).

CHG-403L	PHYSICAL CHEMISTRY PRACTICAL -II	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

1. Surface tension measurements.

- c) Determine the surface tension of given solution using drop number method.
- d) Study the variation of surface tension of detergent solutions with concentration.

2. Viscosity measurement using Ostwald's viscometer.

- c) Determination of viscosity of (i) ethanol (ii) amyl alcohol and (iii) aqueous solution of sugar at room temperature.
- d) Study the variation of viscosity of sucrose solution with the concentration of solute.

3. Indexing of a given powder diffraction pattern of a cubic crystalline system.

4. Chemical Kinetics

- a) To determine the order of the reaction between thiosulphate and HCl.
- b) To determine the order of reaction for acid hydrolysis of methyl acetate at room temperature.
- c) To study the effect of acid strength on the hydrolysis of an ester.
- d) To study the kinetics of the saponification of ethyl acetate by integrated rate method.

5. Any other experiment carried out in the class.

Reference Books

1. O.P. Pandey, D.N. Bajpai & S. Giri, Practical Chemistry, S. Chand & Company Ltd.
2. B. D. Khosla, V. C. Garg & A. Gulati, *Senior Practical Physical Chemistry*, S. Chand & Co.: New Delhi (2011).
3. C. W. Garland, J.W. Nibler, & D.P. Shoemaker, *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
4. R.C. Das and B. Behra, *Experiments in Physical Chemistry*,; Tata McGraw Hill.

CHG-404 Paper No: IX-G	GENERAL CHEMISTRY	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I: Atomic Structure and Periodic Classification of Elements

Bohr's atomic model, limitations, Idea of elliptical orbits, Schrödinger wave equation, physical significance of ψ and ψ^2 , probability distribution curves, quantum numbers. Modern periodic law, Periodic Table and periodic properties – atomic/ionic radius, ionization energy, electron affinity and electronegativity, scales of electronegativity.

Unit II: Chemical Bonding and Molecular Structure

Chemical Bonding Overlapping of orbital, homo and heterodiatomic molecules, types of bonds: ionic, covalent, coordinate, Metallic and hydrogen bonding, Valence bond theory of covalent bonding and its limitations, Hybridization and hybrid orbitals, resonance, Born-Haber cycle and lattice energy.

Unit III: Solutions

Types of solutions, normality molarity, molality, mole fraction, Raoult's law, ideal, non-ideal and colloidal solutions, phase rule, phase diagrams of one component systems (water and sulphur); two component systems: partially miscible liquids, consolute solution temperature UCST and LCST.

Unit IV: Acids and bases

Theories of acids and bases- Arrhenius, Bronsted-Lowry, Lewis, solvent and Lux-Flood, Relative strengths of acids and bases-effect of solvent, polarity and dielectric constants, effect of substituents and steric effects of substituents.

Books Suggested:

1. Concise Inorganic Chemistry by J. D. Lee.
2. Inorganic Chemistry by Puri and Sharma
3. Principle of Physical Chemistry by Puri, Sharma and Pathania.

CHG-404L	GENERAL CHEMISTRY PRACTICAL -II	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	03 (100)

1. To prepare standard solution of sodium carbonate and determine the percentage of given NaOH and KOH mixture solution (2.5 g/liter) by using HCl solution.
2. To prepare standard solution of potassium dichromate and find out the strength of given potassium dichromate solution using sodium thiosulphate (hypo solution) as an intermediate.
3. To prepare standard solution of potassium permanganate and find out the strength of given potassium permanganate solution using sodium thiosulphate (hypo solution) as an intermediate.
4. To prepare standard solution of copper(II) sulphate and find out the strength of given copper(II) sulphate solution using sodium thiosulphate (hypo solution) as an intermediate.
5. To determine the viscosity of pure liquids and binary mixtures by Ostwald viscometer.
6. Determination of the surface tension of pure liquids and binary mixtures.
7. Determination of partition coefficient of iodine between water and carbon tetrachloride or toluene or chloroform.
8. Determination of partition coefficient of Benzoic acid between water and toluene.

Books Suggested:

1. Practical Chemistry, OP Pandey, DN Bajpai, S. Giri, S. Chand & Company Ltd., 2008.
2. Senior Practical Physical Chemistry by B.D. Khosla, V.C. Garg and AdarshKhosla – R. Chand & Co. Delhi.

CHG-501 Paper No: X-G	INORGANIC CHEMISTRY- III	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I Transition Elements (*d*-block elements)

Introduction; elements of first transition series; their general properties: electronic configuration, density, melting and boiling point/s, reactivity, ionization energies, variable oxidation states and their stabilities; Colour and magnetic properties, magnetic susceptibility and its measurement.

Unit II Inner Transition Elements (*f* block elements)

Introduction; Lanthanides series: electronic configuration, their oxidation states, extraction of lanthanides, colour & electronic spectra, magnetic properties, lanthanide contraction.

Unit III Coordination Chemistry

Double salts and coordination compounds; structures of coordination compounds; Werner's work; ligands and their classification; IUPAC nomenclature; isomerism: structural and stereo (with special reference to coordination number 4 & 6),

Unit IV Theories of Metal-Ligand bonding (M-L Bonding)

Shapes and energies of *d*-orbitals, Valence bond theory (inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu) and drawbacks of VBT; Crystal field theory and Molecular orbital theory for *Oh* complexes; CFSE and calculation of CFSE, strength of ligands, spectrochemical series; factors affecting the magnitude of CFSE; Complexes of coordination numbers 4 & 6 (inner & outer orbital complexes), octahedral effects of Crystal field splitting, comparison of CFSE for *Oh* and *Td* complexes, tetragonal distortion (Jahn –Teller distortion).

Books Suggested

1. Concise Inorganic Chemistry by J.D. Lee.
2. Inorganic Chemistry by W.W. Portfield.
3. Inorganic Chemistry by D.E. Shriver, P.W. Atkins and C.H. Longford.
4. Inorganic Chemistry by A.G. Sharpe.
5. Basic Inorganic Chemistry by F.A. Cotton, G. Wilkinson & P.L. Gaus.

CHG-501L	INORGANIC CHEMISTRY- PRACTICAL III	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

A. Synthesis and calculation of percentage yield of the following:

- i. Ni-DMG Complex $[\text{Ni}(\text{DMG})_2]$.
- ii. Cis and Trans potassiumbisoxalatodiaquachromate(III).
- iii. Tetraamminecopper(II)sulphate, $[\text{Cu}(\text{NH}_3)_4]\text{SO}_4$.
- iv. Potassium tris(oxalato)ferrate(III).
- v. Acetylacetonato complexes of $\text{Cu}^{2+}/\text{Fe}^{3+}$ and find the λ_{max} of these complexes.

B. Gravimetric Analysis:

- i. Determination of Al as Aluminium 8-dehydroxyquinolate
- ii. Determination of SO_4^{2-} ion as barium sulphate.
- iii. Determination of aluminium as aluminum oxide.

Books Suggested:

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis 6th Ed.*, Pearson, 2009.
2. Marr & Rockett *Practical Inorganic Chemistry*. John Wiley & Sons 1972.

CHG-502 Paper No: XI-G	ORGANIC CHEMISTRY-III	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I: Carboxylic acids and their derivatives

Carboxylic acids (aliphatic and aromatic) Preparation: Acidic and Alkaline hydrolysis of esters. Reactions: Hell – Vohlard - Zelinsky Reaction. Preparation: Acid chlorides, Anhydrides, Esters and Amides from acids and their interconversion. Reactions: Comparative study of nucleophilicity of acyl derivatives. Reformatsky Reaction, Perkin condensation.

Unit II: Amino Acids, Peptides and Proteins

Preparation of Amino Acids: Strecker synthesis using Gabriel's phthalimide synthesis. Zwitterion, Isoelectric point and Electrophoresis. Reactions of Amino acids: ester of – COOH group, acetylation of –NH₂ group, complexation with Cu²⁺ ions, ninhydrin test. Overview of Primary, Secondary, Tertiary and Quaternary Structure of proteins. Determination of Primary structure of Peptides by degradation Edmann degradation (N-terminal) and C-terminal (thiohydantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (upto dipeptides) by N-protection (tbutyloxycarbonyl and phthaloyl) & C-activating groups and Merrifield solid-phase synthesis.

Unit III: Carbohydrates

Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disaccharides (sucrose, cellobiose, maltose, lactose) and polysaccharides (starch and cellulose) excluding their structure elucidation.

Unit IV: Amines and Diazonium Salts

Amines (Aliphatic and Aromatic): (Upto 5 carbons) Preparation: from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann Bromamide reaction. Reactions: Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, with HNO₂, Schotten –Baumann Reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation. Diazonium salts: Preparation: from aromatic amines. Reactions: conversion to benzene, phenol, dyes.

Reference Books

1. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Finar, I. L. Organic Chemistry (Volume 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Nelson, D. L. & Cox, M. M. Lehninger's Principles of Biochemistry 7th Ed., W. H. Freeman.
5. Berg, J.M., Tymoczko, J.L. & Stryer, L. Biochemistry, W.H. Freeman, 2002

CHG-502L	ORGANIC CHEMISTRY PRACTICAL -III	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

Section I

1. Systematic Qualitative Organic Analysis of Organic Compounds possessing monofunctional groups (-COOH, phenolic, aldehydic, ketonic, amide, nitro, amines) and preparation of one derivative.

Section II.

1. Separation of amino acids by paper chromatography
2. Determination of the concentration of glycine solution by formylation method.
3. Titration curve of glycine
4. Action of salivary amylase on starch
5. Effect of temperature on the action of salivary amylase on starch.
6. Differentiation between a reducing and a nonreducing sugar

Reference Books

1. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996.
2. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.
3. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry, Universities Press

CHG-504 Paper No: XII- G	POLYMER CHEMISTRY	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit-I Introduction and History of Polymeric Materials

Introduction to concepts and classification of polymers; a brief history of polymers, definitions and terms used in polymer literature; polymers nomenclature; importance of synthetic polymers; classification of polymers on the basis of molecular structure, thermal properties, chain configuration, methods of polymerization and applications

Unit-II Synthesis of Polymers

Characteristics of step growth and chain growth polymerization; mechanism of free radical polymerization ionic and step growth polymerizations; copolymers; types of copolymers; copolymer structure and monomer reactivity ratios; copolymer equation and its significance.

Unit-III Molecular weights and mechanical properties of polymers

Basic principles of polymer molecular weight- number average molecular weight; weight average molecular weight; viscosity average molecular weight; molecular weight distribution curve; technique for measurements of molecular weights
Thermal transition in polymers; crystallization of polymers; degree of crystallinity; amorphous polymers; glass transition temperature (tg); measurements of tgs.

Unit-IV Commercial polymers

Preparation, properties and application of thermoplastic polymers and thermoset polymers; polyethylene; polypropylene, polystyrene polystyrene, poly(vinyl chloride); polyacrylamide; polyurethane; polyesters; alkyd resins; phenol-formaldehyde; polyamides and polysiloxanes; Additives used in plastic manufacture.

Reference Books

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.

CHG-504L	POLYMER CHEMISTRY PRACTICAL	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

1. Polymer synthesis

- 1.1 To prepare polystyrene by bulk polymerization and report the yield and solubility of the prepared polymer
- 1.2 To prepare polyvinylacetate by solution polymerization and convert polyvinylacetate to polyvinyl alcohol by alkaline hydrolysis.
- 1.3 To prepare copolymers of styrene and methyl methacrylate. Report the yield and solubility.
- 1.4 To synthesize Novolac and resole resins

2. Polymer analysis

- 2.1 To determine the viscosity average molecular weight of the polymers prepared in experiments 1.1 and 1.2 by using ubbelohde viscometer.
- 2.2 To determine the hydroxyl number of polyvinylalcohol by colorimetric method.

3. Polymer characterization

- 3.1 To determine the tensile strength of the polymers prepared.
- 3.2 To study the IR spectra of the polymers

Reference Books

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)

CHG-603 Paper No: XIII- G	PHYSICAL CHEMISTRY -III	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I. Chemical Energetics

Review of thermodynamics and the Laws of Thermodynamics. Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature– Kirchoff's equation.

Statement of Third Law of thermodynamics and calculation of absolute entropies of substances.

Unit II. Chemical Equilibrium

Reversible and irreversible reactions, Characteristics of chemical equilibrium, Formulation of equilibrium law, equilibrium law for ideal gases, relation between K_p and K_c and K_x . Reaction quotient, factors affecting the equilibrium constant. Equilibrium between gases and solids, equilibrium constant for a system of real gases, equilibrium constant of reactions in solution. Thermodynamic treatment of equilibrium constant. Variation of equilibrium constant with temperature, pressure and concentration, effect of inert gas on reaction equilibrium, Le – Chatelier's principle.

Unit III. Ionic Equilibria

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization. Acid-base concept. Dissociation constants of weak acids and weak bases. Ionization constant and Ionic product of water. The pH scale, Buffer solutions, Calculations of pH values of buffer mixtures, Derivation of Henderson equation and its applications, buffer capacity and buffer action. Salt hydrolysis, Determination of hydrolysis constant, degree of hydrolysis and pH for different salts. Relation between K_h , K_a and K_b . Solubility and solubility product of sparingly soluble salts – Applications of solubility product principle and Common ion effect.

Unit IV. Photochemistry

Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients. Laws of photochemistry, quantum yield, actinometry, examples of low and high quantum yields, differential rate law of photochemical reactions, photosensitized reactions, quenching.

Books Recommended:

1. Essentials of Physical Chemistry, B.S. Bahl, G.D. Tuli and Arun Bahl, S. Chand & Company Ltd.
2. A Text Book of Physical Chemistry, A.S. Negi and S.C. Anand, New Age International Publishers.
3. Physical Chemistry, G. M. Barrow, International Student Edition, McGraw Hill.
4. Physical Chemistry through Problems, S. K. Dogra and S. Dogra Wiley Eastern Ltd.
5. Physical Chemistry, P. W. Atkins, & J. de Paula, 10th Ed., Oxford University Press (2014).

CHG-603L	PHYSICAL CHEMISTRY PRACTICAL -III	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

1. Determination of the heat capacity of a calorimeter.
2. Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) of solution of salts.
3. To determine the enthalpy of neutralization of a weak acid / weak base versus strong base/ strong acid and determine the enthalpy of ionisation of the weak acid / weak base.
4. To determine the enthalpy of hydration of CuSO_4 .
5. pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.
6. Determination of dissociation constant of a weak acid.
7. To verify Beer-Lambert law for KMnO_4 / $\text{K}_2\text{Cr}_2\text{O}_7$ and determine the concentration of the given substance.
8. **Any other experiment carried out in the class.**

Reference Books

1. O.P. Pandey, D.N. Bajpai & S. Giri, Practical Chemistry, S. Chand & Company Ltd.
2. B. D. Khosla, V. C. Garg & A. Gulati, *Senior Practical Physical Chemistry*, S.Chand & Co.: New Delhi (2011).
3. C. W. Garland, J.W. Nibler, & D.P. Shoemaker, *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
4. A.M. Halpern & G.C. McBane, *Experimental Physical Chemistry 3rd Ed.*; W.H. Freeman & Co.: New York (2003).

CHG-604 Paper No: XIV- G	GREEN CHEMISTRY	Theory (Marks)		Total Credits
		U.E (75)	I.A (25)	03 (100)

Unit I: Introduction to Green Chemistry

What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.

Unit II: Principles of Green Chemistry and Designing a Chemical synthesis

Twelve principles of Green Chemistry with their explanations and examples, Green solvents – supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorinated biphasic solvent, PEG, solventless processes, immobilized solvents and how to compare greenness of solvents. Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy. Selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups. Catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis. Prevention of chemical accidents designing greener processes, inherent safer design, principle of ISD “What you don’t have cannot harm you”, greener alternative to Bhopal Gas Tragedy (safer route to carbonyl) and Flixborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation.

Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

Unit III: Examples of Green Synthesis/ Reactions and some real world cases

Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis). Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave assisted reactions in organic solvents Diels-Alder reaction and Decarboxylation reaction. Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine). Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO₂ for precision cleaning and dry cleaning of garments. Designing of Environmentally safe marine antifoulant. Rightfit pigment: synthetic azopigments to replace toxic organic and inorganic pigments. An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn. Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of no Trans-Fats and Oils. Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting.

Unit IV: Future Trends in Green Chemistry

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; co crystal controlled solid state synthesis (C²S³); Green chemistry in sustainable development.

Reference Books

1. Ahluwalia, V.K. & Kidwai, M.R. *New Trends in Green Chemistry*, Anamalaya Publishers (2005).
2. Anastas, P.T. & Warner, J.K.: *Green Chemistry - Theory and Practical*, Oxford University Press (1998).
3. Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
4. Cann, M.C. & Connely, M.E. *Real-World cases in Green Chemistry*, American Chemical Society, Washington (2000).
5. Ryan, M.A. & Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, Washington (2002).
6. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.

CHG-604L	GREEN CHEMISTRY PRACTICAL	Theory (Marks)		Total Credits
		U.E (25)	I.A (25)	01 (50)

- Using renewable resources
Preparation of biodiesel from vegetable/ waste cooking oil.
- Use of enzymes as catalysts
Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide.
- Alternative Green solvents
 - Extraction of D-limonene from orange peel using liquid CO₂ prepared from dry ice.
 - Mechanochemical solvent free synthesis of azomethines
- Alternative sources of energy
Photoreduction of benzophenone to benzopinacol in the presence of sunlight.
- Avoiding waste
Synthesis of Tris(acetylacetonato)manganese(III) without the use of any buffer.

Reference Books:

- Anastas, P.T & Warner, J.C. Green Chemistry: Theory and Practice, Oxford University Press (1998).
- Kirchoff, M. & Ryan, M.A. Greener approaches to undergraduate chemistry experiment. American Chemical Society, Washington DC (2002).
- Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. I.K. Green Chemistry Experiment: A monograph International Publishing House Pvt Ltd. New Delhi. Bangalore ISBN 978-93-81141-55-7 (2013).
- Cann, M.C. & Connelly, M. E., Real world cases in Green Chemistry, American Chemical Society (2008).