Syllabus and Scheme of Examination
For
B.Sc. (Honors) and B.Sc. (General) with Chemistry

University of Kalyani

West Bengal

Under
Choice Based Credit System

December, 2017

Prepared by
UGBOS (Chemistry)

Preamble

In response to the notification (No.FCUG/KU-914/17-18 dt 16.11.2017) of University of Kalyani, the Undergraduate Board of Studies in Chemistry of University of Kalyani has revised and modified syllabi of **B.Sc. (Honors) with Chemistry** and **Chemistry courses for B.Sc. (General)** under Semester and CBCS (Choice Based Credit System) scheme following the recommendations and Guidelines of UGC (University Grant Commission) and WBHEC (West Bengal Higher Education Council). Content, structure and date of effect of this proposed syllabus will be decided by the appropriate authority of University of Kalyani after acceptance and approval.

The objectives and overview of the requirements have been stated by the WBHEC in the Introduction of their proposed draft syllabus which has been reiterated below

"The main objective of framing this new syllabus is to give the students a holistic understanding of the subject giving substantial weightage to both the core content and techniques used in Chemistry. The syllabus has given equal importance to the three main branches of Chemistry – Physical, Inorganic and Organic.

The ultimate goal of the syllabus is that the students at the end are able to secure a job. Keeping in mind and in tune with the changing nature of the subject, adequate emphasis has been given on new techniques and understanding of the subject.

Each University should take necessary measure to ensure that affiliated college or department must have the following facilities: UV-VIS Spectrophotometer with printer, FT-IR Spectrophotometer with printer, Internet facility and requisite number of computers. Also, for proper maintenance of above mentioned facilities, clean & dry AC rooms are mandatory.

It is essential that Chemistry students select their general electives courses from Physics, Mathematics and/or any branch of Life Sciences disciplines.

Also, to maintain equal importance of all three major sections of Chemistry, it is recommended that elective course "Advanced Physical Chemistry" may be made compulsory and students are free to select any three out of remaining five recommended elective

courses.

Project Work followed by a power point presentation may be introduced instead of the 4^{th} Elective with a credit of 6 split into 2+4, where 2 credits will be for continuous evaluation and 4 credits reserved for the merit of the dissertation."

Introduction

The new syllabus as stated in Preamble has been delineated in 7 sections. Course wise credit distributions are given in Section 1 and Section 5 for B.Sc(Honors) and B.Sc. (General) respectively in tabular form. Semester wise CBCS curricula, assignment of specific course names for Chemistry, credit in each course and choices of subjects are given in tabular form in Section 2 and Section 6 for B.Sc (Honors) and B.Sc. (General) respectively.

There are 14 Core courses distributed over six semesters of B.Sc. (Honors) with Chemistry. Each Core course consists of theory and practical components. Core courses have been named as CHEMHT- N (N= 1 to 14) for theory and CHEMHP-N (N=1 to 14) for practical. All these courses are compulsory for B.Sc. (Honors) with Chemistry.

There are 4 courses for "Skill Enhancement" from which candidates have to **choose** two, one out of two in Semester – I (CHEMHS-1A or CHEMHS-1B) and another (CHEMHS-2A or CHEMHS-2B) from the other two.

Candidates have to choose 4 courses out of 6 under "Discipline Specific Elective (DSE)" papers. The choices and names are given in tabular form in Section 2. One course under DSE has been assigned as project work following the suggestion of WBHEC.

Students of B.Sc. (Honors) have to choose 4 "Generic Elective (GE)" papers from two science subjects (Physics, Mathematics and any branch of Life Science) other than Chemistry. *E.g.*, if a student chooses Physics and Math then he/she have to choose 2 GE papers from Physics and 2 from Math.

Details of all the Chemistry courses are given in Section 3 and Section 7 for B.Sc(Honors) and B.Sc.(General) respectively.

The choices under GE courses for B.Sc. (Honors) with subjects other than Chemistry have been given in Section 4.

Syllabus and Scheme of Examination For B.Sc. (Honors) with Chemistry

1. Course wise Credit Distribution in B.Sc. (Honors)

Course	Total no of Papers	Credit			
		Theory		Practical	
		Per paper	Total	Per paper	Total
Core Courses	14	4	4 x 14=56	2	2x14=28
Discipline Specific Elective	4	4	4x4=16	2	2x4=8
Generic Elective	4	4	4x4=16	2	2x4=8
Ability Enhancement (Language)	2	2	2x2 = 4	-	-
Skill Enhancement	2	2	2x2 = 4	-	-
Total	26	NA	96	NA	44

2. Semester wise CBCS curricula (Courses, course names, broad area, credit and marks) for B.Sc. (Honors) with Chemistry

Semester	Course	Course Name	Broad area	Credit
I	Core Course-1 (Theory)	CHEMHT-1	Inorganic-1A + Physical – 1A	4
	Core Course-1 (Practical)	CHEMHP-1	Inorganic-1A + Physical – 1A	2
	Core Course-2 (Theory)	CHEMHT-2	Organic - 1	4
	Core Course-2 (Practical)	CHEMHP-2	Organic - 1	2
	Generic Elective-1 (Theory) *	TBD	TBD	4
	Generic Elective-1 (Practical)	TBD	TBD	2
	Ability Enhancement Compulsory Course - 1	TBD	English communication / Environmental Science	2
II	Core Course-3 (Theory)	CHEMHT-3	Inorganic-1B + Physical – 1B	4
	Core Course-3 (Practical)	CHEMHP-3	Inorganic-1B + Physical – 1B	2
	Core Course-4 (Theory)	CHEMHT-4	Organic - II	4
	Core Course-4 (Practical)	CHEMHP-4	Organic - II	2
	Generic Elective-2 (Theory)	TBD	TBD	4
	Generic Elective-2 (Practical)	TBD	TBD	2
	Ability Enhancement Compulsory Course - 2	TBD	English communication / Environmental Science	2
III	Core Course-5 (Theory)	CHEMHT-5	Physical – II	4
	Core Course-5 (Practical)	CHEMHP-5	Physical – II	2
	Core Course-6 (Theory)	CHEMHT-6	Inorganic - II	4
	Core Course-6 (Practical)	CHEMHP-6	Inorganic - II	2
	Core Course-7	CHEMHT-7	Organic-III	4

	(Theory)			
	Core Course-7 (Practical)	CHEMHP-7	Organic-III	2
	Generic Elective-3 (Theory)	TBD	TBD	4
	Generic Elective-3 (Practical)	TBD	TBD	2
	Skill Enhancement Course – 1 (Any one from this group)	CHEMHS – 1A	IT skills for Chemist	2
		CHEMHS-1B	Basic Analytical Chemistry	2
IV	Core Course-8 (Theory)	CHEMHT-8	Physical – III	4
	Core Course-8 (Practical)	CHEMHP-8	Physical – III	2
	Core Course-9 (Theory)	CHEMHT-9	Inorganic - III	4
	Core Course-9 (Practical)	CHEMHP-9	Inorganic - III	2
	Core Course-10 (Theory)	CHEMHT-10	Organic-IV	4
	Core Course-10 (Practical)	CHEMHP-10	Organic-IV	2
	Generic Elective-4 (Theory)	TBD	TBD	4
	Generic Elective-4 (Practical)	TBD	TBD	2
	Skill Enhancement Course – 2 (Any one from this group)	CHEMHS – 2A	Pharmaceutical Chemistry	2
		CHEMHS - 2B	Analytical clinical Biochemistry	2
V	Core Course-11 (Theory)	CHEMHT-11	Inorganic - IV	4
	Core Course-11 (Practical)	CHEMHP-11	Inorganic - IV	2
	Core Course-12 (Theory)	CHEMHT-12	Physical-IV	4
	Core Course-12 (Practical)	CHEMHP-12	Physical - IV	2
	Discipline Specific Elective-1 (Theory) (Any one from this group)	CHEMHTDSE-1A	Polymer Chemistry	4
		CHEMHTDSE-1B	Inorganic Materials of Industrial Importance	
	Discipline Specific Elective-1 (Practicals	CHEMHPDSE-1A	Polymer Chemistry	2

	of DSE-1. Either of the two that corresponds to the theory chosen)			
		CHEMHPDSE-1B	Inorganic Materials of Industrial Importance	
	Discipline Specific Elective-2 (Theory) (Any one from this group)	CHEMHTDSE-2A	Analytical Methods in Chemistry	4
		CHEMHTDSE-2B	Instrumental Methods of Chemical Analysis	
		CHEMHTDSE-2C	Green Chemistry	
	Discipline Specific Elective- 2 (Practical) (Any one, that corresponds to the theory, from this group)	CHEMHPDSE-2A	Analytical Methods in Chemistry	2
		CHEMHPDSE-2B	Instrumental Methods of Chemical Analysis	
		CHEMHPDSE-2C	Green Chemistry	
VI	Core Course-13 (Theory)	CHEMHT-13	Inorganic - V	4
	Core Course-13 (Practical)	CHEMHP-13	Inorganic - V	2
	Core Course-14 (Theory)	CHEMHT-14	Organic-V	4
	Core Course-14 (Practical)	CHEMHP-14	Organic - V	2
	Discipline Specific Elective-3 (Theory)	CHEMHTDSE-3	Advanced Physical Chemistry	4
	Discipline Specific Elective- 3(Practical)	CHEMHPDSE-3	Advanced Physical Chemistry	2
	Discipline Specific Elective-4 (Theory)	CHEMHTDSE-4	Dissertation	4
	Discipline Specific Elective- 4 (Practical)	CHEMHPDSE-4	Project work Presentation (Power point)	2

***** B.Sc. (Honors) with Chemistry students should select their general electives courses from Physics, Mathematics and any branch of Life Sciences disciplines.

3. Chemistry Syllabus of B.Sc.(Honors) with Chemistry

Semester - I

CHEMHT-1	Theory: Extra nuclear structure of atom, Periodic properties, Kinetic Theory and Gaseous state, Chemical Thermodynamics - I	4 Credit

Inorganic Chemistry – IA

1. **Extra nuclear Structure of atom:** **(16L)**
   Bohr's model and atomic spectrum of hydrogen, Limitations of Bohr's model and Sommerfeld's modifications, de Broglie's concept, Heisenberg's uncertainty principle and its significance, Time independent Schrödinger's wave equation (without application and solution detail), Significance of ψ and ψ^2, Radial and angular wave functions for hydrogen atom (qualitative idea), radial probability distribution curves, shapes of s, p, d and f orbitals (qualitative idea), Quantum numbers and their significance, Pauli's exclusion principle, aufbau principle and limitations, Hund's rules, exchange energy, Electronic configurations of atoms. Elementary idea of microstates.
2. **Periodic properties :** **(14L)**
   Modern IUPAC periodic table and classification of elements in the table; Effective nuclear charge and its calculation using Slater's rules; Atomic radii, Ionic radii and Pauling's method for determining univalent ionic radii; Electronegativity (Pauling's, Mulliken's, Allred-Rochow's and Sanderson's scales) and its applications, Ionization energy, Electron affinity and factors influencing these properties; Group trends and periodic trends of these properties with reference to s, p and d-block elements. Secondary periodicity; Inert pair effect.

Reference Books:

1. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991. 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)

Physical Chemistry - IA

1. **Kinetic Theory and Gaseous state** **18 L**
   Kinetic Theory of gases: Concept of pressure and temperature; Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules).
   Maxwell's distribution of speed and energy: 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; Calculation of number

of molecules having energy ≥ ε, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases.

Real gas and virial equation: 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 behaviour, other equations of state (Berthelot, Dietrici); Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; virial equation of state; van der Waals equation expressed in virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard - Jones potential - elementary idea).

2. Chemical Thermodynamics - I **12 L**

Zeroth and 1st law of Thermodynamics: Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics; Concept of heat, work, internal energy and statement of first law; enthalpy, H; relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions; Joule's experiment and its consequence.

Thermochemistry: Standard states; Heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; Laws of thermochemistry; bond energy, bond dissociation energy and resonance energy from thermochemical data, Kirchhoff's equations and effect of pressure on enthalpy of reactions.

Reference Books

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa.3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.4. Engel, T. & Reid, P. Physical Chemistry, Pearson. 5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 6. Maron, S. & Prutton Physical Chemistry. 7. Ball, D. W. Physical Chemistry, Thomson Press. 8. Mortimer, R. G. Physical Chemistry, Elsevier. 9. Laidler, K. J. Chemical Kinetics, Pearson. 10. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry. 11. Rakshit, P.C., Physical Chemistry Sarat Book House. 12. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill. 13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas. 14. Clauze & Rosenberg, Chemical Thermodynamics

CHEMHP-1	**Practical :**	**2 Credit**

Inorganic Chemistry – IA

i. Method of preparation of standard solutions of titrants
ii. Estimation of carbonate and hydroxide present together in a mixture
iii. Estimation of carbonate and bicarbonate present together in a mixture

Reference Book

Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

Physical Chemistry - IA

i. Determination of pH of unknown solution (buffer), by color matching method.
ii. Determination of heat of neutralization of a strong acid by a strong base.
iii. Determination of heat of solute ion of oxalic acid from solubility measurement.

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.

CHEMHT-2	**Theory: Basics of Organic Chemistry, Bonding and Physical Properties, General Treatment of Reaction Mechanism and Stereochemistry**	**4 Credit**

Organic Chemistry – I

1. Bonding and Physical Properties: (18L)

Valence Bond Theory:

Concept of hybridisation, shapes of molecules, resonance (including hyperconjugation); calculation of formal charges and double bond equivalent (DBE); orbital pictures of bonding (sp^3, sp^2, sp: C-C, C-N & C-O systems and s-cis and s-trans geometry for suitable cases).

Electronic displacements:

Inductive effect, field effect, mesomeric effect, resonance energy; bond polarization and bond polarizability; electromeric effect; steric effect, steric inhibition of resonance.

MO theory:

Qualitative idea about molecular orbitals, bonding and antibonding interactions, idea about σ, σ*, π, π*, n – MOs; basic idea about Frontier MOs (FMO); concept of HOMO, LUMO and SOMO; interpretation of chemical reactivity in terms of FMO interactions; sketch and energy levels of π MOs of i) acyclic p orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems), ii) cyclic p orbital system (neutral systems: [4], [6]-annulenes; charged systems: 3-, 4-, 5-membered ring systems); Hückel's rules for aromaticity up to [10]-annulene (including mononuclear heterocyclic compounds up to 6-membered ring); concept of antiaromaticity and homoaromaticity; non-aromatic molecules; Frost diagram; elementary idea about α and β; measurement of delocalization energies in terms of β for buta-1,3-diene, cyclobutadiene, hexa-1,3,5-triene and benzene.

Physical properties:

Influence of hybridization on bond properties: bond dissociation energy (BDE) and bond energy; bond distances, bond angles; concept of bond angle strain (Baeyer's strain theory); melting point/boiling point and solubility of common organic compounds in terms of covalent & non-covalent intermolecular forces; polarity of molecules and dipole moments; relative stabilities of isomeric hydrocarbons in terms of heat of hydrogenation, heat of combustion and heat of formation.

2. General Treatment of Reaction Mechanism – I : (24L)

Mechanistic classification:

Ionic, radical and pericyclic (definition and example); reaction type: addition, elimination and substitution reactions (definition and example); nature of bond cleavage and bond formation: homolytic and heterolytic bond fission, homogenic

and heterogenic bond formation; curly arrow rules in representation of mechanistic steps; reagent type: electrophiles and nucleophiles (elementary idea); electrophilicity and nucleophilicity in terms of FMO approach.

Reactive intermediates:
Carbocations (carbenium and carbonium ions), carbanions, carbon radicals, carbenes, benzyne, nitrenes: generation and stability, structure using orbital picture and electrophilic/nucleophilic behavior of reactive intermediates (elementary idea).

3. **Stereochemistry-I : (18L)**

Bonding geometries of carbon compounds and representation of molecules:
Tetrahedral nature of carbon and concept of asymmetry; Fischer, sawhorse, flying-wedge and Newman projection formulae and their inter translations.

Concept of chirality and symmetry:
Symmetry elements and point groups (C_{nh}, C_{nv}, C_n, D_{nh}, D_{nd}, D_n, S_n (C_s, C_i); molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of epimers; concept of stereogenicity, chirotopicity and pseudoasymmetry; chiral centres and number of stereoisomerism: systems involving 1/2/3-chiral centre(s) (AA, AB, ABA and ABC types).

Relative and absolute configuration:
D/L and R/S descriptors; erythro/threo and meso nomenclature of compounds; syn/anti nomenclatures for aldols; E/Z descriptors for C=C, conjugated diene, triene, C=N and N=N systems; combination of R/S- and E/Z- isomerisms.

Optical activity of chiral compounds:
Optical rotation, specific rotation and molar rotation; racemic compounds, racemisation (through cationic, anionic, radical intermediates and through reversible formation of stable achiral intermediates); resolution of acids, bases and alcohols via diastereomeric salt formation; optical purity and enantiomeric excess; invertomerism of chiral trialkylamines.

Reference Books:
1.Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012. 2. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited. 3. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited. 4. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). 5. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education). 6. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009. 7. Eames, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003. 8. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.

CHEMHP-2	Practical :	2 Credit

Organic Chemistry – I

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. **Determination of boiling point:**
   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]
3. **Identification of a Pure Organic Compound by chemical test(s):**
   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. Bhattacharyya, R. C, A Manual of Practical Chemistry. 2. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors. 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).

Semester – II

CHEMHT-3	**Theory: Redox reactions and Precipitation reactions, Acid-Base Concepts and Solvents, Chemical Thermodynamics – II, Chemical kinetics**	**4 Credit**

Inorganic Chemistry – IB

a) **Redox Reactions and precipitation reactions :** **(15L)**
Qualitative idea about complimentary, noncomplimentary, disproportionation and comproportionation reactions, standard redox potentials with sign conventions, Electrochemical series and its application to explore the feasibility of reactions and equilibrium constants, Nernst equation; effect of pH, complexation and precipitation on redox potentials, formal potential; Basis of redox titration and redox indicators, Redox potential diagrams (Latimer and Frost) of common elements and their applications.
Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulphides, carbonates, sulphates and halides.

b) **Acid-Base Concepts and Solvents :** **(15L)**
Recapitulation of Arrhenius concept, Bronsted-Lowry concept, Solvent system concept (in H_2O, liq. NH_3, liq. SO_2 and liq. HF), Lux-Flood concept, Lewis concept, Drago-Wayland equation, Solvent levelling and differentiating effects, Relative strength of different acids and bases, Pauling's rules, Hammett acidity function and super acids, HSAB principle and its applications, Acid-base equilibria in aqueous solution, pH, Buffer, Acid-base neutralization curves and choice of indicators. Gas phase acidity.

Reference Books:

1. Lee, J. D. Concise Inorganic Chemistry ELBS, 1991. 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)

Physical Chemistry – IB

1. Chemical Thermodynamics - II **12 L**

Second Law: Need for a Second law; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; 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; Entropy change of systems and surroundings for various processes and transformations; Entropy and unavailable work; Auxiliary state functions (G and A) and their variation with T, P and V. Criteria for spontaneity and equilibrium.

Thermodynamic relations: Maxwell's relations; Gibbs-Helmholtz equation, Joule-Thomson experiment and its consequences; inversion temperature; Joule-Thomson coefficient for a van der Waals gas; General heat capacity relations.

2. Chemical kinetics **18 L**

Rate law, order and molecularity: Introduction of rate law, Extent of reaction; rate constants, order; Forms of rates of First, second and nth order reactions; Pseudo first order reactions (example using acid catalyzed hydrolysis of methyl acetate); Determination of order of a reaction by half -life and differential method; Opposing reactions, consecutive reactions and parallel reactions (with explanation of kinetic and thermodynamic control of products; all steps first order).

Role of Temperature 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.

Reference Books

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa.3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.4. Engel, T. & Reid, P. Physical Chemistry, Pearson. 5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 6. Maron, S. & Prutton Physical Chemistry. 7. Ball, D. W. Physical Chemistry, Thomson Press. 8. Mortimer, R. G. Physical Chemistry, Elsevier. 9. Laidler, K. J. Chemical Kinetics, Pearson. 10. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry. 11. Rakshit, P.C., Physical Chemistry Sarat Book House. 12. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill. 13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas. 14. Clauze & Rosenberg, Chemical Thermodynamics

CHEMHP-3	Practical	2 Credit

Inorganic Chemistry – IB

i. Estimation of Fe(II) using $K_2Cr_2O_7$ solution
ii. Estimation of Fe(III) using $K_2Cr_2O_7$ and $KMnO_4$ solution
iii. Estimation of Ca^{2+} using $KMnO_4$ solution
iv. Estimation of Cu^{2+} iodometrically
v. Estimation of Cr^{3+} using $K_2Cr_2O_7$ solution

Reference Book

Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

Physical Chemistry – IB

i. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate.
ii. Study of kinetics of decomposition of H_2O_2.

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.Ltd.

CHEMHT-4	Theory: Stereochemistry, General Treatment of Reaction Mechanism, Substitution and Elimination Reactions	4 Credit

Organic Chemistry – II

1. **Stereochemistry-II:** **(14L)**

Chirality arising out of stereoaxis:

Stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in allenes, spiro compounds, alkylidenecycloalkanes and biphenyls; related configurational descriptors (R_a/S_a and P/M); atropisomerism; racemisation of chiral biphenyls; buttressing effect.

Concept of prostereoisomerism:

Prostereogenic centre; 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 propseudoasymmetric 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).

2. **General Treatment of Reaction Mechanism II :** **(18L)**

Reaction thermodynamics:

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

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.

Reaction kinetics:

Rate constant and free energy of activation; concept of order and molecularity; free energy profiles for one-step, two-step and three-step reactions; catalyzed reactions: electrophilic and nucleophilic catalysis; kinetic control and thermodynamic control of reactions; isotope effect: primary and secondary kinetic isotopic effect (k_H/k_D); principle of microscopic reversibility; Hammond's postulate.

3. **Substitution and Elimination Reactions: (28L)**

Free-radical substitution reaction:

Halogentaion of alkanes, mechanism (with evidence) and stereochemical features; reactivity-selectivity principle in the light of Hammond's postulate.

Nucleophilic substitution reactions:

Substitution at sp^3 centre: 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 ambident nucleophiles, cyanide & nitrite); substitutions involving NGP; role of crown ethers and phase transfer catalysts; [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides]. Concept of aliphatic electrophilic substitution reactions (S_E1, S_E2, S_Ei).

Elimination reactions:

E1, E2, E1cb and E_i (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. Eames, 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. 14. March, J. Advanced Organic Chemistry, Fourth edition, Wiley.

CHEMHP-4	Practical :	2 Credit

Organic Chemistry – II

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 noted.

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.

Semester – III

CHEMHT-5	Theory: Transport processes, Applications of Thermodynamics – I, Foundation of Quantum Mechanics,	4 Credit

Physical Chemistry – II

1. Transport processes **20 L**

Viscosity: General features of fluid flow (streamline flow and turbulent flow); Newton's equation, viscosity coefficient; Poiseuille's equation; Principle of determination of viscosity coefficient of liquids by falling sphere method; Temperature variation of viscosity of liquids and comparison with that of gases.

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.

Transport number, Principles of Hittorf's and Moving-boundary method.

2. Applications of Thermodynamics –I 20 L

Partial properties and chemical potential: Chemical potential and activity, partial molar quantities, relation between chemical potential and Gibb's free energy and other thermodynamic state functions; variation of chemical potential (μ) with temperature and pressure; Gibbs-Duhem equation; fugacity and fugacity coefficient; Variation of thermodynamic functions for systems with variable composition; Equations of states for these systems, Change in G, S H and V during mixing for binary solutions.

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; Definitions of K_P, K_C and K_X; Van't Hoff's reaction isobar and isochore from different standard states; Shifting of equilibrium due to change in external parameters e.g. temperature and pressure; variation of equilibrium constant with addition to inert gas; Le Chatelier's principle.

Nernst's distribution law; Application-(finding out Keq using Nernst distribution law for $KI+I_2 = KI_3$ and dimerization of benzene.

Chemical potential and other properties of ideal substances-pure and mixtures:

Pure ideal gas: Its chemical potential and other thermodynamic functions and their changes during a change of thermodynamic parameters of mixing; Chemical potential of an ideal gas in an ideal gas mixture; Concept of standard states and choice of standard states of ideal gases.

Condensed Phase: Chemical potential of pure solid and pure liquids, Ideal solution–Definition, Raoult's law; Mixing properties of ideal solutions, chemical potential of a component in an ideal solution; Choice of standard states of solids and liquids.

3. Foundation of Quantum Mechanics 20 L

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, eigenfunctions and eigenvalues; 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 eigenfunctions and eigenvalues. Properties of particle in a box wave functions (normalisation, orthogonality, probability distribution); Expectation values of x, 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.

Reference Books

1. Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press. 2. Castellan, G. W. Physical Chemistry, Narosa. 3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 4. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 4. Rakshit, P.C., Physical Chemistry, Sarat Book House. 5. Moore, W. J. Physical Chemistry, Orient Longman. 6. Mortimer, R. G. Physical Chemistry, Elsevier. 7. Denbigh, K. The Principles of Chemical Equilibrium Cambridge

University Press. 8. Engel, T. & Reid, P. Physical Chemistry, Pearson. 9. Levine, I. N. Quantum Chemistry, PHI. 10. Atkins, P. W. Molecular Quantum Mechanics, Oxford. 11. emansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill. 12. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas. 13. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics:Basic Concepts and Methods Wiley. 14. Glasstone, S. An Introduction to Electrochemistry, East-West Press.

CHEMHP-5	Practical :	2 Credit

Physical Chemistry – II

i. Study of viscosity of unknown liquid (glycerol, sugar) with respect to water.
ii. Determination of partition coefficient for the distribution of I_2 between water and CCl_4.
iii. Determination of K_{eq} for $KI + I_2 = KI_3$, using partition coefficient between water and CCl_4.
Iv. Conductometric titration of an acid (strong, weak/ monobasic, dibasic) against strong base.
v. Study of saponification reaction conductometrically.
vi. Verification of Ostwald's dilution law and determination of Ka of weak acid.

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.

CHEMHT-6	Theory: Chemical Bonding – I, Chemical Bonding – II, Metal extraction and purification from ores and minerals	4 Credit

Inorganic Chemistry – II

1. **Chemical Bonding – I:** **(22L)**
Ionic Bond: Lattice energy, Born-Lande equation with derivation and importance of Kapustinskii expression for lattice energy, Born-Haber cycle and its applications, Polarising power and polarisability of ions, Fajan's rules and its applications, radius ratio rules – its applications and limitations, salvation energy and solubility energetics of dissolution process; Packing in crystals, voids in crystal lattice, packing efficiency, Structure of ionic solids: rock salt, zinc blende, wurtzite, fluorite, antifluorite, perovskite and layer lattice. Qualitative idea about stoichiometric and non-stoichiometric crystal defects.
2. **Chemical Bonding – II:** **(28L)**
Covalent Bond: Lewis structures, formal charge; Qualitative idea of V.B.Theory, directional properties of covalent bond, Concept of Equivalent and non equivalent Hybridization and shapes of simple molecules and ions (examples from main groups), Stereochemically non-rigid molecules – Berry's pseudorotation, Resonance and Dipole moments of inorganic molecules and ions, VSEPR theory and Bent's rule and their applications; M.O. Theory (elementary pictorial approach), concept of bond order, MO diagram of homo-nuclear diatomics (1^{st} and 2^{nd} period elements), hetero-nuclear diatomics (HF, CO, NO, NO^+ and CN^-) and triatomics (H_2O and BeH_2). Electron sea model and elementary idea about band theory, classification of inorganic solids and their

conduction properties according to band theory; Hydrogen bonding: classifications, its effect on the properties of compounds and its importance in biological systems, vander Waal's forces.

3. **Metal extraction and purification : Basic Metallurgy (10L)**
   Idea about ores and minerals, operations involved in metallurgy, Flow chart diagram for the extraction of pure Ti, Ni and U(including reactions) from their important ores and their uses.

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry 5th Ed., John Wiley and sons 2008. 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. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970. 4. Porterfield, H. W., Inorganic Chemistry, Second Edition, Academic Press, 2005. 5. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980. 6. Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India. 7. Gillespie, R. J. and Hargittai, I., The VSEPR Model of Molecular Geometry, Prentice Hall (1992). 8. Albright, T., Orbital interactions in chemistry, John Wiley and Sons (2005). 9. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998). 10. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.

CHEMHP-6	**Practical :**	**2 Credit**

Inorganic Chemistry – II

i. Estimation of Fe(II) and Fe(III) in a given mixture using $K_2Cr_2O_7$ solution
ii. Estimation of Fe(III) and Cu(II) in a given mixture using $K_2Cr_2O_7$ solution
iii. Estimation of Cr(VI) and Mn(II) in a given mixture using $K_2Cr_2O_7$ solution
iv. Estimation of Fe(III) and Cr(VI) in a given mixture using $K_2Cr_2O_7$ solution
v. Estimation of Fe(II) and Mn(II) in a given mixture using $KMnO_4$ solution
vi. Estimation of Fe(III) and Ca(II) in a given mixture using $KMnO_4$ solution

Reference Books

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

CHEMHT-7	**Theory: Chemistry of alkenes and alkynes, Aromatic Substitution, Carbonyl and Related Compounds, Organometallics**	**4 Credit**

Organic Chemistry – III

1. **Chemistry of alkenes and alkynes: (16L)**
   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; dissolving metal reduction of alkenes; 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.

2. **Aromatic Substitution: (8L)**

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_NAr mechanism; cine substitution (benzyne mechanism), structure of benzyne.

3. **Carbonyl and Related Compounds: (30L)**

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, cyano hydrins 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, 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.

Elementary ideas of Green Chemistry: 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.

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 annulations.

Substitution at sp^2 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).

4. **Organometallics: (6L)**
   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.

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. 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

CHEMHP-7	**Practical :**	**2 Credit**

Organic Chemistry – III

Qualitative Analysis of Single Solid Organic Compounds:

1. Detection of special elements (N, S, Cl, Br) by Lassaigne's test
2. Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
3. Detection of the following functional groups by systematic chemical tests:
4. Aromatic amino (Ar-NH_2), aromatic nitro (Ar-NO_2), amido (-$CONH_2$, including imide), phenolic hydroxyl (Ph–OH), carboxylic acid (-COOH), carbonyl (-CHO and >C=O); only one test for each functional group is to be reported.
5. Melting point of the given compound
6. Preparation, purification and melting point determination of a crystalline derivative of the given compound
7. 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 least six) organic compounds

Reference Books:

1. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, 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. Clarke, H. T., A Handbook of Organic Analysis (Qualitative and Quantitative), Fourth Edition, CBS Publishers and Distributors (2007). 6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.

CHEMHS – 1A	IT skills for Chemist	2 Credit

1. Mathematics (10L)

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

ii. Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities.

iii. Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression).

iv. Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms). Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

v. Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

vi. Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

2. Computer programming (10L)

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis. BASIC programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

3. Hands On (10L)

i. Introductory writing activities: Introduction to word processor and structure drawing (ChemSketch) software. Incorporating chemical structures, chemical equations, and expressions from chemistry (e.g. Maxwell-Boltzmann distribution law, Bragg's law, van der Waals equation, etc.) into word processing documents.

ii. Handling numeric data: Spreadsheet software (Excel), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs. Incorporating tables and graphs into word processing documents. Simple calculations, plotting graphs using a

spreadsheet (Planck's distribution law, radial distribution curves for hydrogenic orbitals, gas kinetic theory- Maxwell-Boltzmann distribution curves as function of temperature and molecular weight), spectral data, pressure-volume curves of van der Waals gas (van der Waals isotherms), data from phase equilibria studies. Graphical solution of equations.

iii. Numeric modelling: Simulation of pH metric titration curves. Excel functions LINEST and Least Squares. Numerical curve fitting, linear regression (rate constants from concentration- time data, molar extinction coefficients from absorbance data), numerical differentiation (e.g. handling data from potentiometric and pH metric titrations, pKa of weak acid), integration (e.g. entropy/enthalpy change from heat capacity data).

iv. Statistical analysis: Gaussian distribution and Errors in measurements and their effect on data sets. Descriptive statistics using Excel. Statistical significance testing: The t test. The F test.

v. Presentation: Presentation graphics

Reference Books

1. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008). 2. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005). 3. Steiner, E. The Chemical Maths Book Oxford University Press (1996). 4. Yates, P. Chemical calculations. 2nd Ed. CRC Press (2007). 5. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5. 6. Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages. 7. Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985). 8. Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996).

CHEMHS – 1B	Basic Analytical Chemistry	2 Credit

1. Introduction **(2L)**

Strategies of Analytical Chemistry and its interdisciplinary applicability. Protocol of sampling. Variability and validity of analytical measurements. Presentation of experimental data and results, from the point of view of significant figures.

2. Complexometry **(4L)**

Complexometric titrations, Chelation, Chelating agents, use of indicators. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

Soil Analysis

Composition, pH of soil samples, estimation of calcium and magnesium content.

3. Analysis of water **(4L)**

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 Biological Oxygen Demand (BOD).

4. Analysis of food products **(4L)**

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.

Analysis of preservatives and colouring matter.

5. Chromatography **(4L)**

Definition, general introduction on principles of chromatography, paper chromatography, TLC etc.

Paper chromatographic separation of mixture of metal ion (Fe^{3+} and Al^{3+}).
To compare paint samples by TLC method.

6. **Ion-exchange** **(4L)**
Column, ion-exchange chromatography etc. 2. Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

7. **Analysis of cosmetics** **(3L)**
Major and minor constituents and their function
Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.
Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc oxide and Calcium carbonate by complexometric titration

8. **Suggested Applications (Any one)** **(2L)**
To study the use of phenolphthalein in trap cases.
To analyse arson accelerants.
To carry out analysis of gasoline.

9. **Suggested Instrumental demonstrations** **(3L)**
Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.
Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.
Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drinks

Reference Books

1. Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. Instrumental Methods of Analysis, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988. 2. Skoog, D.A., Holler, F.J. & Crouch, S. Principles of Instrumental Analysis, Cengage Learning India Edition, 2007. 3. Skoog, D.A.; West, D.M. & Holler, F.J. Analytical Chemistry: An Introduction 6th Ed., Saunders College Publishing, Fort Worth, Philadelphia (1994). 4. Harris, D. C. Quantitative Chemical Analysis, 9th ed. Macmillan Education, 2016. 5. Dean, J. A. Analytical Chemistry Handbook, McGraw Hill, 2004. 6. Day, R. A. & Underwood, A. L. Quantitative Analysis, Prentice Hall of India, 1992. 7. Freifelder, D.M. Physical Biochemistry 2nd Ed., W.H. Freeman & Co., N.Y. USA (1982). 8. Cooper, T.G. The Tools of Biochemistry, John Wiley & Sons, N.Y. USA. 16 (1977). 9. Vogel, A. I. Vogel's Qualitative Inorganic Analysis 7th Ed., Prentice Hall, 1996. 10. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009. 11. Robinson, J.W. Undergraduate Instrumental Analysis 5th Ed., Marcel Dekker, Inc., New York (1995). 12. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.

Semester - IV

CHEMHT-8	Theory: Application of Thermodynamics – II, Electrical Properties of molecules, Quantum Chemistry,	4 Credit

Physical Chemistry – III

1. **Application of Thermodynamics – II** **20 L**

Colligative properties: Vapour pressure of solution; Ideal solutions, ideally dilute solutions and colligative properties; Raoult's law; Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) Osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution; Abnormal colligative properties.

Phase rule: 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; Liquid vapour equilibrium for two component systems; Phenol-water system.

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

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

2. Electrical Properties of molecules **20 L**

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.

Electromotive Force: Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry; Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMFmeasurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass electrodes.

Concentration cells with and without transference, liquid junction potential; Determination of activity coefficients and transference numbers; Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

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.

3. Quantum Chemistry **20 L**

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.

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).

LCAO and HF-SCF: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+; Bonding and antibonding orbitals; Qualitative extension to H_2; Comparison of LCAO-MO and VB treatments of H_2 and their limitations; Hartree-Fock method development, SCF and configuration interaction (**only basics**).

Reference Books

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, VivaPress. 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. Physical Chemistry, Pearson. 11. Maron, S.H., Prutton, C. F., Principles of Physical Chemistry, McMillan. 12. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics:Basic Concepts and MethodsWiley. 13. Rastogi, R. P. &Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas. 14. Glasstone, S. An Introduction to Electrochemistry, East-West Press.

CHEMHP-8	Practical :	2 Credit

Physical Chemistry – III

i. Determination of solubility of sparingly soluble salt in water, in electrolyte with common ions and in neutral electrolyte (using common indicator).
ii. Potentiometric titration of Mohr's salt solution against standard K_2Cr_2O-solution.
iii. Determination of K_{sp} for AgCl by potentiometric titration of $AgNO_3$solution against standard KCl solution.
iv. Effect of ionic strength on the rate of Persulphate –Iodide reaction.
v. Study of phenol-water phase diagram.
vi. 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). 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.

CHEMHT-9	Theory: Radioactivity and nuclear chemistry, Chemistry of s and p-block elements, Coordination Chemistry - I	4 Credit

Inorganic Chemistry – III

1. **Radioactivity and nuclear chemistry : (15L)**
Atomic nucleus – nuclear stability, n/p ratio and different modes of decay, mass defect, packing fraction and nuclear binding energy. Nuclear forces: Meson exchange theory, elementary idea of nuclear shell model and magic numbers. Fission, fusion and spallation reactions, artificial radioactivity, super heavy elements and their IUPAC nomenclature. Moderators, slow and fast neutrons, Applications of radio-isotopes in: determination of structures, establishment of reaction mechanisms and radio-carbon dating, hazards of radiation and safety measures.
2. **Chemistry of s and p-block elements : (30L)**
Diagonal relationship (Li-Mg; B-Si) and anomalous behaviour of first member of each group, Allotropy and catenation (examples of C, P and S compounds). Study of the following compounds with emphasis on preparation, properties, structure and bonding: Berylium hydrides and halides; diborane; borazine; boron nitride, boric acid, borax, fluorocarbons (with environmental effect); oxides and oxyacids of nitrogen, phosphorous, sulphur and chlorine; Peroxo acids of sulphur; tetrasulphur trtranitride; interhalogens, pseudohalogens, polyhalides, fluorides and oxides of xenon. Noble gas clathrates; basic properties of iodine. Synthesis, structural aspects and applications of silicones and phosphazines;

Structural properties of various silicates.

3. **Coordination Chemistry - I : (15L)**

Idea about double salts and complex salts, Werner's theory, EAN rule, classification of ligands and their binding modes, IUPAC nomenclature of coordination compounds (up to two metal centres), overall and stepwise stability constants, chelates, innermetallic complexes, Stereochemistry and isomerism (constitutional and stereo) of complexes with coordination no. 4 and 6.

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. 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).

CHEMHP-9	**Practical :**	**2 Credit**

Inorganic Chemistry – III

A. Complexometric Titration :

i. Estimation of Hardness of water
ii. Estimation of Ca(II) and Mg(II) in a mixture
iii. Estimation of Zn(II) and Mg(II) in a mixture

B. Inorganic Preparation :

i. Mohr's salt
ii. Potassium tris(oxalato)chromate(III) trihydrate
iii. Tetraamminecarbonatocobalt(III) nitrate
iv. Potassiumbis(oxalato)cuprate(II) dihydrate
v. Tris(ethylenediamine)nickel(II) chloride

Reference Book

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

CHEMHT-10	**Theory: Nitrogen compounds, Rearrangements, The Logic of Organic Synthesis, Organic Spectroscopy,**	**4 Credit**

Organic Chemistry – IV

1. **Nitrogen compounds: (8L)**

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 phenylenediamines, 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.

2. **Rearrangements:Mechanism with evidence and stereochemical features for the following: (10L)**

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.

3. **The Logic of Organic Synthesis: (20L)**

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; diastereoselectivity and enantioselectivity (only definition); enantioselectivity: kinetically controlled MPV reduction; diastereoselectivity: addition of nucleophiles to C=O adjacent to a stereogenic centre: Felkin-Anh and Zimmermann-Traxler models.

4. **Organic Spectroscopy: (22L)**

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 λmax for the following systems: conjugated diene, α,β-unsaturated aldehydes and ketones (alicyclic, homoannular and heteroannular); extended conjugated systems (dienes, aldehydes and ketones); relative positions of λmax 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.

Reference Books

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. 6. Pavia, D. L. et al. Introduction to Spectroscopy, 5th Ed. Cengage Learning India Ed. (2015). 7. Dyer, J. Application of Absorption Spectroscopy of Organic Compounds, PHI Private Limited. 8. March, J. Advanced Organic Chemistry, Fourth edition, Wiley. 9. Harwood, L. M., Polar Rearrangements, Oxford Chemistry Primer, Oxford University Press. 10. Bailey, Morgan, Organonitrogen Chemistry, Oxford Chemistry Primer, Oxford University Press. 11. Warren, S. Organic Synthesis the Disconnection Approach, John Wiley and Sons. 12. Warren, S., Designing Organic Synthesis, Wiley India, 2009. 13. Carruthers, W. Modern methods of Organic Synthesis, Cambridge University Press. 14. Willis, C. A., Wills, M., Organic Synthesis, Oxford Chemistry Primer, Oxford University Press.

CHEMHP-10	**Practical :**	**2 Credit**

Organic Chemistry – IV

List of Practical

i. Estimation of glycine by Sörensen's formol method
ii. Estimation of glucose by titration using Fehling's solution
iii. Estimation of sucrose by titration using Fehling's solution
iv. Estimation of vitamin-C (reduced)

v. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) method
vi. Estimation of phenol by bromination (Bromate-Bromide) method
vii. Estimation of formaldehyde (Formalin)
viii. Estimation of acetic acid in commercial vinegar
ix. Estimation of urea (hypobromite method)
x. Estimation of saponification value of oil/fat/ester

Reference Books:

1. Arthur, I. V. Quantitative Organic Analysis, Pearson
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta

CHEMHS – 2A	Pharmaceutical Chemistry	2 Credit

1. **Drugs & Pharmaceuticals: (16L)**
   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).
2. **Fermentation: (6L)**
   Aerobic and anaerobic fermentation. Production of (i) Ethyl alcohol and citric acid, (ii) Antibiotics; Penicillin, Cephalosporin, Chloromycetin and Streptomycin, (iii) Lysine, Glutamic acid, Vitamin B2, Vitamin B12 and Vitamin C.
3. **Hands On Practical: (8L)**
   Preparation of Aspirin and its analysis.
   Preparation of magnesium bisilicate (Antacid).

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.

CHEMHS – 2B	Analytical clinical Biochemistry	2 Credit

1. Review of Concepts from Core Course (8L)

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

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

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

enzymes, Coenzymes and cofactors, Enzyme inhibitors, Introduction to Biocatalysis: Importance in "Green Chemistry" and Chemical Industry.

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

2. Biochemistry of disease: A diagnostic approach by blood/ urine analysis.(12L)

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

Urine: Sampling and preservation, composition and estimation of constituents of normal and pathological urine.

3. Hands On Practical (10L)

Identification and estimation of the following:

i. Carbohydrates – qualitative and quantitative.
ii. Lipids – qualitative.
iii. Determination of the iodine number of oil.
iv. Determination of the saponification number of oil.
v. Determination of cholesterol using Liebermann- Burchard reaction.
vi. Proteins – qualitative.
vii. Isolation of protein.
viii. Determination of protein by the Biuret reaction.
ix. Determination of nucleic acids

Reference Books

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

Semester - V

CHEMHT-11	Theory: Coordination Chemistry – II, Magnetochemistry, Chemistry of d- and f-block elements, Reaction Kinetics and Mechanism	4 Credit

Inorganic Chemistry – IV

1. Coordination Chemistry – II : (28L)

Structure and bonding of coordination compounds on the basis of V.B.Theory and its limitations. Elementary idea about CFT, splitting of d^n configuration in ML_4 to ML_6 and ML_8 systems, factors affecting , measurement of $_o$, spectrochemical series of ligands, CFSE in weak and strong fields, OSSE, High spin and low spin complexes, spin isomerism, tetragonal distortion, Jahn Teller theorem and applications, achievements and limitations of CFT, nephalauxetic effect, stabilisation of unusually high and low oxidation states of 3d series elements, MOT (elementary idea), σ and π bonding in octahedral complexes (a pictorial approach). Colour and electronic spectra of complexes: selection rules for electronic transitions, d-d transition, charge transfer transition (qualitative

idea), L-S coupling and R-S ground state term for atomic no. up to 30, qualitative ORGEL diagram for $3d^1 - 3d^9$ ions with appropriate symbols for the energy levels.

2. **Magnetochemistry : (12L)**
   Classification of magnetic substances, Origin of para magnetic moments, temperature dependence of para magnetism – Curie and Curie-Weiss law, TIP, magnetic susceptibility and its measurement (Gouy method), diamagnetic correction, effective magnetic moment, spin only moment for 3d metals, Orbital contribution to magnetic moment, spin-orbit coupling, quenching of orbital contribution, Sub-normal magnetic moments and antiferromagnetic interactions (elementary idea with examples).
3. **Chemistry of d- and f-block elements : (12L)**
   d-block elements: Characteristic properties, Comparison among the elements of 3d series with reference to electronic configuration, oxidation states and E^0 values; General comparison between 3d, 4d and 5d series elements in term of electronic configuration, oxidation states, atomization energy, magnetic properties and coordination chemistry.
   f-block elements: Comparison between d and f-block elements; Electronic configuration, oxidation states, variation of magnetic properties (Ln^{3+}), atomic and ionic(3+) radii of lanthanoids; consequences of lanthanide contraction, separation of lanthanides by ion exchange and solvent extraction methods; comparison between lanthanoids and actinoids.
4. **Reaction Kinetics and Mechanism: (8L)**
   Introduction to inorganic reaction mechanisms, substitution reactions in square planar complexes; *trans*-effect - theories and applications; lability and inertness in octahedral complexes towards substitution reactions. Elementary concept of *cis*-effect.

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.

CHEMHP-11	Practical :	2 Credit

Inorganic Chemistry – IV

A. Quantitative:

i. Estimation of available chlorine in bleaching powder using iodometry
ii. Estimation of available oxygen in pyrolusite using permanganometry
iii. Estimation of Cu in brass using iodometry
iv. Estimation of Fe in cement using permanganometry
v. Estimation of chloride gravimetrically
vi. Estimation of Ni(II) using DMG gravimetrically

B. Experiment :

i. Paper chromatographic separation of Ni(II) and Co(II)
ii. Measurement of 10Dq by spectrophotometric method
iii. Preparation of $Mn(acac)_3$ and determination of its λ_{max} colorimetrically

Reference Book

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

CHEMHT-12	**Theory: Molecular Spectroscopy, Photochemistry, Surface phenomenon,**	**4 Credit**

Physical Chemistry – IV

1. **Molecular Spectroscopy** **24 L**

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

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.\

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Vibrational Raman spectra, Stokes and anti-Stokes lines.

Nuclear Magnetic Resonance (NMR) spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and low resolution spectra.

Electron Spin Resonance (ESR) spectroscopy: Its principle, ESR of simple radicals.

2. **Photochemistry** **18 L**

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.

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.

Rate of Photochemical processes: Photochemical equilibrium and the differential rate of photochemical reactions, Photostationary state; HI decomposition, H_2-Br_2 reaction, dimerisation of anthracene; photosensitised reactions, quenching; Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence.

3. **Surface phenomenon** **18 L**

Surface tension and energy: 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.

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.

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; Electrokinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrin's method;

Stability of colloids and zeta potential; Micelle formation.

Reference Books

1. Castellan, G. W. Physical Chemistry, Narosa. 2. Levine, I. N. Physical Chemistry, Tata McGraw-Hill . 3. Atkins, P. W. & Paula, J. de Atkin's, Physical Chemistry, Oxford University Press. 4. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 5. Mortimer, R. G. Physical Chemistry, Elsevier. 6. Laidler, K. J.Chemical Kinetics, Pearson. 7. Banwell, C. N. Fundamentals of Molecular Spectroscopy, Tata-McGraw-Hill. 8. Barrow, G. M. Molecular Spectroscopy, McGraw-Hill. 9. Hollas, J.M. Modern Spectroscopy, Wiley India. 10. McHale, J. L. Molecular Spectroscopy, Pearson Education. 11. Wayne, C. E. & Wayne, R. P. Photochemistry, OUP. 12. Brown, J. M. Molecular Spectroscopy, OUP. 13. Levine, I. N. Quantum Chemistry, PHI. 14. Atkins, P. W. Molecular Quantum Mechanics, Oxford.

CHEMHP-12	**Practical :**	**2 Credit**

Physical Chemistry – IV

i. Determination of surface tension of a liquid using Stalagmometer.
ii. Determination of CMC from surface tension measurements.
iii. Verification of Beer and Lambert's Law for $KMnO_4$and $K_2Cr_2O_7$solution.
iv. Study of kinetics of $K_2S_2O_8$+ KI reaction, spectrophotometrically.
v. Determination of pH of unknown buffer, spectrophotometrically.
vi. Spectrophotometric determination of CMC.

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.

CHEMHTDSE-1A	**Theory: Introduction, Functionality and its importance, Kinetics of Polymerization, Crystallization and crystallinity, Nature and structure of polymers, molecular weight of polymers, Tg , Solubility and Properties**	**4 Credit**

Polymer Chemistry

1. **Introduction and history of polymeric materials** **4 L**
   Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.
2. **Functionality and its importance** **6 L**
   Criteria for synthetic polymer formation, classification of polymerization processes, elationships between functionality, extent of reaction and degree of polymerization. Bi-functional systems, Poly-functional systems.
3. **Kinetics of Polymerization** **8 L**
   Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations.
4. **Crystallization and crystallinity** **4 L**
   Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point.
5. **Nature and structure of polymers** **4 L**

Structure Property relationships.

6. **Determination of molecular weight of polymers** **6 L**
   (M_n, M_w, etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.
7. **Glass transition temperature (Tg) and determination of Tg** **4 L**
   Free volume theory, WLF equation, Factors affecting glass transition temperature (Tg).
8. **Polymer Solution** **10 L**
   Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Lower and Upper critical solution temperatures.
9. **Properties of Polymer** **14 L**
   (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 sulphide polypyrrole, polythiophene)].

Reference Book

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.

CHEMHPDSE-1A	**Practical :**	**2 Credit**

Polymer Chemistry

1. **Polymer Synthesis**
   a. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA).
   b. Polymerization using benzoyl peroxide (BPO) / 2,2'-azo-bis-isobutylonitrile (AIBN)
   c. Preparation of nylon 66/6.
2. **Polymer characterization**
   a. Determination of molecular weight by viscometry:
      i. Polyacrylamide-aq.NaNO2 solution
      ii. Poly vinyl proplylidine (PVP) in water
   b. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.
   c. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG) (OH group).
   d. Determination of hydroxyl number of a polymer using colorimetric method.
3. **Polymer analysis**
   a. Estimation of the amount of HCHO in the given solution by sodium sulphite method.

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). 5. P. Munk & T.M. Aminabhavi, Introduction to Macromolecular Science, 2nd ed. John Wiley & Sons (2002). 6. L. H. Sperling, Introduction to Physical Polymer Science, 4th ed. John Wiley & Sons (2005). 7. M.P. Stevens, Polymer Chemistry: An Introduction 3rd ed. Oxford University Press (2005). 8. Seymour/ Carraher's Polymer Chemistry, 9th ed. by Charles E. Carraher, Jr. (2013).

CHEMHTDSE-1B	**Theory: Silicate Industries, Fertilizers, Surface Coatings, Batteries, Alloys, Catalysis and explosives**	**4 Credit**

Inorganic Materials of Industrial Importance

1. Silicate Industries **(9L)**

i. 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.

ii. 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.

iii. Cements: Classification of cement, ingredients and their role, Manufacture of cement and the setting process, quick setting cements.

2. Fertilizers **(9L)**

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.

3. **Surface Coatings** **(9L)**

Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Pigments, toners and laker pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Water and Oil paints, additives, Metallic coatings (electrolytic and electroless),

4. Batteries **(9L)**

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.

5. Alloys **(9L)**

Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation).. Composition and properties of different types of steels.

6. Catalysis **(9L)**

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.

7. Chemical explosives **(6L)**

Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX). Introduction to rocket propellants.

Reference Books

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)

CHEMHPDSE-1B	**Practical :**	**2 Credit**

Inorganic Materials of Industrial Importance

List of Practicals

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).

Reference Books

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)

CHEMHTDSE-2A	**Theory: Qualitative and quantitative, Optical methods of analysis. Thermal and Electroanalytical methods of analysis. Separation techniques**	**4 Credit**

Analytical Methods in Chemistry

1. **Qualitative and quantitative aspects of analysis** **(10L)**
   Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution of errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals
2. **Optical methods of analysis** **(20L)**
   i. .Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.
   ii. UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;
   iii. 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.

iv. 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.

v. Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and detector, choice of flame and Burner designs. Techniques of atomization and sample introduction; Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples.

3. Thermal methods of analysis (8L)

Theory of thermogravimetry (TG), instrumentation. Composition determination of Ca and Mg from their mixture.

4. Electroanalytical methods (10L)

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.

5. Separation techniques (12L)

i. Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation.

ii. Technique of extraction: batch, continuous and counter current extractions.

iii. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.

iv. Chromatography: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange.

v. Development of chromatograms: frontal, elution and displacement methods.

vi. Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

vii. Separation and analysis using GC and HPLC (dye and pesticide analysis)

viii. Role of computers in instrumental methods of analysis

Reference Books

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009. 2. Willard, H.H. Et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988. 3. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004. 4. Harris, D.C.: Exploring Chemical Analysis, 9th Ed. New York, W.H. Freeman, 2016. 5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age International Publisher, 2009. 6. Skoog, D.A. Holler F.J. & Nieman, T.A. Principles of Instrumental Analysis, Cengage Learning India Ed. 7. Mikes, O. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979. 8. Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.

CHEMHPDSE-2A	Practical :	2 Credit

Analytical Methods in Chemistry

1. **Separation Techniques – Chromatography**

i. Separation of mixtures Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the RF values.

ii. Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their RF values.

iii. Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

2. **Solvent Extractions**

To separate a mixture of Ni2+ & Fe2+ by complexation with DMG and extracting the Ni2+ - DMG complex in chloroform, and determine its concentration by spectrophotometry.

3. **Ion exchange:**

Determination of exchange capacity of cation exchange resins and anion exchange resins.

4. **Spectrophotometry**

i. Determination of pKa values of indicator using spectrophotometry

ii. Analysis of soil: a. Determination of pH of soil. b. Total soluble salt c. Estimation of calcium / magnesium / phosphate / nitrate.

Reference Books

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009. 2. Willard, H.H. Et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988. 3. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004. 4. Harris, D.C.: Exploring Chemical Analysis, 9th Ed. New York, W.H. Freeman, 2016. 5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age International Publisher, 2009. 6. Skoog, D.A. Holler F.J. & Nieman, T.A. Principles of Instrumental Analysis, Cengage Learning India Ed. 7. Mikes, O. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979. 8. Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.

CHEMHTDSE-2B	**Theory: Introduction to spectroscopic methods of analysis, Molecular spectroscopy, Chromatography, Elemental analysis, NMR spectroscopy, Electroanalytical techniques, Radiochemical Methods: Elementary Analysis, Radiochemical Methods: Elementary Analysis**	4 Credit

Instrumental Methods of Chemical Analysis

1. **Introduction to spectroscopic methods of analysis** **(8L)**

Recap of the spectroscopic methods covered in detail in the core chemistry syllabus: Classification of analytical methods and the types of instrumental methods. Consideration of electromagnetic radiation

2. **Molecular spectroscopy** **(14L)**

Infrared spectroscopy:

Interactions with molecules: absorption and scattering. Means of excitation (light sources), separation of spectrum (wavelength dispersion, time resolution), detection of the signal (heat, differential detection), interpretation of spectrum (qualitative, mixtures, resolution), advantages of Fourier Transform (FTIR). Samples and results expected. Applications: Issues of quality assurance and

quality control, Special problems for portable instrumentation and rapid detection.

UV-Visible/ Near IR – emission, absorption and fluorescence

Excitation sources (lasers, time resolution), wavelength dispersion (grating, prism, filter). Resolution, detection of signal (photocells, photomultipliers, diode arrays), sensitivity and S/N, Single and Double Beam instruments, Interpretation (quantification, mixtures).

3. **Chromatography (12L)**

Principles of Gas chromatography, liquid chromatography, supercritical fluid chromatography, Importance of column chromatographic technology (packing, capillaries), Separation based on increasing number of factors (volatility, solubility, interactions with stationary phase, size, electrical field)

Detection of different samples, single and coupled / hyphenated detector

4. **Elemental analysis (12L)**

Mass spectrometry (electrical discharges).

Atomic spectroscopy: Atomic absorption, Atomic emission, and Atomic fluorescence.

Excitation and atomisation (flames, electrical discharges, plasmas), Wavelength separation and resolution (dependence on technique), Detection of radiation (simultaneous/scanning, signal noise), Interpretation (errors due to molecular and ionic species, matrix effects, other interferences).

5. **NMR spectroscopy (6L)**

Principle, Instrumentation, Factors affecting chemical shift, Spin- coupling, Applications.

6. **Electroanalytical techniques (4L)**

Potentiometry & Voltammetry

7. **Radiochemical Methods: Elementary Analysis (4L)**

Basic idea of X-ray analysis and electron spectroscopy (surface analysis)

Reference Books

1.D.A. Skoog, F.J. Holler & S. Crouch (ISBN 0-495-01201-7) Principles of Instrumental Analysis, Cengage Learning India Edition, 2007. 2. Willard, Merritt, Dean, Settle, Instrumental Methods of Analysis, 7th ed, IBH Book House, New Delhi. 3. Atkins, P.W & Paula, J.D. Physical Chemistry, 10th Ed., Oxford University Press (2014). 4. Kakkar, R. Atomic and Molecular Spectroscopy: Concepts and Applications. Cambridge University Press, 2015. 5. Castellan, G. W. Physical Chemistry 4th Ed., Narosa (2004). 6. Banwell, C. N. & McCash, E. M. Fundamentals of Molecular Spectroscopy 4th Ed. Tata McGraw- Hill: New Delhi (2006). 7. Smith, B.C. Infrared Spectral Interpretations: A Systematic Approach. CRC Press, 1998. 8. Moore, W.J., Physical Chemistry Orient Blackswan, 1999.

CHEMHPDSE-2B	Practical :	2 Credit

Instrumental Methods of Chemical Analysis

1. Safety Practices in the Chemistry Laboratory
2. Determination of Cobalt and Nickel from mixture
3. Study of Electronic Transitions in Organic Molecules (i.e., acetone in water)
4. IR Absorption Spectra (Study of Aldehydes and Ketones)
5. Determination of Calcium, Iron, and Copper in Food by Atomic Absorption
6. Potentiometric Titration of a Chloride - Iodide Mixture
7. Analysis of illicit drugs.
8. Detection in the field and confirmation in the laboratory of flammable accelerants or explosives
9. Detection of steroids.

10. Detection of pollutants from wastes.
11. Fibre analysis
12. Titration curve of an amino acid.
13. Determination of the void volume of a gel filtration column.
14.Quantitative Analysis of Mixtures by Gas Chromatography (i.e.,chloroform and carbon tetrachloride)
15.Separation of Carbohydrates by HPLC
16.Determination of Caffeine in Beverages by HPLC
17.Cyclic Voltammetry of the Ferrocyanide/ Ferricyanide Couple
18.Nuclear Magnetic Resonance
19.Use of fluorescence to do "presumptive tests" to identify blood or other body fluids.
20.Use of "presumptive tests" for anthrax or cocaine
21.Collection, preservation, and control of blood evidence being used for DNA testing
22.Use of capillary electrophoresis with laser fluorescence detection for nuclear DNA (Y chromosome only or multiple chromosome)
23.Use of sequencing for the analysis of mitochondrial DNA

Reference Books

1. Skoog, D.A. Holler F.J. & Nieman, T.A. Principles of Instrumental Analysis, Cengage Learning India Ed. 2. Willard, H.H., Merritt, L.L., Dean, J. & Settoe, F.A. Instrumental Methods of Analysis, 7th Ed. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.

CHEMHTDSE-2C	Theory: Introduction to Green Chemistry, Principles of Green Chemistry and Designing a Chemical synthesis, Examples, Future Trends	4 Credit

Green Chemistry

1. **Introduction to Green Chemistry: (4L)**
   What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry
2. **Principles of Green Chemistry and Designing a Chemical synthesis: (26L)**
   Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following:
   Designing a Green Synthesis using these principles; Prevention of Waste/ byproducts; maximum incorporation of the materials used in the process into the final products , Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.
   Prevention/ minimization of hazardous/ toxic products reducing toxicity.
   risk = (function) hazard × exposure; waste or pollution prevention hierarchy.
   Green solvents– supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorous 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.
   Use of catalytic reagents (wherever possible) in preference to

stoichiometric reagents; 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 carcarbaryl) and Flixiborough 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.

3. **Examples of Green Synthesis/ Reactions and some real world cases (26L)**

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 CO_2 for precision cleaning and dry cleaning of garments.

Designing of Environmentally safe marine antifoulant.

Right fit 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

4. **Future Trends in Green Chemistry: (4L)**

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

CHEMHPDSE-2C	**Practical :**	**2 Credit**
Green Chemistry		

Safer starting materials:
Preparation and characterization of nanoparticles of gold using tea leaves.
Using renewable resources:
Preparation of biodiesel from vegetable/ waste cooking oil.
Avoiding waste:
Principle of atom economy.
Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.
Preparation of propene by two methods can be studied

a. Triethylamine ion + OH^- → propene + trimethylpropene + water

b. 1-propanol $\xrightarrow{H_2SO_4}$ Propene + water

Other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy.
Use of enzymes as catalysts:
Benzoin condensation using Thiamine cation (anchored enzyme) as a catalyst instead of cyanide.

Alternative Green solvents:
Extraction of D-limonene from orange peel using liquid CO_2 prepared from dry ice. Mechanochemical solvent free synthesis of azomethines

Alternative sources of energy:
Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).
Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Reference Books

1. Anastas, P.T & Warner, J.C. Green Chemistry: Theory and Practice, Oxford University Press (1998). 2. Kirchoff, M. & Ryan, M.A. Greener approaches to undergraduate chemistry experiment. American Chemical Society, Washington DC (2002). 3. Ryan, M. A. Introduction to Green Chemistry, Tinnesand; (Ed), American Chemical Society, Washington DC (2002). 4. Sharma, R. K.; Sidhwani, I. T. & Chaudhari, M. K. I. K. Green Chemistry Experiment: A monograph International Publishing House Pvt Ltd. New Delhi. Bangalore CISBN 978-93-81141-55-7 (2013). 5. Cann, M. C. & Connelly, M. E. Real world cases in Green Chemistry, American Chemical Society (2008). 6. Cann, M. C. & Thomas, P. Real world cases in Green Chemistry, American Chemical Society (2008). 7. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2nd Edition, 2010. 8. Pavia, D. L., Lampman, G. M., Kriz, G. S. & Engel, R. G. Introduction to Organic Laboratory Techniques: A Microscale and Macro Scale Approach, W.B.Saunders, 1995.

Semester - VI

CHEMHT-13	**Theory: Molecular Symmetry and Point group, (12 L) Bio-inorganic Chemistry, Organometallic Chemistry and Catalysis**	**4 Credit**
Inorganic Chemistry – V		

1. **Molecular symmetry and Point group :** **(10)**
   Symmetry as a universal theme, concept of symmetry elements and operations (with examples); symmetry properties of atomic orbitals (s, p and d); concept of point groups, identification of molecular point groups in some simple molecules and ions; applications of symmetry for polarity and chirality.
2. **Bio-inorganic Chemistry :** **(25)**
   Essential elements of life, Role of metal ions in living systems- a brief review, Elementary idea about proteins, enzymes and ionophores; Structure of ATP, Na^+ ion pump and transport of Na^+ and K^+ across cell membrane; active site structures and bio-functions of haemoglobin, myoglobin, carboxy peptidase A, carbonic anhydrase B, cytochrome c, ferredoxins and chlorophyll; biological nitrogen fixation; toxic metals (Pb, Cd and Hg) and their effects, Wilson disease, chelation therapy; platinum and gold complexes as drugs (examples only).
3. **Organometallic Chemistry and Catalysis :** **(25)**
   Definition, Classification of organometallic compounds, hapticity of ligands, nomenclature, 16- electron & 18-electron rule and its applications; preparation and structure of mono- and bi-nuclear carbonyls of 3d series, synergic effect of CO and use of IR data to explain extent of back bonding; General methods of preparation of metal-carbon σ-bonded complexes, Zeise's salt, Metal-carbon multiple bonding; Preparation, structures, properties and reactions of ferrocene; elementary idea about oxidative addition, reductive elimination, insertion reactions; Study of the following catalytic processes: alkene hydrogenation (Wilkinson's catalyst), hydroformylation, Wacker process, Synthetic gasoline (Fischer Tropsch reaction) and Olefin polymerization reaction (Ziegler-Natta catalyst)

CHEMHP-13	**Practical :**	**2 Credit**

Inorganic Chemistry – V

Qualitative semimicro analysis

Qualitative semimicro analysis of mixtures containing four radicals (excluding oxide and carbonate). Emphasis should be given to the understanding of the chemistry of different reactions and to assign the most probable composition.

Basic Radicals: K^+, NH_4^+, Mg^{2+}, Ca^{2+}, Ba^{2+}, Sr^{2+}, Al^{3+}, Cr^{3+}, Mn^{2+}, Fe^{3+}/ Fe^{2+}, Co^{2+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+} / Sn^{4+}, As^{3+}/As^{5+}, Sb^{3+}/ Sb^{5+}

Acid Radicals: Cl^-, Br^-, I^-, S^{2-}, SO_4^{2-}, $S_2O_3^{2-}$, SCN^-, NO_3^-, NO_2^-, BO_3^{3-}, PO_4^{3-}, AsO_4^{3-} and H_3BO_3

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

CHEMHT-14	**Theory: Carbocycles and Heterocycles, Cyclic Stereochemistry, Pericyclic reactions, Carbohydrates, Carbohydrates, Biomolecules**	**4 Credit**

Organic Chemistry – V

1. **Carbocycles and Heterocycles:** **(16L)**
   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.

2. **Cyclic Stereochemistry: (10L)**
   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_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic syn elimination and fragmentation reactions.
3. **Pericyclic reactions: (8L)**
   Mechanism, stereochemistry, regioselectivity 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.
4. **Carbohydrates: (12L)**
   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).
5. **Biomolecules: (14L)**
   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.

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 (enzymatic) of peptides: use of CNBr.

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. Sengupta, 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. (Pearson Education). 12. Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press. 13. Eames, 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.

CHEMHP-14	Practical :	2 Credit

Organic Chemistry – V

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

Spectroscopic Analysis of Organic Compounds:

1. Assignment of labelled peaks in the 1H NMR spectra of the known organic compounds explaining the relative δ-values and splitting pattern.
2. Assignment of labelled 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:

a. 4-Bromoacetanilide
b. 2-Bromo-4'-methylacetophenone
c. Vanillin
d. 2-Methoxyacetophenone
e. 4-Aminobenzoic acid
f. Salicylamide
g. 2-Hydroxyacetophenone
h. 1,3-Dinitrobenzene
i. Benzylacetate
j. trans-4-Nitrocinnamaldehyde
k. Diethyl fumarate
l. 4-Nitrobenzaldehyde
m. 4-Methylacetanilide
n. Mesityl oxide
o. 2-Hydroxybenzaldehyde
p. 4-Nitroaniline
q. 2-Hydroxy-3-nitrobenzaldehyde
r. 2,3-Dimethylbenzonitrile
s. Pent-1-yn-3-ol
t. 3-Nitrobenzaldehyde
u. 3-Ethoxy-4-hydroxybenzaldehyde
v. 2-Methoxybenzaldehyde
w. Methyl 4-hydroxybenzoate
x. Methyl 3-hydroxybenzoate
y. 3-Aminobenzoic acid
z. Ethyl 3-aminobenzoate
aa. Ethyl 4-aminobenzoate
bb. 3-nitroanisole
cc. 5-Methyl-2-nitroanisole
dd. 3-Methylacetanilide

Reference Books

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta, 2003. 2. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015. 3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012). 4. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education.

CHEMHTDSE-3	Theory: Crystal Structure, Statistical Thermodynamics, Special selected topics,	4 Credit

Advanced Physical Chemistry

1. **Crystal Structure** **20 L**

   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).

   Crystal planes: Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of dhkl; 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.

2. **Statistical Thermodynamics** **18 L**

   Configuration: Macrostates, microstates and configuration; 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.

3. **Special selected topics** **22 L**

   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.

   3rd law: Absolute entropy, Plank's law, Calculation of entropy, Nernst heat theorem.

   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.

Reference Books

1. Castellan, G. W. Physical Chemistry, Narosa. 2. Levine, I. N. Physical Chemistry, Tata McGraw-Hill. 3. Moore, W. J. Physical Chemistry, Orient Longman. 4. Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press. 5. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press. 6. Engel, T. & Reid, P. Physical Chemistry, Pearson. 7. Nash, L. K. Elements of Statistical Thermodynamics, Dover. 8. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas. 9. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill. 10. Billmeyer, F. W. Textbook of Polymer Science, John Wiley & Sons, Inc. 11. Seymour, R. B. & Carraher, C. E. Polymer Chemistry: An Introduction, Marcel Dekker, Inc. 12. Odian, G. Principles of Polymerization, Wiley. 13. Billmeyer, F. W. Textbook of Polymer Science, Wiley Interscience, 1971.

CHEMHPDSE-3	Practical :	2 Credit

Advanced Physical Chemistry

Computer Programming based on numerical methods for:

i. Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid).

ii. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).
iii. Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values.
iv. Simple exercises using molecular visualization software.

Reference Books

1. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008). 2. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005). 3. Yates, P. Chemical Calculations. 2nd Ed. CRC Press (2007). 4. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5. 5. Noggle, J. H. Physical Chemistry on a Microcomputer. Little Brown & Co. (1985).

CHEMHTDSE-4	**Theory:**	**4 Credit**
Project Work		
A dissertation has to be prepared on consultation with teachers/mentors on a topic from any area of Chemistry. During examination a thorough viva-voce will be conducted by the examiners/adjudicators. The dissertation will be evaluated on the basis of written documents submitted by the candidate, originality and importance.		
CHEMHPDSE-4	**Practical :**	**2 Credit**
Project Work		
A power point presentation has to be prepared and a short oral presentation will be considered for continuous evaluation. A PDF file/print copy of the power point will be required to be submitted.		