Syllabus Chemistry
(Hons.)
for SEM-I to SEM-VI
under CBCS

(to be effective from Academic Year: 2017-18)

The University of Burdwan
Burdwan, West Bengal

Type of Courses

Course type	Description	Number of Courses		Credit
		B. Sc. (Honours)	B.Sc. (Regular)	
CC	Core Course	14	12 (4 papers each from 3 disciplines of choice)	6
DSE	Discipline Specific Elective	4	6 (2 papers each from 3 discipline of choice including interdisciplinary papers)	6
GE	Generic Elective	4	-	6
AECC (ENVS & ENGLISH/MIL)	Ability Enhancement Compulsory Course	(1+1)	(1+1)	(4+2)
SEC	Skill Enhancement Course	2	4	2
TOTAL CREDIT		**142**	**122**	

Structure at a glance for Chemistry (H) at UG level, B.U.:

1st Semester

Course Code	Course Title	Course Type	Credit per course	Marks
CC-1	Organic Chemistry-I (Theo) Organic Chemistry-I (Prac)	Core Course – I	4+2	75
CC-2	Physical Chemistry-I (Theo) Physical Chemistry-I (Prac)	Core Course – II	4+2	75
GE-1	Any discipline other than chemistry	Generic Elective – 1	6	75
AECC-1	ENVS	Ability Enhancement Compulsory Course – I	4	100
TOTAL			22	325

2nd Semester

Course Code	Course Title	Course Type	Credit per course	Marks
CC-3	Inorganic Chemistry-I (Theo) Inorganic Chemistry-I (Prac)	Core Course – III	4+2	75
CC-4	Organic Chemistry-II (Theo) Organic Chemistry-II (Prac)	Core Course – IV	4+2	75
GE-2	Any discipline other than chemistry	Generic Elective – 2	6	75
AECC-2	Communicative Eng./MIL	Ability Enhancement Compulsory Course – II	2	50
TOTAL			20	275

3rd Semester

Course Code	Course Title	Course Type	Credit per course	Marks
CC-5	Physical Chemistry-II (Theo) Physical Chemistry-II (Prac)	Core Course – V	4+2	75
CC-6	Inorganic Chemistry-II (Theo) Inorganic Chemistry-II (Prac)	Core Course – VI	4+2	75
CC-7	Organic Chemistry-III (Theo) Organic Chemistry-III (Prac)	Core Course – VII	4+2	75
SEC-1	IT skill in Chemistry or Basic analytical chemistry	Skill Enhancement Course – 1	2	50
GE-3	Any discipline other than chemistry	Generic Elective – 3	6	75
TOTAL			26	350

4th Semester

Course Code	Course Title	Course Type	Credit per course	Marks
CC-8	Physical Chemistry-III (Theo) Physical Chemistry-III (Prac)	Core Course – VIII	4+2	75
CC-9	Inorganic Chemistry-III (Theo) Inorganic Chemistry-III (Prac)	Core Course – IX	4+2	75
CC-10	Organic Chemistry – IV (Theo) Organic Chemistry – IV (Prac)	Core Course - X	4+2	75
SEC-2	Pharmaceutical chemistry or Analytical clinical biochemistry	Skill Enhancement Course – II	2	50
GE-4	Any discipline other than chemistry	GE – 4	6	75
TOTAL			26	350

5th Semester

Course Code	Course Title	Course Type	Credit per course	Marks
CC-11	Inorganic Chemistry-IV (Theo) Inorganic Chemistry-IV (Prac)	Core Course – XI	4+2	75
CC-12	Organic Chemistry-V (Theo) Organic Chemistry-V (Prac)	Core Course – XII	4+2	75
DSE-1	Compulsory Course (Advanced Physical Chemistry) (Theo + Prac)	Discipline Specific Elective	4+2	75
DSE-2	Analytical methods in chemistry or Instrumental methods of chemical analysis (Theo + Prac)	Discipline Specific Elective	4+2	75
TOTAL			24	300

6th Semester

Course Code	Course Title	Course Type	Credit per course	Marks
CC-13	Inorganic Chemistry-V (Theo) Inorganic Chemistry-V (Prac)	Core Course – XIII	4+2	75
CC-14	Physical Chemistry-IV (Theo) Physical Chemistry-IV (Prac)	Core Course – XIV	4+2	75
DSE-3	Green chemistry or polymer chemistry (Theo + Prac)	Discipline Specific Elective	4+2	75
DSE-4	Inorganic materials of industrial importance (Theo + Prac) or Dissertation followed by power point presentation	Discipline Specific Elective	4+2 or 6	75
TOTAL			24	300

Introduction

The syllabus for Chemistry (Hons.) at undergraduate level using the Choice Based Credit system has been framed in compliance with model syllabus given by UGC, New Delhi and State Council under Department of Higher Education, Government of West Bengal.

The main objective of framing this new syllabus is to give the students a comprehensive understanding of the subject giving substantial heftiness 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 completion of the course would be able to secure a job. Keeping in mind and in tune with the fast changing nature of the subject, adequate emphasis has been given on new techniques and understanding of the subject.

The affiliated undergraduate colleges under 'The University of Burdwan' are requested to take necessary measure to ensure that the students must know the modern instruments used in Chemical analysis like ultrasonication, UV-VIS Spectrophotometric analysis, FT-IR Spectroscopy etc.; moreover, the colleges are also requested to take suitable measures to provide computers with Internet facilities to the students as well as the faculty members. As a result of this, the chemistry department of various undergraduate colleges may take the initiative to arrange educational tour for the students studying in 5^{th} and 6^{th} Semester to academic institute/university where the students can access and be enriched with the modern and sophisticated instruments as mentioned above.

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 4th 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.`

CHEMISTRY (H)

1st Semester:

Course Code: CC-1

Course Title: Organic Chemistry-I (Theo): Basics of Organic Chemistry 4 Credits

Bonding and Physical Properties:

1. 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).

2. Electronic displacements: inductive effect, field effect, mesomeric effect, resonance energy; bond polarization and bond polarizability; electromeric effect; steric effect, steric inhibition of resonance.

3. 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.

4. 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.

General Treatment of Reaction Mechanism I

1. 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.
2. Reactive intermediates: carbocations (carbenium and carbonium ions), carbanions, carbon radicals, carbenes: generation and stability, structure using orbital picture and electrophilic/nucleophilic behavior of reactive intermediates (elementary idea).

Stereochemistry-I

1. 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.
2. Concept of chirality and symmetyry; symmetry elements and point groups (C_v, C_{nv}, C_{nh}, C_n, D_h, 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).

3. 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.

4. 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.

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. James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
8. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
9. Morrison, R. T. Study guide to organic Chemistry, Pearson.

Course Code: CC-1

Course Title: Organic Chemistry-I (Prac): Basics of Organic Chemistry 2 Credits

Separation

Based upon solubility, by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. NaHCO3, 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.

Determination of boiling point

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

Identification of a Pure Organic Compound by Chemical Test(s)

Solid compounds: oxalic acid, succinic acid, resorcinol, urea, glucose and salicylic acid.

Liquid Compounds: acetic acid, ethyl alcohol, acetone, aniline 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).

Course Code: CC-2

Course Title: Physical Chemistry-I (Theo) 4 Credits

Kinetic Theory and Gaseous state

1. 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); Wall collision and rate of effusion.

2. 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 $\geq \varepsilon$, Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases.

3. 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).

Chemical Thermodynamics

1. Zeroth and 1^{st} 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.

2. 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; Adiabatic flame temperature; explosion temperature.

3. 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.

4. 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.

Chemical kinetics

1. 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).

2. 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).

3. 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.

4. Autocatalysis; periodic 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.
15. Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry.
16. Bajpai, D. N., Advanced Physical Chemistry.
17. Rajaram, J. Chemical Thermodynamics: Classical, Statistical and Irreversible, Pearson.

Course Code: CC-2

Course Title: Physical Chemistry-I (Prac) 2 Credits

List of Practical

1. Determination of pH of unknown solution (buffer), by color matching method;
2. Determination of the reaction rate constant of hydrolysis of ethylacetate in the presence of an equal quantity of sodium hydroxide;
3. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate;
4. Study of kinetics of decomposition of H_2O_2 by KI;
5. Determination of solubility product of PbI_2 by titremetric method.

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.

Course Code: Generic Elective-1 (Theo.) 4 Credits

(For the students of discipline other than chemistry)

Course Title: Atomic Structure, Chemical Periodicity, Acids And Bases, Redox Reactions, General Organic Chemistry & Aliphatic Hydrocarbons

Inorganic Chemistry

1. **Atomic Structure**

Bohr's theory for hydrogen atom (simple mathematical treatment), atomic spectra of hydrogen and Bohr's model, Sommerfeld's model, quantum numbers and their significance, Pauli's exclusion principle, Hund's rule, electronic configuration of many-electron atoms, Aufbau principle and its limitations.

2. **Chemical Periodicity**

Classification of elements on the basis of electronic configuration: general characteristics of s-, p-, d- and f-block elements. Positions of hydrogen and noble gases. Atomic and ionic radii, ionization potential, electron affinity, and electronegativity; periodic and group-wise variation of above properties in respect of s- and p- block elements.

3. **Acids and bases**

Brönsted–Lowry concept, conjugate acids and bases, relative strengths of acids and bases, effects of substituent and solvent, differentiating and levelling solvents. Lewis acid-base concept, classification of Lewis acids and bases, Lux-Flood concept and solvent system concept. Hard and soft acids and bases (HSAB concept), applications of HSAB process.

4. **Redox reactions**

Balancing of equations by oxidation number and ion-electron method oxidimetry and reductimetry.

Organic Chemistry

1. **Fundamentals of Organic Chemistry**

Electronic displacements: inductive effect, resonance and hyperconjugation; cleavage of bonds: homolytic and heterolytic; structure of organic molecules on the basis of VBT; nucleophiles electrophiles; reactive intermediates: carbocations, carbanions and free radicals.

2. **Stereochemistry**

Different types of isomerism; geometrical and optical isomerism; concept of chirality and optical activity (up to two carbon atoms); asymmetric carbon atom; elements of symmetry (plane and centre); interconversion of Fischer and Newman representations; enantiomerism and diastereomerism, meso compounds; threo and erythro, D and L, cis and trans nomenclature; CIP Rules: R/S (upto 2 chiral carbon atoms) and E/Z nomenclature.

3. **Nucleophilic Substitution and Elimination Reactions**

Nucleophilic substitutions: SN1 and SN2 reactions; eliminations: E1 and E2 reactions (elementary mechanistic aspects); Saytzeff and Hofmann eliminations; elimination vs substitution.

4. **Aliphatic Hydrocarbons**

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structures.

5. **Alkanes**: (up to 5 Carbons). Preparation: catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: mechanism for free radical substitution: halogenation.

6. **Alkenes**: (up to 5 Carbons). Preparation: elimination reactions: dehydration of alcohols and dehydrohalogenation of alkyl halides; cis alkenes (partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alkaline $KMnO_4$) and trans-addition (bromine) with mechanism, addition of HX [Markownikoff's (with mechanism) and anti-Markownikoff's addition], hydration, ozonolysis, oxymercuration-demercuration and hydroboration-oxidation reaction.

7. **Alkynes**: (up to 5 Carbons). Preparation: acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides.

8. **Reactions**: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alkaline $KMnO_4$.

References Books:

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

2. Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley.

3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. Concepts and Models in Inorganic Chemistry, John Wiley & Sons.
4. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education Ind.
5. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
6. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
7. Madan, R. L. Organic Chemistry, S. Chand & Sons.
8. Wade, L. G., Singh, M. S., Organic Chemistry.
9. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
10. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
11. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
12. Sen Gupta, Subrata. Basic Stereochemistry of Organic molecules.
13. Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.
14. Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.
15. Malik, W. U., Tuli, G. D., Madan, R. D., Selected Topics in Inorganic Chemistry.

Course Code: Generic Elective-1 (Prac) 2 Credits

(For the students of discipline other than chemistry)

Course Title: Atomic Structure, Chemical Periodicity, Acids And Bases, Redox Reactions, General Organic Chemistry & Aliphatic Hydrocarbons

Inorganic Chemistry

1. Estimation of oxalic acid by titrating it with $KMnO_4$.
2. Estimation of Mohr's salt by titrating with $KMnO_4/K_2Cr_2O_7$.
3. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.

Organic Chemistry

Qualitative Analysis of Single Solid Organic Compound(s)

1. Detection of special elements (N, Cl, and S) in organic compounds.
2. Solubility and Classification (solvents: H_2O, dil. HCl, dil. NaOH)
3. Detection of functional groups: Aromatic-NO_2, Aromatic -NH_2, -COOH, carbonyl (no distinction of –CHO and >C=O needed), -OH (phenolic) in solid organic compounds.

Experiments 1 to 3 with unknown (at least 6) solid samples containing not more than two of the above type of functional groups should be done.

Reference Books

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Das, S. C., Chakraborty, S. B., Practical Chemistry.
3. Mukherjee, K. S. Text book on Practical Chemistry, New Oriental Book Agency.
4. Ghosal, Mahapatra & Nad, An Advanced course in practical Chemistry, New Central Book Agency.
5. Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors
6. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996.
7. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.

2nd Semester:

Course Code: CC-3

Course Title: Inorganic Chemistry-I (Theo) 4 Credits

Extra nuclear Structure of atom

Bohr's theory, its limitations and atomic spectrum of hydrogen atom; Sommerfeld's Theory. Wave mechanics: de Broglie equation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2. Quantum numbers and their significance. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of s, p, d and f orbitals. Pauli's Exclusion Principle, Hund's rules and multiplicity, Exchange energy, Aufbau principle and its limitations, Ground state Term symbols of atoms and ions for atomic number upto 30.

Chemical periodicity

Modern IUPAC Periodic table, Effective nuclear charge, screening effects and penetration, Slater's rules, atomic radii, ionic radii (Pauling's univalent), covalent radii, lanthanide contraction. Ionization potential, electron affinity and electronegativity (Pauling's, Mulliken's and Allred-Rochow's scales) and factors influencing these properties, group electronegativities. Group trends and periodic trends in these properties in respect of s-, p- and d-block elements. Secondary periodicity, Relativistic Effect, Inert pair effect.

Acid-Base reactions

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

Redox Reactions and precipitation reactions

Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential. Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential

diagram (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples);

Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides.

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. Atkins, 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).

Course Code: CC-3

Course Title: Inorganic Chemistry-I (Prac) 2 Credits

Oxidation-Reduction Titrimetric

1. Estimation of Fe(II) using standardized $KMnO_4$ solution
2. Estimation of oxalic acid and sodium oxalate in a given mixture
3. Estimation of Fe(II) and Fe(III) in a given mixture using $K_2Cr_2O_7$ solution.
4. Estimation of Fe(III) and Mn(II) in a mixture using standardized $KMnO_4$ solution
5. Estimation of Fe(III) and Cu(II) in a mixture using $K_2Cr_2O_7$.
6. Estimation of Fe(III) and Cr(III) in a mixture using $K_2Cr_2O_7$.

Reference Books:

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

Course Code: CC-4

Course Title: Organic Chemistry-II (Theo) 4 Credits

Stereochemistry II

1. 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 (Ra/Sa and P/M); atropisomerism; racemisation of chiral biphenyls; buttressing effect.

2. 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.

3. 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.

4. 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).

General Treatment of Reaction Mechanism II

1. Reaction thermodynamics: free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change via BDE, intermolecular & intramolecular reactions.

2. 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.

3. Tautomerism: prototropy (keto-enol, amido-imidol, nitroso-oximino, diazo-amino and enamine-imine systems); 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.

4. 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 (kH /kD); principle of microscopic reversibility.

Substitution and Elimination Reactions

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

2. Nucleophilic substitution reactions: substitution at sp^3 centre: mechanisms (with evidence), relative rates & stereochemical features: SN1, SN2, SN2', SN1' (allylic rearrangement) and SNi; 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].

3. Elimination reactions: E1, E2, E1cB and Ei (pyrolytic syn eliminations); formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity; comparison between substitution and elimination.

Reference Books:

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

Course Code: CC-4

Course Title: Organic Chemistry-II (Prac) 2 Credits

Organic Preparations

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

1. Nitration of acetanilide
2. Condensation reactions: Synthesis of 7-hydroxy-4-methylcoumarin
3. Hydrolysis of amides/imides/esters
4. Acetylation of phenols/aromatic amines (using Zn-dust/Acetic Acid)
5. Benzoylation of phenols/aromatic amines
6. Side chain oxidation of toluene and p-nitrotoluene
7. Diazo coupling reactions of aromatic amines
8. Bromination of acetanilide using green approach (Bromate-Bromide method)
9. Green 'multi-component-coupling' reaction: Synthesis of dihydropyrimidone
10. 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.
7. Vishnoi, N. K., Advanced Practical Organic Chemistry.

Course Code: Generic Elective-2 (Theo) 4 Credits

(For the students of discipline other than chemistry)

Course Title: States of Matter & Chemical Kinetics, Chemical Bonding & Molecular Structure, P-Block Elements

Physical Chemistry

1. **Kinetic Theory of Gases and Real gases**

a. 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); Rate of effusion

b. Nature of distribution of velocities, Maxwell's distribution of speed and kinetic energy; Average velocity, root mean square velocity and most probable velocity; Principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases

c. 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; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states

d. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only)

2. **Liquids**

a. Definition of Surface tension, its dimension and principle of its determination using stalagmometer; Viscosity of a liquid and principle of determination of coefficient of viscosity using Ostwald viscometer; Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only)

3. **Solids**

a. Forms of solids, crystal systems, unit cells, Bravais lattice types, Symmetry elements; Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices; Miller indices of different planes and interplanar distance, Bragg's law; Structures of NaCl, KCl and CsCl (qualitative treatment only); Defects in crystals; Glasses and liquid crystals.

4. **Chemical Kinetics**

a. Introduction of rate law, Order and molecularity; Extent of reaction; rate constants; Rates of First, second and nth order reactions and their Differential and integrated forms (with derivation); Pseudo first order reactions; Determination of order of a reaction by half-life and differential method; Opposing reactions, consecutive reactions and parallel reactions

b. Temperature dependence of rate constant; Arrhenius equation, energy of activation; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment).

Inorganic Chemistry

1. **Chemical Bonding and Molecular Structure**

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

b. Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements.

c. Concept of resonance and resonating structures in various inorganic and organic compounds.

d. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods. (including idea of s- p mixing) and heteronuclear diatomic molecules such as CO, NO and NO+. Comparison of VB and MO approaches.

2. Comparative study of p-block elements

a. Group trends in electronic configuration, modification of pure elements, common oxidation states, inert pair effect, and their important compounds in respect of the following groups of elements:

i. B-Al-Ga-In-Tl

ii. C-Si-Ge-Sn-Pb

iii. N-P-As-Sb-Bi

iv. O-S-Se-Te

v. F-Cl-Br-I

Reference Books:

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
5. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
6. Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.
7. Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.
8. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
9. Mandal, A. K. Degree Physical and General Chemistry Sarat Book House.
10. Pahari, S., Physical Chemistry New Central Book Agency.
11. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency.
12. Cotton, F.A. & Wilkinson, G. Basic Inorganic Chemistry, Wiley.
13. Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
14. Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
15. Rodgers, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Ltd., 2008.

Course Code: Generic Elective-2 (Prac) 4 Credits

(For the students of discipline other than chemistry)

Course Title: States of Matter & Chemical Kinetics, Chemical Bonding & Molecular Structure, P-Block Elements

Physical Chemistry

1. Surface tension measurement (use of organic solvents excluded)
   a. Determination of the surface tension of a liquid or a dilute solution using a Stalagmometer
   b. Study of the variation of surface tension of a detergent solution with concentration
2. Viscosity measurement (use of organic solvents excluded)
   a. Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald's viscometer
   b. Study of the variation of viscosity of an aqueous solution with concentration of solute.

Inorganic Chemistry

Qualitative semi-micro analysis of mixtures containing three radicals. Emphasis should be given to the understanding of the chemistry of different reactions.

Acid Radicals: Cl^-, Br^-, I^-, NO_2^-, NO_3^-, S_2^-, SO_4^{2-}, PO_4^{3-}, BO_3^{3-}, H_3BO_3.

Basic Radicals: Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Cr^{3+}, Mn^{2+}, Fe^{3+}, Ni^{2+}, Cu^{2+}, NH^{4+}.

Reference Books:

1. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta, 2003.
2. Palit, S.R., Practical Physical Chemistry Science Book Agency.
3. Mukherjee, N.G., Selected Experiments in Physical Chemistry J. N. Ghose & Sons.
4. Dutta, S.K., Physical Chemistry Experiments Bharati Book Stall.
5. Svehla, G. Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
6. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

3rd Semester:

Course Code: CC-5

Course Title: Physical Chemistry-II (Theo) 4 Credits

Transport Processes:

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

2. 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.

3. 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-Hückel 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.

4. Transport number, Principles of Hittorf's and Moving-boundary method; Wien effect, Debye-Falkenhagen effect, Walden's rule.

Application of Thermodynamics – I

1. 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.

2. 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 and its derivation.

3. Nernst's distribution law; Application- (finding out K_{eq} using Nernst dist law for $KI+I_2 \Leftrightarrow KI_3$ and dimerization of benzene.

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

a) Pure ideal gas-its Chemical potential and other thermodynamic functions and their changes during a process; 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.

b) 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.

Foundation of Quantum Mechanics

1. 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).

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

3. 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.

4. Particle in a box: Setting up of Schrödinger equation for one-dimensional box and its solution; Comparison with free particle eigenfunctions and eigenvalues. Properties of PB 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.

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

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.
5. Rakshit, P.C., Physical Chemistry, Sarat Book House.
6. Moore, W. J. Physical Chemistry, Orient Longman.
7. Mortimer, R. G. Physical Chemistry, Elsevier.
8. Denbigh, K. The Principles of Chemical Equilibrium Cambridge University Press.
9. Engel, T. & Reid, P. Physical Chemistry, Pearson.
10. Levine, I. N. Quantum Chemistry, PHI.
11. Atkins, P. W. Molecular Quantum Mechanics, Oxford.
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. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics:Basic Concepts and Methods Wiley.
15. Glasstone, S. An Introduction to Electrochemistry, East-West Press.
16. Alberty, R. A., Sibley, R., Physical Chemistry, 5th Ed., Wiley, (2018).
17. Kapoor, K. L., A Textbook of Physical Chemistry, Vols. 1 & 4, Macmillan Publishers India Limited, (2006).

Course Code: CC-5

Course Title: Physical Chemistry-II (Prac) 2 Credits

1. Study of viscosity of unknown liquid (glycerol, sugar) with respect to water.
2. Determination of partition coefficient for the distribution of I_2 between water and CCl_4.
3. Determination of K_{eq} for $KI + I_2 \Leftrightarrow KI_3$, using partition coefficient between water and CCl_4.
4. Conductometric titration of an acid (strong, weak/ monobasic, dibasic) against strong base.
5. Study of saponification reaction conductometrically.
6. Verification of Ostwald's dilution law and determination of K_a 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.

Course Code: CC-6

Course Title: Inorganic Chemistry-II (Theo) 4 Credits

Chemical Bonding-I

1. Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its application and limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy. Solubility energetics of dissolution process.

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

Chemical Bonding-II

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

2. Metallic Bond: Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids – stoichiometric and non-stoichiometric.

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

Radioactivity

1. Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers.

2. Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Separation and uses of isotopes.

3. Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures.

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.
11. Atkins, P., Overton, T., Rourke, J., Weller, M., Armstrong, F,. Shriver & Atkins, Inorganic Chemistry, Fifth Edition, Oxford University Press.
12. Arnikar, H. J. Essentials of Nuclear Chemistry, New Age International, 1995.

Course Code: CC-6

Course Title: Inorganic Chemistry-II (Prac) 2 Credits

Iodo/Iodimetric Titrations

1. Estimation of Cu(II).
2. Estimation of Vitamin C.
3. Estimation of arsenite by iodimetric method.
3. Estimation of Cu in brass.
4. Estimation of Cr and Mn in Steel.

Reference Book(s)

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

Course Code: CC-7

Course Title: Organic Chemistry-III (Theo) 4 Credits

Chemistry of alkenes and alkynes

1. Addition to C=C: mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenations, iodolactonisation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, syn and anti-hydroxylation, ozonolysis, addition of singlet and triplet carbenes; electrophilic addition to diene (conjugated dienes and allene); radical addition: HBr addition; mechanism of allylic and benzylic bromination in competition with brominations across C=C; use of NBS; Birch reduction of benzenoid aromatics; interconversion of E- and Z-alkenes.

2. 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.

Aromatic Substitution

1. 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.

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

Carbonyl and Related Compounds

1. 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 reaction; 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.

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

3. Aldol, Friedel-Crafts, Michael, Knoevenagel, Cannizzaro, Benzoin condensation and Dieckmann condensation by greener approach.

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

5. 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).

Organometallics

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard and organolithium to carbonyl compounds; substitution on -COX; conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky 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.

Course Code: CC-7

Course Title: Organic Chemistry-III (Prac) 2 Credits

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: H2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
3. Detection of the following functional groups by systematic chemical tests:
4. aromatic amino ($-NH_2$), aromatic nitro ($-NO_2$), amido ($-CONH_2$, including imide), phenolic – OH, carboxylic acid (-COOH), carbonyl (-CHO and >C=O); only one test for each functional group is to be reported.
5. Melting point of the given compound
6. Preparation of one derivative of the given sample

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.
7. Ghoshal, A., Mahapatra, B., Nad, A. K. An Advanced Course in Practical Chemistry, New Central Book Agency (2007).

Course Code: SEC-1

Course Title: IT skill in Chemistry 2 Credits

Mathematics

1. 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.

2. Uncertainty in measurement: Displaying uncertainties, 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).

3. 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).

4. 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).

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

Computer Programming

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. 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).

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.

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).

Course Code: SEC-1

Course Title: Basic Analytical Chemistry 2 Credits

Introduction

Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. Presentation of experimental data and results. Role of significant figures.

Analysis of soil

Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators.

Analysis of water

Definition of pure water, contaminants (different type), water sampling methods, water purification methods.

Analysis of food products

Nutritional value of foods, idea about food processing and food preservations and adulteration.

Chromatography

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

Ion-exchange

Column, ion-exchange chromatography etc., determination of ion exchange capacity of anion / cation exchange resin.

Analysis of cosmetics

Major and minor constituents and their function: Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.

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 sixth 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.

Course Code: Generic Elective-3 (Theo) 4 Credits

(For the students of discipline other than chemistry)

Title: **Chemical Energetics, Equilibria, Organic Chemistry-II**

Physical Chemistry

4. Chemical Energetics

a. Intensive and extensive properties; 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

b. 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, Kirchoff's equation and effect of pressure on enthalpy, Adiabatic flame temperature; explosion temperature

c. Statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines, Carnot cycle, Physical concept of Entropy; Carnot engine, refrigerator and efficiency; Entropy change of systems and surroundings for various processes and transformations; Auxiliary state functions (G and A) and Criteria for spontaneity and equilibrium.

5. Chemical Equilibrium:

a. Thermodynamic conditions for equilibrium, degree of advancement; 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 and relation among them; van't Hoff's reaction isotherm, 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.

6. Ionic Equilibria:

a. Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water; Ionization of weak acids and bases, pH scale, common ion effect; Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts; Buffer solutions; Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

Organic Chemistry

Functional group app roach for the following reactions (preparations & reactions) to be studied in context to their structures.

1. Aromatic Hydrocarbons

Benzene: Preparation: from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid. Reactions: electrophilic substitution (general mechanism); nitration (with mechanism), halogenations (chlorination and bromination), sulphonation and Friedel-Craft's reaction (alkylation and acylation) (up to 4 carbons on benzene); side chain oxidation of alkyl benzenes (up to 4 carbons on benzene).

2. Organometallic Compounds

Introduction; Grignard reagents: Preparations (from alkyl and aryl halide); concept of umpolung; Reformatsky reaction.

3. Aryl Halides

Preparation: (chloro-, bromo- and iodobenzene): from phenol, Sandmeyer reactions. Reactions (Chlorobenzene): nucleophilic aromatic substitution (replacement by –OH group) and effect of nitro substituent (activated nucleophilic substitution).

4. Alcohols, Phenols and Ethers

a. Alcohols: (up to 5 Carbons). Preparation: 1°-, 2°- and 3°- alcohols: using Grignard reagent, reduction of aldehydes, ketones, carboxylic acid and esters; Reactions: With sodium, HX (Lucas test), oxidation (alkaline $KMnO_4$, acidic dichromate, concentrated HNO_3); Oppenauer oxidation;

b. Diols: Preparation (with OsO_4); pinacol- pinacolone rearrangement (with mechanism) (with symmetrical diols only).

c. Phenols: Preparation: cumene hydroperoxide method, from diazonium salts; acidic nature of phenols; Reactions: electrophilic substitution: nitration and halogenations; Reimer -Tiemann reaction, Houben–Hoesch condensation, Schotten –Baumann reaction, Fries rearrangement and Claisen rearrangement.

d. Ethers: Preparation: Williamson's ether synthesis; Reaction: cleavage of ethers with HI.

5. Carbonyl Compounds

Aldehydes and Ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde, acetone and benzaldehyde): Preparation: from acid chlorides, from nitriles and from Grignard reagents; general properties of aldehydes and ketones; Reactions: with HCN, ROH, $NaHSO_3$, NH_2-G

derivatives and with Tollens' and Fehling's reagents; iodoform test; aldol condensation (with mechanism); Cannizzaro reaction (with mechanism), Wittig reaction, benzoin condensation; Clemmensen reduction, Wolff- Kishner reduction and Meerwein-Pondorff- Verley (MPV) reduction.

Reference Books:

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
5. Ekambaram, S. General Chemistry, Pearson.
6. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
7. Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.
8. Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.
9. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.
10. Mandal, A. K. Degree Physical and General Chemistry Sarat Book House.
11. Pahari, S., Physical Chemistry New Central Book Agency.
12. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency.
13. Sethi, A. Conceptual Organic Chemistry; New Age International Publisher.
14. Parmar, V. S. A Text Book of Organic Chemistry, S. Chand & Sons.
15. Madan, R. L. Organic Chemistry, S. Chand & Sons.
16. Wade, L. G., Singh, M. S., Organic Chemistry, Pearson.
17. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
18. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
19. Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.

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Course Code: Generic Elective-3 (Prac) 2 Credits

(For the students of discipline other than chemistry)

Title: **Chemical Energetics, Equilibria, Organic Chemistry-II**

Ionic Equilibria

1. Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH-meter and compare it with the indicator method.

2. Preparation of buffer solutions and find the pH of an unknown buffer solution by colour matching method (using following buffers).

a. Sodium acetate-acetic acid; b. Ammonium chloride-ammonium hydroxide.

3. Study of the solubility of benzoic acid in water.

Organic Chemistry

Identification of a pure organic compound

1. Solid compounds: oxalic acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.

2. Liquid Compounds: acetone, aniline and nitrobenzene.

References

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

2. Palit, S.R., Practical Physical Chemistry Science Book Agency

3. Mukherjee, N.G., Selected Experiments in Physical Chemistry J. N. Ghose & Sons

4. Dutta, S.K., Physical Chemistry Experiments Bharati Book Stall

5. Bhattacharyya, R. C, A Manual of Practical Chemistry.

6. Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., Textbook of Practical Organic Chemistry, Prentice-Hall, 5th edition, 1996.

4th Semester:

Course Code: CC-8

Course Title: Physical Chemistry-III (Theo) 4 Credits

Application of Thermodynamics – II

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

2. Phase rule: Definitions of phase, component and degrees of freedom; Phase rule and its derivations; Phase diagram for water, CO_2, Sulphur

3. First order phase transition and Clapeyron equation; Clausius-Clapeyron equation - derivation and use; Liquid vapour equilibrium for two component systems.

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

5. 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.

Electrical Properties of molecules

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

2. 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 EMF

measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone and glass electrodes.

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

Quantum Chemistry

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

2. 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)

3. 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.

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, Viva Press.
4. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
5. Moore, W. J. Physical Chemistry, Orient Longman.
6. Mortimer, R. G. Physical Chemistry, Elsevier.
7. Engel, T. & Reid, P. Physical Chemistry, Pearson.
8. Levine, I. N. Quantum Chemistry, PHI.
9. Atkins, P. W. Molecular Quantum Mechanics, Oxford.
10. Engel, T. & Reid, P. 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 Methods Wiley.
13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.
14. Glasstone, S. An Introduction to Electrochemistry, East-West Press.

Course Code: CC-8

Course Title: Physical Chemistry-III (Prac) 2 Credits

List of Practical

1. Determination of solubility of sparingly soluble salt in water, in electrolyte with common ions and in neutral electrolyte (using common indicator).
2. Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$ solution.
3. Determination of K_{sp} for AgCl by potentiometric titration of $AgNO_3$ solution against standard KCl solution.
4. Effect of ionic strength on the rate of Persulphate – Iodide reaction.
5. Study of phenol-water phase diagram.

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.

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Course Code: CC-9

Course Title: Inorganic Chemistry-III (Theo) 4 Credits

Inorganic Chemistry III

General Principles of Metallurgy:

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

Chemistry of s and p Block Elements:

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

Noble Gases:

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

Inorganic Polymers:

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

Coordination Chemistry-I :

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

Reference Books:

1. 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, 980.
6. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998)**.**
7. Sarkar, R, General and inorganic chemistry, Volume II, New central book agency, (2012).

Course Code: CC-9

Course Title: Inorganic Chemistry-III (Prac) 2 Credits

Complexometric titration

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

Inorganic preparations

1. $[Cu(CH_3CN)4]PF_6/ClO_4$
2. Potassium dioxalatodiaquachromate(III)
3. Tetraamminecarbonatocobalt (III) ion
4. Potassium tris(oxalate)ferrate(III)
5. Tris-(ethylenediamine) nickel(II) chloride.
6. $[Mn(acac)_3]$ and $Fe(acac)_3]$ (acac= acetylacetonate).

Reference Books:

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

Course Code: CC-10

Course Title: Organic Chemistry-IV (Theo) 4 Credits

Nitrogen compounds

1. 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.

2. 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.

3. Alkylnitrile and isonitrile: preparation and reaction (with mechanism): Thorpe nitrile condensation, von Richter reaction.

4. Diazonium salts and their related compounds: reactions (with mechanism) involving replacement of diazo group; reactions: Gomberg, Meerwein, Japp-Klingermann.

Rearrangements

Mechanism with evidence and stereochemical features for the following:

1. 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.

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

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

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

5. 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.

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

The Logic of Organic Synthesis

1. 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).

2. Strategy of ring synthesis: thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique.

3. 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 model.

Organic Spectroscopy:

1. UV Spectroscopy: introduction; types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; Bathochromic and Hypsochromic shifts; intensity of absorptions (Hyper-/Hypochromic effects); application of Woodward's Rules for calculation of λ_{max} for the following systems: conjugated diene, α,β-unsaturated aldehydes and ketones (alicyclic, homoannular and heteroannular); extended conjugated systems (dienes, aldehydes and ketones); relative positions of λ_{max} considering conjugative effect, steric effect, solvent effect, effect of pH; effective chromophore concentration: keto-enol systems; benzenoid transitions.

2. 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.

3. 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.

4. 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.
7. Pavia, D. L. et al. Introduction to Spectroscopy, 5th Ed. Cengage Learning India Ed. (2015).
8. Dyer, J. Application of Absorption Spectroscopy of Organic Compounds, PHI Private Limited.
9. March, J. Advanced Organic Chemistry, Fourth edition, Wiley.
10. Harwood, L. M., Polar Rearrangements, Oxford Chemistry Primer, Oxford University Press.
11. Bailey, Morgan, Organonitrogen Chemistry, Oxford Chemistry Primer, Oxford University Press.
12. Warren, S. Organic Synthesis the Disconnection Approach, John Wiley and Sons.

13. Warren, S., Designing Organic Synthesis, Wiley India, 2009.
14. Carruthers, W. Modern methods of Organic Synthesis, Cambridge University Press.
15. Willis, C. A., Wills, M., Organic Synthesis, Oxford Chemistry Primer, Oxford University Press.

Course Code: CC-10

Course Title: Organic Chemistry-IV (Prac) 2 Credits

List of Practical

1. Estimation of glucose by titration using Fehling's solution
2. Estimation of vitamin-C (reduced)
3. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) method
4. Estimation of phenol by bromination (Bromate-Bromide) method
5. Estimation of formaldehyde (Formalin)
6. Estimation of acetic acid in commercial vinegar
7. Estimation of urea (hypobromite method)
8. Estimation of saponification value of oil/fat/ester.

Reference Books

1. Vogel, A. I. Qualitative Organic Analysis, Pearson.
2. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta.
3. Ghoshal, A., Mahapatra, B., Nad, A. K. An Advanced Course in Practical Chemistry, New Central Book Agency (2007).
4. Ahluwalia, V. K., Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, Universities Press (India) Pvt. Ltd. (2000).

Course Code: SEC-2

Course Title: Pharmaceuticals Chemistry 2 Credits

Drugs & Pharmaceuticals

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

Fermentation

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.

Reference Books

1. Patrick, G. L. Introduction to Medicinal Chemistry, Oxford University Press, UK, 2013.
2. Singh, H. & Kapoor, V.K. Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi, 2012.
3. Foye, W.O., Lemke, T.L. & William, D.A.: Principles of Medicinal Chemistry, 4th ed., B.I. Waverly Pvt. Ltd. New Delhi.
4. El-Mansi, E.M.T., Bryce, C.F.A., Ddemain, A.L., Allman, A.R., Fermentatias Microbiology and Biotechnology, 2nd Ed. Taylor & Francis.
5. Prescott & Dunn's Industrial Microbilogy, 2004, CBS Publisher.

Course Code: SEC-2

Course Title: Analytical Clinical Biochemistry 2 Credits

Review of Concepts from Core Course

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

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

3. Enzymes: Nomenclature, Characteristics (mention of Ribozymes), and Classification; Effect of temperature and pH on enzyme activity; Active site, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme inhibitors, Introduction to Biocatalysis: Importance in "Green Chemistry" and Chemical Industry.

4. 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.

5. Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy.

Biochemistry of disease: A diagnostic approach

1. 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.

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

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.

Course Code: Generic Elective-4 (Theo) 4 Credits

(For the students of discipline other than chemistry)

Title: **Solutions, Phase Equilibria, Conductance, Electrochemistry & Analytical and Environmental Chemistry**

Physical Chemistry

1. Solutions

a. Ideal solutions and Raoult's law, deviations from Raoult's law – non-ideal solutions; Vapour pressure-composition and temperature-composition curves of ideal and non-ideal solutions; Distillation of solutions; Lever rule; Azeotropes.

b. Critical solution temperature; effect of impurity on partial miscibility of liquids; Immiscibility of liquids- Principle of steam distillation; Nernst distribution law and its applications, solvent extraction.

2. Phase Equilibria

a. Phases, components and degrees of freedom of a system, criteria of phase equilibrium; Gibbs Phase Rule and its thermodynamic derivation; Derivation of Clausius – Clapeyron equation and its importance in phase equilibria; Phase diagrams of one-component system (water).

3. Conductance

a. 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; Ostwald's dilution law; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations (acid-base).

b. Transport Number and principle of Moving-boundary method.

4. Electromotive force

a. 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; Electrochemical series; Thermodynamics of a reversible cell, calculation of thermodynamic properties: G, H and S from EMF data.

b. Concentration cells with and without transference, liquid junction potential; pH determination using hydrogen electrode and quinhydrone; Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).

Analytical and Environmental Chemistry

1. Chemical Analysis

a. Gravimetric analysis: solubility product and common ion effect; requirements of gravimetry; gravimetric estimation of chloride, sulphate, lead, barium, nickel, copper and zinc.

b. Volumetric analysis: primary and secondary standard substances; principles of acid-base, oxidation –reduction and complexometric titrations; indicators: acid-base, redox and metal ion; principles of estimation of mixtures: $NaHCO_3$ and Na_2CO_3 (by acidimetry); iron, copper, manganese and chromium (by redox titration); zinc, aluminum, calcium and magnesium (by complexometric EDTA titration).

c. Chromatography: Chromatographic methods of analysis: column chromatography and thin layer chromatography.

2. Environmental Chemistry

a. The Atmosphere: composition and structure of the atmosphere; troposphere, stratosphere, mesosphere and thermosphere; ozone layer and its role; major air pollutants: CO, SO2, NOx and particulate matters – their origin and harmful effects; problem of ozone layer depletion; green house effect; acid rain and photochemical smog; air pollution episodes: air quality standard; air pollution control measures: cyclone collector, electrostatic precipitator, catalytic converter.

b. The Hydrosphere: environmental role of water, natural water sources, water treatment for industrial, domestic and laboratory uses; water pollutants; action of soaps and detergents, phosphates, industrial effluents, agricultural runoff, domestic wastes; thermal pollution, radioactive pollution and their effects on animal and plant life; water pollution episodes: water pollution control measures : waste water treatment; chemical treatment and microbial treatment; water quality standards: DO, BOD, COD, TDS and hardness parameters; desalination of sea water : reverse osmosis, electrodialysis.

c. The Lithosphere: water and air in soil, waste matters and pollutants in soil, waste classification, treatment and disposal; soil pollution and control measures.

Reference Books:

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).

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

3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).

4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).

5. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).

6. Chugh, K.L., Agnish, S.L. A Text Book of Physical Chemistry Kalyani Publishers.

7. Bahl, B.S., Bahl, A., Tuli, G.D., Essentials of Physical Chemistry S. Chand & Co. ltd.

8. Palit, S. R., Elementary Physical Chemistry Book Syndicate Pvt. Ltd.

9. Pahari, S., Physical Chemistry New Central Book Agency.

10. Pahari, S., Pahari, D., Problems in Physical Chemistry New Central Book Agency.

11. Banerjee, S. P. A Text Book of Analytical Chemistry, The New Book Stall.

12. Gangopadhyay, P. K. Application Oriented Chemistry, Book Syndicate.

13. Mondal, A. K & Mondal, S. Degree Applied Chemistry, Sreedhar Publications.

14. Banerjee, S. P. A Text Book of Analytical Chemistry, The New Book Stall.

15. Manahan, S. Environmental Chemistry, CRC Press, 9^{th} Ed.

Course Code: Generic Elective-4 (Prac) 2 Credits

(For the students of discipline other than chemistry)

Title: **Solutions, Phase Equilibria, Conductance, Electrochemistry & Analytical and Environmental Chemistry**

Physical Chemistry

1. Distribution Law (Any one)

Study of the equilibrium of one of the following reactions by the distribution method:

a. I_2 (aq) + I^- (aq) = I^{3-} (aq)

b. Cu^{2+} (aq) + xNH^2 (aq) = $[Cu(NH_3)x]^{2+}$

2. Conductance

a. Determination of dissociation constant of a weak acid (cell constant, equivalent conductance are also determined)

b. Perform the following conductometric titrations: (Any one)

i. Strong acid vs. strong base.

ii. Weak acid vs. strong base.

3. Potentiometry

Perform the following potentiometric titrations:

a. Weak acid vs. strong base.

b. Potassium dichromate vs. Mohr's salt.

Analytic and Environmental Chemistry

1. To find the total hardness of water by EDTA titration.

2. To find the PH of an unknown solution by comparing color of a series of HCl solutions + 1 drop of methyl orange, and a similar series of NaOH solutions + 1 drop of phenolphthalein.

3. To determine the rate constant for the acid catalysed hydrolysis of an ester.

4. Determination of the strength of the H_2O_2 sample.

5. To determine the solubility of a sparingly soluble salt, e.g. KHTa (one bottle).

References Books:

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

2. Palit, S.R., Practical Physical Chemistry Science Book Agency.

3. Mukherjee, N.G., Selected Experiments in Physical Chemistry J. N. Ghose & Sons.

4. Dutta, S.K., Physical Chemistry Experiments Bharati Book Stall.
5. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
6. Ghosal, Mahapatra & Nad, An Advanced Course in Practical Chemistry, New Central Book Agency.
7. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta, 2003.
8. Das, S. C., Chakraborty, S. B., Practical Chemistry.

5th Semester:

Course Code: CC-11

Course Title: Inorganic Chemistry-IV (Theo) 4 Credits

Coordination Chemistry-II

VB description and its limitations. Elementary Crystal Field Theory: splitting of d^n configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series. Jahn- Teller distortion. Octahedral site stabilization energy (OSSE). Metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples). Magnetism and Colour: Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ ions. Racah parameter. Selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea).

Chemistry of d- and f- block elements

Transition Elements:

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

Lanthanoids and Actinoids:

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

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

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Course Code: CC-11

Course Title: Inorganic Chemistry-IV (Prac) 2 Credits

Chromatography of metal ions

Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:

1. Ni (II) and Co (II)
2. Fe (III) and Al (III)

Gravimetry

1. Estimation of nickel (II) using Dimethylglyoxime (DMG).
2. Estimation of copper as CuSCN
3. Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminium oxinate)
4. Estimation of chloride

Spectrophotometry

1. Measurement of 10Dq of 3d metal complexes by spectrophotometric method.
2. Determination of λ_{max} of $KMnO_4$ and $K_2Cr_2O_7$.

Reference Books:

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

Course Code: CC-12

Course Title: Organic Chemistry-V (Theo) 4 Credits

Carbocycles and Heterocycles

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

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

Cyclic Stereochemistry

Alicyclic compounds: concept of I-strain; conformational analysis: cyclohexane, mono and disubstituted cyclohexane; symmetry properties and optical activity; ring-size and ease of cyclisation; conformation & reactivity in cyclohexane system: consideration of steric and stereoelectronic requirements; elimination (E2, E1), nucleophilic substitution (SN1, SN2, SNi, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic syn elimination and fragmentation reactions.

Pericyclic reactions

Mechanism, stereochemistry, regioselectivity in case of

1. Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions.

2. Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions.

3. Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3]- and [1,5]-H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements.

Carbohydrates

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

Biomolecules

1. Amino acids: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction; resolution of racemic amino acids.

2. Peptides: peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using N-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: C-terminal and N-terminal unit determination (Edman, Sanger & 'dansyl' methods); partial hydrolysis; specific cleavage of peptides: use of CNBr.

3. Nucleic acids: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; elementary idea of double helical structure of DNA (Watson-Crick model); complimentary base–pairing in DNA.

Alkaloids and Terpenoids

General studies on terpenoids and alkaloids; determination of structure of α-Terpenol and ephedrine.

Reference Books:

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

Course Code: CC-12

Course Title: Organic Chemistry-V (Prac) 2 Credits

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 mixture of dyes
4. Paper chromatographic separation of a mixture containing 2/3 amino acids

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.

Course Code: DSE-1

Course Title: Advanced Physical Chemistry (Theo) 4 Credits

Crystal Structure

1. Bravais Lattice and Laws of Crystallography: Types of solid, Bragg's law of diffraction; Laws of crystallography (Haüy's law and Steno's law); Permissible symmetry axes in crystals; Lattice, space lattice, unit cell, crystal planes, Bravais lattice. Packing of uniform hard sphere, close packed arrangements (fcc and hcp); Tetrahedral and octahedral voids.

2. Crystal planes: Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of d_{hkl}; Relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation)

3. Determination of crystal structure: Powder method; Structure of NaCl and KCl crystals.

Statistical Thermodynamics

1. Configuration: Macrostates, microstates and configuration; calculation with harmonic oscillator; variation of W with E; equilibrium configuration

2. Boltzmann distribution: Thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation); Applications to barometric distribution; Partition function, concept of ensemble - canonical ensemble.

3. Partition function: molecular partition function and thermodynamic properties, Maxwell's speed distribution; Gibbs' paradox.

Special selected topics

1. Specific heat of solid: Coefficient of thermal expansion, thermal compressibility of solids; Dulong –Petit's law; Perfect Crystal model, Einstein's theory – derivation from partition function, limitations; Debye's T^3 law – analysis at the two extremes (without derivation of T^3 law).

2. 3rd law: Absolute entropy, Planck's law, Calculation of entropy, Nernst heat theorem

3. Polymers: Classification of polymers, nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers; Criteria for synthetic polymer formation; Relationships between functionality, extent of reaction and degree of polymerization; Mechanism and kinetics of step growth and copolymerization; Conducting polymers.

4. 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.

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.
14. McQuarrie, D. A. Mathematics for Physical Chemistry, University Science Books (2008).
15. Tanford, C., Physical chemistry of macromolecules, John Wiley & Sons, Inc., 440 Park Ave. South, New York 16, N. Y., 1961.

Course Code: DSE-1

Course Title: Advanced Physical Chemistry (Prac) 2 Credits

List of Practical

Computer Programming based on numerical methods for:

1. Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid)
2. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations)
3. Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values
4. Matrix operations (Application of Gauss-Siedel method in colourimetry)

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).

Course Code: DSE-2

Course Title: Analytical methods in chemistry (Theo) 4 Credits

Qualitative and quantitative aspects of analysis

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

Optical methods of analysis

1. Origin of spectra, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

2. UV-Visible Spectrophotometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

3. 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.

4. Infrared Spectroscopy: 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.

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

Thermal methods of analysis

Theory of thermogravimetry (TG), basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.

Electroanalytical methods

Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values.

Separation techniques

1. Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation.
2. Technique of extraction: batch, continuous and counter current extractions.
3. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.
4. Chromatography: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange.
5. Development of chromatograms: frontal, elution and displacement methods.
6. Qualitative and quantitative aspects of chromatographic methods of analysis: TLC, LC, GLC, and HPLC.
7. Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of enantiomeric composition using NMR, Chiral solvents and chiral shift reagents. Chiral chromatographic techniques using chiral columns (GC and HPLC).
8. 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.

Course Code: DSE-2

Course Title: Analytical methods in chemistry (Prac) 2 Credits

Separation Techniques - Chromatography

1. *Separation of mixtures*

Separation and identification of the monosaccharides in a mixture (glucose & fructose) by paper chromatography. Reporting the R_f values.

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

3. Separation of the active ingredients of plants, flowers and juices by TLC

Solvent Extractions

1. To separate a mixture of Ni^{2+} & Fe^{2+} by complexation with DMG and extracting the Ni^{2+}-DMG complex in chloroform, and determine its concentration by spectrophotometry.

2. *Analysis of soil*:

a. Determination of pH of soil.

b. Total soluble salt

c. Estimation of calcium, magnesium, phosphate, nitrate

3. *Ion exchange*:

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

Spectrophotometry

1. Determination of pKa values of indicator using spectrophotometry
2. Determination of chemical oxygen demand (COD)
3. Determination of Biological oxygen demand (BOD)

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. And Nieman, T.A. Principles of Instrumental Analysis, Cengage Learning India Edition.
7. Mikes, O. & Chalmes, R.A. Laboratory Handbook of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
8. Ditts, R.V. Analytical Chemistry: Methods of separation. Van Nostrand, New York, 1974.

Course Code: DSE-2

Course Title: Instrumental methods of chemical analysis (Theo) 4 Credits

Molecular spectroscopy

1. Infrared spectroscopy: Interactions of light with molecules: absorption and scattering phenomena, light sources, wavelength dispersion, time resolution, detection of the signal, interpretation of spectrum, advantages of Fourier Transform in infrared spectroscopy (FTIR).

Applications: Quality assurance and quality control, problems on on-line monitoring of samples.

2. UV-Visible and fluorescence spectroscopy: Excitation sources, wavelength dispersion, placement of sample, Detection of signal, sensitivity, signal to noise ratio (S/N), single and double beam instruments, Interpretation of results, absorption vs. fluorescence spectrum: mirror image relationship.

Separation techniques

1. Chromatography: Gas chromatography, liquid chromatography, supercritical fluids, Importance of column technology (packing, capillaries), parameters influencing separation.

2. Detection: Gas and liquid, Detection using IR and Mass spectroscopic techniques, as a means of further analysis (use of tags and coupling to IR and MS), Electrophoresis and its use for DNA analysis.

Elemental analysis

1. Mass spectrometry.

2. Atomic absorption, Atomic emission, and Atomic fluorescence.

3. Atomization techniques: Flames, electrical discharges, plasmas; Radiation sources; Interpretation: Errors due to molecular and ionic species, matrix effects, other interferences.

NMR spectroscopy

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

Electroanalytical Methods: Elementary ideas

Potentiometry & Voltammetry

Elementary idea as advanced spectroscopic techniques

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.

Course Code: DSE-2

Course Title: Instrumental methods of chemical analysis (Prac) 2 Credits

List of Practicals

1. Safety Practices in the Chemistry Laboratory
2. Determination of the isoelectric pH of a protein.
3. Determination of Cobalt and Nickel in a Mixture of (by spectrophometry)
4. Study of Electronic Transitions in Organic Molecules (i.e., acetone in water)
5. IR Absorption Spectral study of Aldehydes and Ketones (only analysis)
6. Potentiometric Titration of a Chloride-Iodide Mixture
7. Cyclic Voltammetry of the Ferrocyanide/Ferricyanide Couple
8. Nuclear Magnetic Resonance: Spectral analysis and interpretation of NMR spectra.

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.

6th Semester:

Course Code: CC-13

Course Title: Inorganic Chemistry-V (Theo) 4 Credits

Bioinorganic Chemistry

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

Organometallic Chemistry

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

Catalysis by Organometallic Compounds

Study of the following industrial processes

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

Reaction Kinetics and Mechanism

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

Reference Books

1. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.
2. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.
3. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997.
4. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6^{th} Ed. 1999., Wiley.
5. Bertini, I., Gray, H. B., Lippard, S.J., Valentine, J. S., Viva, 2007.
6. Basolo, F, and Pearson, R.C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.
7. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.
8. Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988.
9. Collman, J. P. et al. Principles and Applications of Organotransition Metal Chemistry. Mill Valley, CA: University Science Books, 1987.
10. Crabtree, R. H. The Organometallic Chemistry of the Transition Metals. New York, NY: John Wiley, 2000.

Course Code: CC-13

Course Title: Inorganic Chemistry-V (Prac) 2 Credits

Qualitative semimicro analysis

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

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

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

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

Reference Books

1. Svehla, G., Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
2. Das, A. K., A text book on medicinal aspects of bio-inorganic chemistry, CBS Publishers & Distributors, New Delhi, 2nd edition.
3. Das, A. K., Bio-Inorganic chemistry, Books & Allied, Kolkata (2007).
4. Karmakar, P., Sarkar (Sain), R., Ray, S., Ghosh, A.K. Concise Practical Chemistry (B.Sc. General and Honours), PART-I, The New Book Stall, Kolkata (2018).

Course Code: CC-14

Course Title: Physical Chemistry-IV (Theo) 4 Credits

Molecular Spectroscopy

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

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

3. Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration.

4. Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion

5. Nuclear Magnetic Resonance (NMR) spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and low resolution spectra, different scales, spin-spin coupling and high resolution spectra.

Photochemistry

1. Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, Stark-Einstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields

2. Photochemical Processes: Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; Fluorescence and phosphorescence, Jablonski diagram;

3. 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.

Surface phenomenon

1. 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 surfaces; Vapour pressure over curved surface; Temperature dependence of surface tension

2. 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;

3. 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.

Course Code: CC-14

Course Title: Physical Chemistry-IV (Prac) 2 Credits

List of Practical

1. Determination of surface tension of a liquid using Stalagmometer.
2. Determination of CMC from surface tension measurements.
3. Verification of Beer and Lambert's Law for $KMnO_4$ and $K_2Cr_2O_7$ solution.
4. Determination of pH of unknown buffer, spectrophotometrically.

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.

Course Code: DSE-3

Course Title: Green Chemistry (Theo) 4 Credits

DSE-T4 Green Chemistry: Principles and applications

Twelve principles and goals of green Chemistry:

* Designing greener processes: Prevention of waste/ by-products; 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.

* Green solvents– supercritical carbon dioxide, water as green solvent, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents.

* Use of microwaves and ultrasonic energy in green processes.

* Selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/ protecting groups.

* Preferential use of catalytic reagents over stoichiometric reagents; comparison of heterogeneous and homogeneous catalysis, bio-catalysis, photo-catalysis.

* Development of green analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

Examples of Green Synthesis/ Reactions and some real world cases

* Green synthesis of adipic acid: Starting from cyclohexanol/cyclohexanone/cyclohexene

* Microwave assisted reactions in water: Hofmann Elimination, oxidation of toluene and alcohols; Diels-Alder reaction and Decarboxylation reaction

* Ultrasound assisted reactions: Simmons-Smith reaction.

* Application of surfactant absorbed carbon dioxide for dry cleaning and precision cleaning of garments.

* Rightfit pigment: synthetic azopigments to replace toxic organic and inorganic pigments.

* An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.

* Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of no Trans-Fats and Oils

Future scope:

Oxidising and reducing reagents and catalysts; multifunctional reagents; combinatorial green chemistry;

Green chemistry in sustainable development: Bio-diesel, bio-ethanol and biogas.

Reference Book

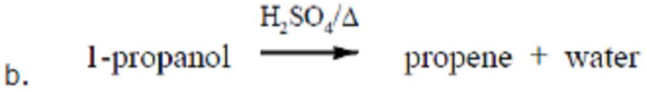
1. Anastas, P.T. & Warner, J.K.: Green Chemistry - Theory and Practical, Oxford University Press (1998).
2. Matlack, A.S. Introduction to Green Chemistry, Marcel Dekker (2001).
3. Cann, M.C. & Connely, M.E. Real-World cases in Green Chemistry, American Chemical Society, Washington (2000).
4. Ryan, M.A. & Tinnesand, M. Introduction to Green Chemistry, American Chemical Society, Washington (2002).
5. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2nd Edition, 2010.
6. Gurtu, J. N., Gurtu, A. Introductory Green Chemistry, Pragati Prakashan (2014).

Course Code: DSE-3 2 Credits

Course Title: Green Chemistry (Prac)

1. Preparation of propene by two methods can be studied

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

b. 

2. Other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy.

3. Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide.

4. 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.

Course Code: DSE-3

Course Title: Polymer Chemistry (Theo) 4 Credits

Introduction and history of polymeric materials

Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.

Functionality and its importance

Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bi-functional systems, Poly-functional systems.

Kinetics of Polymerization

Mechanism and kinetics of step growth, radical chain growth, kinetics of copolymerization, polymerization techniques.

Determination of molecular weight of polymers

$\overline{M}_n$, $\overline{M}_w$, etc. (by end group analysis), viscometry, osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

Glass transition temperature (Tg) and determination of Tg

Free volume theory, WLF equation, Factors affecting glass transition temperature (Tg).

Polymer Solution

Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions**.**

Properties of Polymer (Physical, thermal, Flow & Mechanical Properties)

Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers. Polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac).

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.
6. Tanford, C., Physical chemistry of macromolecules, John Wiley & Sons, Inc., 440 Park Ave. South, New York 16, N. Y., 1961.

Course Code: DSE-3

Course Title: Polymer Chemistry (Prac) 2 Credits

Polymer Synthesis

1. Preparation of nylon 66/6
2. Preparations of novalac resin/ resold resin.

Polymer Characterization

1. Determination of molecular weight by viscometry:

a. Polyacrylamide-aq.$NaNO_2$ solution

b. (Poly vinyl proplylidine (PVP) in water

2. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer Analysis

1. 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).

Course Code: DSE-4

Course Title: Inorganic materials of industrial importance (Theo) 4 Credits

Silicate Industries

1. 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.

2. 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.

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

Fertilizers

Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

Surface Coatings

Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Oil paint, Vehicle, modified oils, Pigments, toners and lakes pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, additives, Metallic coatings (electrolytic and electroless), metal spraying and anodizing.

Batteries

Primary and secondary batteries, battery components and their role, Characteristics of Battery. Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.

Alloys

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

Catalysis

General principles and properties of catalysts, homogenous catalysis (Hydroformylation, Wacker (Smidt) Process, Monsanto acetic acid process, Wilkinson's catalyst), and heterogenous catalysis (Zeigler-Natta Polymerizations, water gas reaction), catalytic steps and their industrial applications, Deactivation or regeneration of catalysts.

Phase transfer catalysts, application of zeolites as catalysts.

Chemical explosives

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

Reference Book

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).

Course Code: DSE-4

Course Title: Inorganic materials of industrial importance (Prac) 2 Credits

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. Determination of composition of dolomite (by complexometric titration).
5. Analysis of (Cu, Ni); (Cu, Zn) in alloy or synthetic samples.
6. Analysis of Cement.
7. 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).

Course Code: DSE-4

Course Title: Dissertation followed by power point presentation (4 + 2) Credits