THE UNIVERSITY OF BURDWAN

Syllabus of 3-Year Degree/4-Year Honours

in

Chemistry

Under Curriculum and Credit Framework for Undergraduate Programme (CCFUP) as per National Education Policy 2020

with effect from 2023-24

Semester-wise and Course-wise Distribution of Credit & Marks under CCFUP of NEP, 2020

Sem	Course type	Paper code	Course name	Credit				Marks			
				T	Lec	Prac	Tut	Th	Prac	IA	T
I	Major	CHEM1011	Basic Chemistry-I	4	3	1	0	40	20	15	75
	Minor	CHEM1021	General Chemistry-I	4	3	1	0	40	20	15	75
	Multi/ Interdisciplinary	CHEM1031	Chemistry for household importance	3	3	0	0	40	00	10	50
	Ability Enhancement Course (AEC) MIL (L_1-1)	AEC1041	Arabic/ Bengali/ Hindi/ Sanskrit/ Santali/ Urdu Or Equivalent Course from SWAYAM or other UGC recognized Platform.	2	2	0	0	40	00	10	50
	Skill Enhancement Course (SEC)	CHEM1051	Drugs and pharmaceuticals	3	3	0	0	40	00	10	50
	Common Value Added (CVA) Course	CVA 1061	Environmental Science/Education	4	3	1	0	60	20	20	100
II	Major	CHEM2011	Basic Chemistry-II	4	3	1	0	40	20	15	75
	Minor	CHEM2021	General Chemistry-II	4	3	1	0	40	20	15	75
	Multi/ Interdisciplinary	CHEM2031	Chemistry of Dyes, pigments, cosmetics and perfumes	3	3	0	0	40	00	10	50
	Ability Enhancement Course (AEC) English (L_2-1)	ENGL2041	Functional English Or Equivalent Course from SWAYAM or other UGC recognized Platform.	2	2	0	0	40	00	10	50
	Skill Enhancement Course (SEC)	CHEM2051	Basic Analytical Chemistry	3	3	0	0	40	00	10	50
	Common Value Add-ed (CVA) Course	CVA 2061	Understanding India/Digital and Technological solutions, Health & wellness, Yoga education, Sports & fitness	4	3	1/0	0/1	80/ 60	00/20	20	100
III	Major	CHEM3011	Inorganic Chemistry (Th)	5	5	0	0	60	00	15	75
		CHEM3012	Inorganic Chemistry (Prac)	5	0	5	0	00	60	15	75
	Minor (Vocational Education & Training)	MSR3021 OR HRM3021 OR	Medical Sales Representative OR Human Resource	4	3	0	1	60	00	15	75

		RSA3021	Management OR Retail Sales Associate								
	Multi/ Inter disciplinary	CHEM3031	Chemistry of Soil and Fertilizer	3	2	0	1	40	00	10	50
	Ability Enhancement Course (AEC) MIL (L_1-2)	AEC3041	Arabic/Bengali/Hindi/Sanskrit/Santali/Urdu or equivalent course form SWAYAM or any other UGC recognized platform	2				40		10	50
	Skill Enhancement Course (SEC)	CHEM3051	IT skill in Chemistry	3	2	0	1	40	00	10	50
IV	Major	CHEM4011	Organic Chemistry (Th)	5	5	0	0	60	00	15	75
		CHEM4012	Physical Chemistry (Th)	5	5	0	0	60	00	15	75
		CHEM4013	Organic Chemistry (Prac)	5	0	5	0	00	60	15	75
	Minor	CHEM4021	General Chemistry-III	4	3	1	0	40	20	15	75
	Minor (other than Chemistry)	…….4021		4						15	75
	Ability Enhancement Course (AEC) (English, L_2-2)	ENGL4041	Language and Creativity Or Equivalent Course from SWAYAM or other UGC recognized Platform.	2				40	00	10	50
V	Major	CHEM5011	Inorganic Chemistry	5	4	1	0	40	20	15	75
	Major	CHEM5012	Organic Chemistry	5	4	1	0	40	20	15	75
	Major	CHEM5013	Physical Chemistry	5	4	1	0	40	20	15	75
	Minor (Vocational Education & Training)	MSR5021 OR HRM5021 OR RSA5021	Medical Sales Representative OR Human Resource Management OR Retail Sales Associate	4	3	0	1	60	00	15	75
	Internship	INT5081		2	0	2	0	00	50 (Project/ Field Diary : 30+ Viva-voce: 20)	00	50

VI	Major	CHEM6011	Inorganic Chemistry (Th)	4	4	0	0	60	00	15	75
	Major	CHEM6012	Organic Chemistry (Th)	4	4	0	0	60	00	15	75
	Major	CHEM6013	Physical Chemistry (Th)	4	4	0	0	60	00	15	75
	Major	CHEM6014	Inorganic & Physical Chemistry (Prac)	4	0	4	0	00	60	15	75
	Minor (Vocational Education & Training)	MSR6021 OR HRM6021 OR RSA6021	Medical Sales Re-presentative OR Human Resource Management OR Retail Sales Asso-ciate	4	3	0	1	60	00	15	75
VII	Major/Core Course	CHEM7011	Inorganic General	6	4	0	2	40	20	15	75
	Major/Core Course	CHEM7012	Nuclear-Analytical General	6	4	0	2	40	20	15	75
	Major/Core Course	CHEM7013	Organic General	6	4	0	2	40	20	15	75
	Major/Core Course	CHEM7014	Physical General	6	4	0	2	40	20	15	75
	Minor Course	CHEM7021	Industrial Chemistry	4	3	0	1	60	00	15	75
VIII Hons. with Research Project/ Dissertation	Major/Core Course	CHEM 8011	Research Methodology & Ethics	6	6	0	0	60	00	15	75
	Minor Course	CHEM 8021	Medicinal Chemistry	4	3	0	1	60	00	15	75
	Research Project/ Dissertation	CHEM 8091		12	0	12	0	Seminar Presentation, Preparation & Submission of Research Project/Dissertation-135 + Viva-90			225
OR											
VIII Hons.	Major/Core Course	CHEM 8011	Research Methodology & Ethics	6	6	0	0	60	00	15	75
	Major/Core Course	CHEM 8012	Inorganic & Nuclear Analytical General	4	4	0	0	60	00	15	75
	Major/Core Course	CHEM8013	Physical & Organic General	4	4	0	0	60	00	15	75
	Major/Core Course	CHEM 8014	Practical General	4	0	4	0	00	60	15	75
	Minor Course	CHEM8021	Medicinal Chemistry	4	3	0	1	60	00	15	75
	Grand total (Sem. I - VIII)			**178**							**3075**

Semester-I

Chemistry MAJOR

Paper code: CHEM1011
Paper title: Basic Chemistry-I
Credits 3 + 1

Course objective

- Several fundamental aspects of inorganic, organic and physical chemistry is discussed for the basic understanding of the students
- The topics covered will help the students for studying higher in chemical sciences
- Easy organic chemistry practical using several chemical and physical methods will enhance the basic knowledge of students' hands-on training

Course outcome

- Students will be introduced with several basic aspects of theory and practical of chemical sciences. This will grow the foundation of the subject for studying various advanced topics in future semesters.

Theory **Credit: 3**

Atomic structure *6 Hours*

Bohr's theory- its limitations and atomic spectra 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 up to 30

Periodic properties *6 Hours*

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

Acids and bases *6 Hours*

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, concept of organic acids and bases, effect of structure, substituent and solvent on acidity and basicity, proton sponge, gas-phase acidity and basicity

Fundamentals in Organic chemistry *12 Hours*

Electron displacement phenomena and physical properties: inductive effect, field effect, hyperconjugation, mesomeric effect, resonance energy, bond polarization and bond polarizability, electromeric effect, steric effect, steric inhibition of resonance, 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, calculation of formal charges and double bond equivalent (DBE)

Reactive intermediates: carbocations (carbenium and carbonium ions), carbanions, carbon radicals, carbenes, benzynes and nitrenes, generation and stability, structure using orbital picture and electrophilic/nucleophilic behaviour of the reactive intermediates (elementary idea)

Concept of aromaticity: 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

Properties of Gases *4 Hours*

Ideal and real gases: Deviation of gases from ideal behaviour, 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, Dieterici equation of state, 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 Kinetics-I *5 Hours*

Rate law, order and molecularity: Introduction of rate law, extent of reaction, rate constants, order, forms of rate equations of first-, second- and n-th 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 with all steps of first order)

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.

Thermodynamics-I *6 Hours*

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

Thermochemistry: standard states, heats of reaction, enthalpy of formation of molecules and ions and enthalpy of combustion and its applications, laws of thermochemistry, bond energy, bond dissociation energy and resonance energy from thermochemical data, Kirchhoff’s equations and effect of pressure on enthalpy of reactions, adiabatic flame temperature, explosion temperature

Reference Books/ Journals

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

Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

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

Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.

Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

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

Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.

Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.

Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.

Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Pathak & Saha, Organic Chemistry (Volume-1), Books and Allied (P) Ltd.

Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).

Morrison, R. T. Study guide to organic Chemistry, Pearson.

Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.

Castellan, G. W., Physical Chemistry, Narosa Publishing House.

McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.

Engel, T. & Reid, P. Physical Chemistry, Pearson.

Maron, S. &Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.

Mortimer, R. G. Physical Chemistry, Elsevier.

Ball, D. W., Physical Chemistry, Thomson Press.

Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.

Rakshit, P.C., Physical Chemistry, Sarat Book House.

Zemansky, M. W. &Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill.

Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.

Clauze& Rosenberg, Chemical Thermodynamics: Basic concepts & Methods, John Wiley & Sons, 2008.

Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.

Rajaram, J. Chemical Thermodynamics: Classical, Statistical and Irreversible, Pearson.

Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher

Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education

Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.
Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.
Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

Practical **Credit: 1**

Separation, purification and melting point determination

Separation of components of a binary solid mixture based on solubility by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. $NaHCO_3$, etc., 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*-nitrotolune/*p*-anisidine, benzoic acid/benzophenone, urea/benzophenone, salicylic acid/*p*-nitrotoluene, etc.

Determination of boiling point

Boiling points of common organic liquid compounds e.g., ethanol, cyclohexane, ethyl methyl ketone, cyclohexanone, acetylacetone, anisole, crotonaldehyde, mesityl oxide, etc

[Boiling points 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/ Journals

Bhattacharyya, R. C, A Manual of Practical Chemistry.
Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.
Mann, F.G. & Saunders, B.C. Practical Organic Chemistry, Pearson Education (2009).
A.K. Manna, Practical Organic Chemistry, Books & Allied (P) Ltd.
Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.

Chemistry MINOR

Paper code: CHEM1021

Paper title: General Chemistry-I

Credit: 3 + 1

Course objective

- Several fundamental aspects of the subject are discussed so that the principles can be useful for studying other branches of science (physical and/or biological sciences)
- Practical experiments are designed in such a way that the students of other disciplines can have an experience of hands-on training in chemistry at the primary level

Course outcome

- On studying the course, the students will have an idea of chemical sciences, which may be applied for in-depth study of other science streams.

Theory **Credit: 3**

Atomic structure *6 Hours*

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

Periodic properties *6 Hours*

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

Acids and bases *7 Hours*

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, acidity and basicity of common organic compounds

Aliphatic hydrocarbons *10 Hours*

Functional group approach for the following compounds to be studied in context of their preparations, properties, structures and reactions

Alkanes (up to 5 carbons): preparation- catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis using Grignard reagent; Reaction mechanism for free radical substitution, halogenation

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 KMnO4) 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

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, formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alkaline $KMnO_4$

Ideal and real gases *5 Hours*

Concept of pressure and temperature, Deviation of gases from ideal behaviour, compressibility factor, Boyle temperature, Andrew's and Amagat's plots, van der Waals equation and its features, 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

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

Thermodynamics-I *7 Hours*

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

Standard states, heat of reaction, enthalpy of formation of molecules and ions, 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

Chemical Kinetics-I *4 Hours*

Introduction of rate law, order and molecularity, extent of reaction, rate constants, rates of first-, second- and n-th order reactions and their integrated forms (with derivation), pseudo first order reactions, determination of order of a reaction- half-life and differential method, opposing reactions, consecutive reactions and parallel reactions (elementary idea)

Theories of reaction rate: Temperature dependence on reaction rate, Arrhenius equation, energy of activation

Reference Books/ Journals

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

Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

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

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Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher

Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education

Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.

Maron, S. &Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.

Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

Practical **Credit: 1**

Determination of boiling points

Boiling points of common organic liquid compounds e.g., ethanol, cyclohexane, ethyl methyl ketone, cyclohexanone, acetylacetone, anisole, crotonaldehyde, mesityl oxide,etc.

Identification of a pure organic compound

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

Liquid Compounds: acetone, aniline and nitrobenzene

Reference Books/ Journals

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

Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.

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

Manna, A.K., Practical Organic Chemistry, Books & Allied (P) Ltd.

Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.

MULTIDISCIPLINARY

Paper code: CHEM1031

Paper title: Chemistry for Household Importance

Credit: 3

Course objective

- Several topics related to everyday life have been included to grow interest among students for the subject

Course outcome

- The study of the topics may be helpful for the students to get employment

Theory **Credit: 3**

Food chemistry: Food additive, food flavor, adulterant, preservative, artificial sweeteners *8 Hours*

Drugs and pharmaceuticals: Structure and function, antipyretic and analgesic drugs – aspirin, paracetamol, ibuprofen *8 Hours*

Vitamins: Vitamin C and B_{12} *2 Hours*

Antibiotics: Penicillin, sulphaguanidine, chloramphenicol *4 Hours*

Glass and ceramics: Definition and manufacture of glasses, optical and colour glasses *6 Hours*

Surface chemistry: Soaps and detergents *2 Hours*

Chemistry of fuels: Conventional and non-conventional energy sources, classification of fuels, calorific values of fuels like kerosene, coal, coal gas, petrol, liquefied petroleum gas, octane number, biogas *15 Hours*

Reference Books/ Journals

Thapar, Food Chemistry, Pacific Book International

Gayatri Baidya, Textbook of Food Chemistry, Book Rivers

Mandal, S.K., Pharmaceutical Chemistry and Production: An Introductory Textbook Rebeca Ghanta; Bentham Science Publishers 2022, ISBN: 978-1-68108-890-7

Sengupta, S., Application Oriented Chemistry Books Syndicate Pvt. Ltd., 2000

SKILL ENHANCEMENT COURSE

Paper code: CHEM1051

Paper title: Drugs and pharmaceuticals

Credit: 3

Course objective

- Design and development of several organic drugs
- The very detail discussion for growing of very clear idea about the drugs, their synthesis and physiological action

Course outcome

- The clear idea about the drugs may not only grow the general sense about the synthesis and mode of action of the drugs but also help them to have employment in pharmaceutical industry.

Theory **Credit: 3**

Drug discovery, design and development, synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti-inflammatory agents (aspirin, paracetamol, ilbuprofen), antibiotics (penicillin, 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)

45 Hours

Reference Books/ Journals

Patrick, G. L. Introduction to Medicinal Chemistry, Oxford University Press, UK, 2013.

Singh, H. & Kapoor, V.K. Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi, 2012.

Foye, W.O., Lemke, T.L. & William, D.A.: Principles of Medicinal Chemistry, 4th ed., B.I. Waverly Pvt. Ltd. New Delhi.

El-Mansi, E.M.T., Bryce, C.F.A., Ddemain, A.L., Allman, A.R., Fermentatias Microbiology and Biotechnology, 2nd Ed. Taylor & Francis.

Prescott & Dunn's Industrial Microbiology, 2004, CBS Publisher.

Semester-II

Chemistry MAJOR

Paper code: CHEM2011

Paper title: Basic Chemistry-II

Credit: 3 + 1

Course objective

- Several basic topics from inorganic, organic and physical chemistry have been chosen for the development of the general chemistry knowledge of the students.
- This will help to grow the foundation for studying the several aspects of applied chemistry in future.

Course outcome

- The topics will grow the foundation of the students for the subject chemistry for learning any further advanced topics.

Theory **Credit: 3**

Chemical bonding-I *6 Hours*

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, Kapustinskii expression for lattice energy, Madelung constant, Born-Haber cycle and its application, solvation energy, solubility energetics of dissolution process.

Covalent bond: polarizing power and polarizability, ionic potential, Fazan's rules, Lewis structures, formal charge, Valence Bond Theory- 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)

Redox Reactions and Precipitation Reactions *4 Hours*

Balancing of redox reactions: ion-electron method, elementary idea on standard redox potentials- Nernst equation (without derivation), influence of complex formation, precipitation and pH, formal potential

Redox titrations: feasibility, 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

Stereochemistry-I *6 Hours*

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

Chirality and symmetry: 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, epimers, stereogenicity, chirotopicity and pseudoasymmetry, chiral centres and number of stereoisomerism, systems involving 1/2/3-chiral centre(s)- AA, AB, ABA and ABC types

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

Optical activity 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.

General Treatment of Reaction Mechanism *6 Hours*

Free energy profiles: one-, two- and three-step reactions, catalyzed reactions- electrophilic and nucleophilic catalysis, kinetic control and thermodynamic control of reactions, isotope effect- primary and secondary kinetic isotopic effect (k_H /k_D), principle of microscopic reversibility

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

Substitution and Elimination Reactions *6 Hours*

Nucleophilic substitution reactions: substitution at sp3 centre- mechanisms (with evidence), relative rates, stereochemical features, S_N^1, S_N^2, $S_N^{2'}$, $S_N^{1'}$ (allylic rearrangement) and S_N^i, effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite), electrofuges and nucleofuges, substitutions involving NGP, role of crown ethers and phase transfer catalysts [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides]

Elimination reactions: E_1, E_2, E_1cB and Ei (pyrolytic syn eliminations), formation of alkenes and alkynes, mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity, comparison between substitution and elimination

Kinetic Theory of gases *5 Hours*

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

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

Liquid state *6 Hours*

Viscosity: General features of fluid flow (streamline 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

Surface tension and energy: Surface tension, surface energy, excess pressure, capillary rise and surface tension; work f cohesion and adhesion, spreading of liquids over other surfaces; vapour pressure over curved surface; temperature dependence of surface tension, principle of surface tension measurement

Thermodynamics-II *6 Hours*

Second Law: its need and statement, concept of heat reservoirs and heat engines, Carnot cycle, physical concept of entropy, Carnot engine and refrigerator, Kelvin – Planck and Clausius statements and their equivalence in 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 variations (with T, P and V), criteria of spontaneity and equilibrium

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

Reference Books/ Journals

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

Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

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

Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.

Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

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

Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.

Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.

Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.

Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Pathak & Saha, Organic Chemistry (Volume-1), Books and Allied (P) Ltd.

Rajaram, J. Chemical Thermodynamics: Classical, Statistical and Irreversible, Pearson.

Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).

Morrison, R. T. Study guide to organic Chemistry, Pearson.

Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.

Castellan, G. W. Physical Chemistry, Narosa Publishing House.

Maron, S. &Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.

Laidler, K. J. Chemical Kinetics, Pearson.

Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.

Rakshit, P.C., Physical Chemistry, Sarat Book House.

Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas.

Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.

Nasipuri, D. Stereochemistry of Organic Compounds, New Age International (P) Ltd.

Sengupta,S. Basic Stereochemistry of Organic Molecules, Oxford University Press

Manna, A.K. Organic Molecular Spectroscopy, Books and Allied (P) Ltd.

Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.

Engel, T. & Reid, P. Physical Chemistry, Pearson.

Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

Ball, D. W. Physical Chemistry, Thomson Press.

Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher

Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education
Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.

Practical **Credit: 1**

1. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate
2. Study of kinetics of decomposition of H_2O_2 by KI
3. Determination of pH of unknown strong alkali and acid solution by colour matching method
4. Determination of pH of unknown buffer solution by colour matching method
5. Study of viscosity of unknown liquid (glycerol, sugar) with respect to water
6. Determination of surface tension of a liquid using Stalagmometer

Reference Books/ Journals

Bhattacharyya, R. C, A Manual of Practical Chemistry.
Nad, Mahapatra, Ghosal, An Advance course in Practical Chemistry, New Central Book Agency (P) Ltd.
K. S. Mukherjee, Textbook on Practical Chemistry, New Central Book Agency (P) Ltd.
Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.
Poddar and Ghosh, Degree Practical Chemistry, Book Syndicate (P) Ltd.

Chemistry MINOR

Paper code: CHEM2021

Paper title: General Chemistry-II

Credit: 3 + 1

Course objective

- Several basic aspects from inorganic, organic and physical chemistry have been discussed
- Generation of idea for studying physical and biological sciences in future

Course outcome

- The idea created from this course may help to understand students for further studying physical, biological and material sciences.

Theory **Credit: 3**

Thermodynamics-II *5 Hours*

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

Ideal gas *5 Hours*

Collision of gas molecules, collision diameter, collision number and mean free path, frequency of binary collisions (similar and different molecules), rate of effusion

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

Chemical Kinetics-II *5 Hours*

Collision theory, Lindemann theory of unimolecular reaction, outline of Transition State theory (classical treatment)

Fundamentals of Organic Chemistry *6 Hours*

Electronic displacement phenomena- inductive effect, resonance and hyperconjugation, cleavage of bonds- homolytic and heterolytic, structures of organic molecules on the basis of VBT, nucleophiles, electrophiles, reactive intermediates- carbocations, carbanions and free radicals.

Stereochemistry *6 Hours*

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- nomenclatures, CIP rules: R/S (upto 2 chiral carbon atoms) and E/Z nomenclatures.

Nucleophilic Substitution and Elimination Reactions *6 Hours*

Nucleophilic substitutions- S_N1, S_N2 and S_Ni reactions, eliminations- E_1 and E_2 reactions (elementary mechanistic aspects), Saytzeff and Hofmann eliminations, elimination vs. substitution

Chemical Bonding and Molecular Structure *12 Hours*

Ionic Bonding: general characteristics, energy considerations, lattice energy and solvation energy and their importance for stability and solubility of ionic compounds, statement of Born-Landé equation for lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability, Fajans' rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character

Covalent bonding: Valence Bond (VB) theory approach, shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements

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

Molecular orbital (MO) theory approach -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 the idea of s-p mixing) and heteronuclear diatomic molecules such as CO, NO and NO+, comparison of VB and MO approaches

Reference Books/ Journals

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

Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

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

Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.

Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

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

Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.

Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.

Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).
Morrison, R. T. Study guide to organic Chemistry, Pearson.
Pathak & Saha, Organic Chemistry (Volume-1), Books and Allied (P) Ltd.
Castellan, G. W. Physical Chemistry, Narosa Publishing House.
Engel, T. & Reid, P. Physical Chemistry, Pearson.
Maron, S. &Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.
Laidler, K. J. Chemical Kinetics, Pearson.
Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
Rakshit, P.C., Physical Chemistry, Sarat Book House.
Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.
Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.
Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.
Rajaram, J. Chemical Thermodynamics: Classical, Statistical and Irreversible, Pearson.
Nasipuri, D. Stereochemistry of Organic Compounds, New Age International (P) Ltd.
Sengupta,S.Basic Stereochemistry of Organic Molecules, Oxford University Press
Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher
Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education
Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.
Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.

Practical Credit 1

Determination of pH of unknown strong alkali and acid by colour matching method
Study of kinetics of acid-catalyzed hydrolysis of methyl acetate
Estimation of Mohr's salt by titrating with $KMnO_4$/ $K_2Cr_2O_7$
Estimation of sodium carbonate and sodium hydrogen carbonate in a mixture

Reference Books/ Journals

Bhattacharyya, R. C, A Manual of Practical Chemistry.
Nad, Mahapatra, Ghosal, An Advance course in Practical Chemistry, New Central Book Agency (P) Ltd.
K. S. Mukherjee, Textbook on Practical Chemistry, New Central Book Agency (P) Ltd.
Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.
Poddar and Ghosh, Degree Practical Chemistry, Book Syndicate (P) Ltd.

MULTIDISCIPLINARY

Paper code: CHEM2031

Paper title: Chemistry of Dyes, Pigments, Cosmetics and Perfumes

Credit: 3

Course objective

- Introduction of idea of every day products of chemical industries

Course outcome

- Development of idea of several molecules and materials related to dye and cosmetics industry

Theory **Credit: 3**

Definition and classification, structures and theories of coloration, preparation, properties and uses of dyes like phenolphthalein, methyl orange, malachite green, alizarin, indigo, different types of pigments like chlorophyll, carotenoids, anthocyanins, flavonoids (elemental idea)

Preparation and uses of the following: hair dye, hair spray, shampoo, suntan lotions, face powder, lipsticks, talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants and artificial flavours

Essential oils and their importance in cosmetic industries with reference to eugenol, geraniol, sandalwood oil, eucalyptus, rose-oil, 2-phenyl ethyl alcohol, jasmone, civetone, muscone

45 Hours

Reference Books/ Journals

Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearson Education).

Bahl and Bahl, A Text book of Organic Chemistry, S. Chand publication

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

Jain, P. C. &Jain, M: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.

Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

SKILL ENHANCEMENT COURSE

Paper title: CHEM2051

Paper code: Basic Analytical Chemistry

Credit: 3

Course objective

- Development of skill for analyzing several natural and synthetic samples to find out their purity, composition, etc
- Development of skill for advanced separation techniques for natural and synthetic samples

Course outcome

- This course will develop the analysis as well as separation skills of the students which may help them to motivate for joining research and/or have employment.

Theory **Credit: 3**

General principle *8 Hours*

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 *6 Hours*

Composition of soil, concept of pH and pH measurement, complexometric titrations, chelation, chelating agents, use of indicators

Analysis of water *6 Hours*

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

Analysis of food products *6 Hours*

Nutritional value of a food, idea about food processing and food preservations, and adulteration

Chromatography *10 Hours*

Definition, general introduction on principles of chromatography, paper chromatography, TLC etc., column chomatography, ion-exchange chromatography, etc., determination of ion exchange capacity of anion /cation exchange resin

Analysis of cosmetics *9 Hours*

Major and minor constituents of cosmetics and their functions, analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate

Reference Books/ Journals

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.

Skoog, D.A., Holler, F.J. & Crouch, S. Principles of Instrumental Analysis, Cengage Learning India Edition, 2007.

Skoog, D.A.; West, D.M. & Holler, F.J. Analytical Chemistry: An Introduction sixth Ed., Saunders College Publishing, Fort Worth, Philadelphia (1994).

Harris, D. C. Quantitative Chemical Analysis, 9th ed. Macmillan Education, 2016.

Dean, J. A. Analytical Chemistry Handbook, McGraw Hill, 2004.

Day, R. A. & Underwood, A. L. Quantitative Analysis, Prentice Hall of India, 1992.

Freifelder, D.M. Physical Biochemistry 2nd Ed., W.H. Freeman & Co., N.Y. USA (1982).

Cooper, T.G. The Tools of Biochemistry, John Wiley & Sons, N.Y. USA. 16 (1977).

Vogel, A. I. Vogel's Qualitative Inorganic Analysis 7th Ed., Prentice Hall, 1996.

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

Robinson, J.W. Undergraduate Instrumental Analysis 5th Ed., Marcel Dekker, Inc., New York (1995).

Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.

Semester-III

Chemistry MAJOR

Paper code: CHEM3011 (3 and 4 years)
Paper title: Inorganic Chemistry (Theory)
Credit: 5

Course objective

- Discussion of bonding theories (advanced parts)
- Application of the basic theories discussed so far towards coordination chemistry and s- and p-block elements

Course outcome

- After studying several basic aspects of chemistry, students will go through their applications in studying coordination chemistry, s- and p-block elements. On studying different comparative properties s- and p-block elements, proper chemical logic will start to be developed among the students.

Theory **Credit: 5**

Chemical Bonding-II *20 Hours*

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.

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

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

Coordination Chemistry-I *12 Hours*

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

Chemistry of s and p-block elements *35 Hours*

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, pseudohalides, fluorocarbons and chlorofluorocarbons.

Noble Gases *8 Hours*

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

Reference Books/ Journals

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

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

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

Miessler, G. L. & Donald, A. Tarr. Inorganic Chemistry 4th Ed., Pearson, 2010

Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 980

Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998)

Sarkar, R, General and inorganic chemistry, Volume II, New central book agency, (2012)

Chemistry MAJOR

Paper code: CHEM3012 (3 and 4 Years)

Paper title: Inorganic Chemistry (Practical)

Credit: 5

Course objective

- Development of chemical knowledge through several hands-on qualitative experiments
- Learning to synthesize several coordination compounds

Course outcome

- Towards qualitative detection of several radicals, different experiments have to be covered. These will actually grow a clear knowledge and conception in chemistry. Moreover, preparation of modern coordination compounds will create an insight to the synthetic coordination chemistry.

Practical **Credit: 5**

Qualitative analysis of Acid and Basic radicals from an inorganic sample containing four radicals (oxide, hydroxide and carbonate may not be counted among four radicals). Emphasis should be given to the understanding of the chemistry of different reactions and to assign the most probable composition. Semi-micro analysis may also be followed. The use of centrifuge machine, thioacetamide instead of H_2S and spot tests for specific radicals should be introduced

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

Acid Radicals: F^-, Cl^-, Br^-, I^-, $S_2O_3^{2-}$, S^{2-}, SO_4^{2-}, SO_3^{2-}, NO_3^-, NO_2^- , PO_4^{3-}, AsO_4^{3-}, BO_3^{3-}, CrO_4^{2-}.

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

Inorganic preparations

$[Cu(CH_3CN)_4]PF_6/ClO_4$, Potassium dioxalatodiaquachromate(III),

Tetraamminecarbonatocobalt(III) ion, Potassium tris(oxalato)ferrate(III),

Tris(ethylenediamine) nickel(II) chloride, $[Mn(acac)_3]$ and

$[Fe(acac)_3]$ (acacH = acetylacetone)

Reference Books/ Journals

Vogel, A. I. Vogel's Qualitative Inorganic Analysis 7th Ed., Prentice Hall, 1996.

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).

Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.

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

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

K. S. Mukherjee, Textbook on Practical Chemistry, New Central Book Agency (P) Ltd.

MULTIDISCIPLINARY

Paper code: CHEM3031

Paper title: Chemistry of Soil, Fertilizer and detergent

Credit: 3

Course objective

- Development of knowledge of soil
- Development of knowledge of fertilizer
- Idea of pesticide, etc
- Idea of development of several surface-active agents like soap, etc

Course outcome

- Exploring the knowledge of fundamental chemistry towards soil, fertilizer, detergent will not only create general chemical knowledge of the students but also will generate the possibility of employability

Theory **Credit: 3**

Soil: Composition, texture, micro & macro nutrients, soil health, soil conditioner, growth factor, NPK and their determination, soil productivity and effect of pH

10 hours

Fertilizer: 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.

15 hours

Fungicide, pesticide, herbicide with examples, advantage and disadvantage *10 hours*

Soap & Detergents: Different types of soap and detergents with example, surface active and surface inactive substances *10 hours*

Reference Books/ Journals

Thapar, Food Chemistry, Pacific Book International

Gayatri Baidya, Textbook of Food Chemistry, Book Rivers

Mandal, S.K., Pharmaceutical Chemistry and Production: An Introductory Textbook Rebeca Ghanta; Bentham Science Publishers 2022, ISBN: 978-1-68108-890-7

Sengupta, S. Application Oriented Chemistry Books Syndicate Pvt. Ltd., 2000

SKILL ENHANCEMENT COURSE

Paper code: CHEM3051

Paper title: IT skills in Chemistry

Credit: 3

Course objective

- Development of mathematical knowledge and knowledge for computer programming
- Development of knowledge for different data handling softwares

Course outcome

- The course will help the students sound for doing several chemical computations.

Theory **Credit: 3**

Mathematical tools *15 Hours*

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

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)

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)

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)

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

Computer Programming *15 Hours*

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

Fortran or C programming for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson's rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

Handling numeric data *15 Hours*

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 solutions of equations.

Reference Books/ Journals

McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).
Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).

Steiner, E. The Chemical Maths Book Oxford University Press (1996).

Yates, P. Chemical calculations. 2nd Ed. CRC Press (2007).

Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.

Levie, R. de. How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press (2001) 487 pages.

Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).

Venit, S.M. Programming in BASIC: Problem solving with structure and style. Jaico Publishing House: Delhi (1996).

Semester-IV

Chemistry MAJOR

Paper code: CHEM4011 (3 and 4 Years)

Paper title: Organic Chemistry (Theory)

Credit: 5

Course objective

- Development of knowledge for several basic and advanced topics of organic chemistry

Course outcome

- The course will help the students to develop a complete knowledge on stereochemistry, reaction mechanism and others of organic chemistry.

Theory **Credit: 3**

Stereochemistry II *18 Hours*

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.

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

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

Chemistry of alkenes and alkynes *15 Hours*

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

Aromatic Substitution *10 Hours*

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

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

Carbonyl and Related Compounds *24 Hours*

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, LiAlH4, NaBH4, MPV, Oppenauer, Bouveault-Blanc, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols.

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

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

Substitution at sp^2 carbon (C=O system): mechanism (with evidence): BAC^2, AAC^2, AAC^1, AAL^1 (in connection to acid and ester); acid derivatives: amides, anhydrides and acyl halides (formation and hydrolysis including comparison).

Organometallics *8 Hours*

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard and organo-lithium to carbonyl compounds; substitution on - COX; conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organo-lithium and organo-copper reagents; Reformatsky reaction; concept of umpolung and base-nucleophile dichotomy in case of organometallic reagents.

Reference Books/ Journals

Clayden, J., Greeves, N. & Warren, S. Organic Chemistry, Second edition, Oxford University Press, 2012.

Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.

Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Pathak & Saha, Organic Chemistry (Volume-1 & 2), Books and Allied (P) Ltd.

Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd., (Pearsonn Education).

Morrison, R. T. Study guide to organic Chemistry, Pearson.

Nasipuri, D. Stereochemistry of Organic Compounds, New Age International (P) Ltd.

Sengupta, S. Basic Stereochemistry of Organic Molecules, Oxford University Press

Chemistry MAJOR

Paper code: CHEM4012 (3 and 4 Years)

Paper title: Physical Chemistry (Theory)

Credit: 5

Course objective

- Development of knowledge of theories of several experimental and theoretical aspects of chemistry

Course outcome

- The course will help to develop physical chemistry knowledge of solid, liquid and gaseous states of matter. Students will also learn to do quantum chemical calculations for various systems.

Theory **Credit: 5**

Chemical Kinetics-II and Catalysis *12 Hours*

Theories of reaction rate: Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment).

Homogeneous catalysis: Homogeneous catalysis with reference to acid-base catalysis; Primary kinetic salt effect; Enzyme catalysis; Michaelis-Menten equation, Lineweaver-Burk plot, turn over number, autocatalysis; periodic reactions.

Electrochemistry-I *15 Hours*

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.

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

Partial molar properties and Chemical potential *12 Hours*

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

Chemical Equilibrium *14 Hours*

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, Nernst Distribution law & its application-solvent extraction, steam distillation.

Specific heats of solid *5 Hours*

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).

Thermodynamics-III *3 Hours*

Third law of Thermodynamics: Absolute entropy, Planck's law, Calculation of entropy, Nernst heat theorem

Quantum Mechanics-I *14 Hours*

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).

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

Concept of Operators: Elementary concepts of operators, eigenfunctions and eigenvalues; Linear and Hermitian operators; Commutation of operators, commutator and uncertainty relation; Expectation value.

Reference Books/ Journals

Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
Castellan, G. W., Physical Chemistry, Narosa Publishing House.
McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
Engel, T. & Reid, P. Physical Chemistry, Pearson.
Maron, S. & Prutton, Principles of Physical Chemistry, Collier Macmillan Ltd.
Mortimer, R. G. Physical Chemistry, Elsevier.
Ball, D. W., Physical Chemistry, Thomson Press.
Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
Rakshit, P.C., Physical Chemistry, Sarat Book House.
Zemansky, M. W. &Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill.
Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.
Clauze & Rosenberg, Chemical Thermodynamics: Basic concepts & Methods, John Wiley & Sons, 2008.

Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.

Chatterjee Hrishikesh, Physical Chemistry (Volume-1), Platinum Publisher

Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume-2), McGraw Hill Education

Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.

Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.

Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

Chemistry MAJOR

Paper code: CHEM4013 (3 and 4 Years)

Paper title: Organic Chemistry (Practical)

Credit: 5

Course objective

- Detection of several elements in organic molecules
- Detection of functional group in organic molecules
- Organic preparations

Course outcome

- Students will have a hands-on training for detection of elements (N, S, Cl, Br, etc) and synthesis/derivatization of several organic compounds.

Practical **Credit: 5**

A. ***Qualitative Analysis of single solid organic compound***

1) Detection of special elements (N, S, Cl, Br) by Lassaigne's test
2) Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
3) Detection of the following functional groups by systematic chemical tests:

4) Aromatic amino (-NH_2), aromatic nitro (-NO_2), amido (-$CONH_2$), anilide (-CONHAr), phenolic – OH, carboxylic acid (-COOH), ester (-COOR), carbonyl (-CHO and > C=O)
5) Melting point of the given compound
6) Preparation of one suitable derivative of the given sample, crystallization and determination of melting point.

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.

B. ***Organic Preparations***

The following reactions are to be performed, noting the yield of the crude product with melting point:

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) Selective reduction of m-dinitrobenzene to m-nitroaniline
10) Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

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

Reference Books/ Journals

Vogel, A. I. Elementary Practical Organic Chemistry, Part 2: Qualitative Organic Analysis, CBS Publishers and Distributors.

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

Clarke, H. T., A Handbook of Organic Analysis (Qualitative and Quantitative), Fourth Edition, CBS Publishers and Distributors (2007).

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

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

Chemistry MINOR

Paper code: CHEM4021

Paper title: General Chemistry-III

Credit: 3 + 1

Course objective

- Discussion on several general aspects of inorganic, organic and physical chemistry

Course outcome

- This course will help the students to develop advanced topics of chemistry, physics and biology. Students will learn to synthesize several coordination compounds. Students will also learn to estimate hardness of water by chemical analysis.

Theory **Credit: 3**

Liquid state *6 Hours*

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).

Colligative properties *6 Hours*

Raoult's law of relative lowering of vapour pressure, elevation of boiling point, depression of freezing point, osmosis and osmotic pressure, abnormal colligative property and vant Hoff factor, molecular weight determination of unknown solute

Solutions *8 Hours*

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

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

Aromatic hydrocarbons *6 Hours*

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).

Synthetic uses of Grignard reagent & Active methylene compounds *6 Hours*

Synthetic uses of Grignard reagent (GR), ethylacetoacetate (EAA) and diethylmalonate (DEM)

Coordination chemistry *10 Hours*

Double and complex salts, Warner'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.

Radioactivity *3 Hours*

Characteristics, α, β and γ-rays, radioactive disintegration and equilibrium, decay constant, half-life and average life, artificial transmutation and artificial radioactivity, uses

Reference Books/ Journals

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

Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Sarkar, R, General and inorganic chemistry, Volume II, New central book agency, (2012).

Rakshit, P. C., Physical Chemistry, Sarat Book House.

Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.
Sharma, K. K. & Sharma, L. K., A Textbook of Physical Chemistry, Vikas Publishing House.
Bajpai, D. N., Advanced Physical Chemistry, S. Chand Publication.
Kapoor, K.L., Textbook of Physical Chemistry (Volume 1 and Volume 2), McGraw Hill Education
Ghoshal, A. Numerical problems & short questions on Physical Chemistry, Books and Allied (P) Ltd.

Practical **Credit: 1**

A. *Inorganic preparations*

1) Tetraamminecarbonatocobalt(III) ion
2) Potassium tris(oxalato)ferrate(III)
3) Tris(ethylenediamine) nickel (II) chloride

B. *Complexometric titration*

Determination of total hardness of water by using standard EDTA solution

Reference Books/ Journals

Bhattacharyya, R. C, A Manual of Practical Chemistry.
Nad, Mahapatra, Ghosal, An Advance course in Practical Chemistry, New Central Book Agency (P) Ltd.
K. S. Mukherjee, Textbook on Practical Chemistry, New Central Book Agency (P) Ltd.
Ghosh, Das Sharma, Majumdar, Manna, Chemistry in Laboratory, Santra Publication (P) Ltd.
Poddar and Ghosh, Degree Practical Chemistry, Book Syndicate (P) Ltd.

Semester-V

Chemistry MAJOR
Course code: CHEM5011 (3 and 4 Years)

Course title: Inorganic Chemistry
F.M. 75 (40+20+15)
Credit: 5

Course objective

- Development of knowledge for several basic and advanced topics of inorganic chemistry

Course outcome

- The course will help the students to develop a complete knowledge on radioactivity, co-ordination chemistry, transition elements, inorganic polymers as well as practical concept on chromatographic separation technique, gravimetric and spectrophotometric estimation

Theory (F.M. 40) **Credit: 4**

Radioactivity *12 Hours*

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

Co-ordination Chemistry-II *24 Hours*

VB description and its limitations, Elementary Crystal Field Theory: splitting of dn configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series, Jahn- Teller distortion, Octahedral site stabilization energy (OSSE), spinel and inverted spinels, 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 Transition Elements *12 Hours*

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

Inorganic Polymers *12 Hours*

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

Reference Books/ Journals

Arnikar, H. J. Essentials of Nuclear Chemistry, New Age International, 1995.

Lee, J. D. Concise Inorganic Chemistry 5th Ed., John Wiley and sons 2008.

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

Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India.

Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.

Banerjee, S. P., Comprehensive Coordination Chemistry,Books& Allied Pvt. Ltd., 2019

Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

Atkins, P., Overton, T., Rourke, J., Weller, M., Armstrong, F,. Shriver & Atkins, Inorganic Chemistry, Fifth Edition, Oxford University Press.

Practical (F.M. 20) **Credit: 1**

I. Chromatographic separation of metal ions

Paper chromatographic separation of following metal ions:

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

II. Gravimetric estimation

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 $Al(oxine)_3$ (aluminiumoxinate)

4. Estimation of chloride

III. Spectrophotometry

1. Measurement of 10Dq of 3d metal complexes by spectrophotometric method.

2. Determination of λmax of $KMnO_4$ and $K_2Cr_2O_7$.

Reference Books/ Journals

Mendham, R.C., Denney, J.D., Baines, M. Thomas and Siva Sankar, B. Vogel's Text Book on Quantitative Chemical Analysis, 6/e, Pearson.

Nad, A.K., Mahapatra, B. & Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency, 2007.

Das, S.C. Advanced Practical Chemistry, The World Press Pvt. Ltd., 4th Ed. 2010.

Mukhopadhyay, R. & Chattejee, P. Advanced Practical Chemistry, Books & Allied(P) Ltd., 3rd Ed., 2007.

Chemistry MAJOR
Course code: CHEM5012 (3 and 4 Years)
Course title: Organic Chemistry
F.M 75 (40+20+15)
Credit: 5

Course objective

- Development of knowledge for several basic and advanced topics of organic chemistry

Course outcome

- The course will help the students to develop a complete knowledge on pericyclic reactions, retrosynthesis, polynuclear hydrocarbons and study of biomolecules as well as practical concept of volumetric estimation and chromatographic separation of organic sample

Theory (F.M. 40) **Credit: 4**

Pericyclic Reactions *10 Hours*

Mechanism, stereochemistry, regioselectivity in case of

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

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

(iii) 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.

The Logic of Organic Synthesis *10 Hours*

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 1,6-diocarbonyl compounds), reconnection; protection and deprotection strategy (alcohol, amine, carbonyl, acid).

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

Asymmetric synthesis: stereoselective and stereospecific reactions; diastereoselectivity and enantioselectivity (only definition); enantioselectivity: kinetically controlled MPV reduction; diastereoselectivity: addition of nucleophiles to C=O adjacent to a stereogenic centre: Cram's rule, Felkin-Anh model

Polynuclear aromatic hydrocarbons *6 Hours*

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.

Carbohydrates *12 hours*

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 *12 Hours*

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.

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.

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 10 *Hours*

General studies of terpenenoids and alkaloids; biosynthesis of terpenes; determination of structures of citral, nerol, α-terpineol, piperin, ephedrine and coniine

Reference Books/ Journals

Warren, S, Organic Synthesis:The Disconnection approach, Wiley student Ed., 2013.

Fleming, I. Molecular Orbitals and Organic Chemical reactions, Reference/Student Edition, Wiley, 2009.

Fleming, I. Pericyclic Reactions, Oxford Chemistry Primer, Oxford University Press.

Gilchrist, T. L. & Storr, R. C. Organic Reactions and Orbital symmetry, Cambridge University Press.

Nasipuri, D, Stereochemistry of organic compounds, New Age International Publishers, , 2014.

Sen Gupta, S, basic Stereochemistry of Organic molecules, Oxford University press, 2014.

Singh, S & Singh, J, Photochemistry and Pericyclic Reactions, New Age International Publishers, 3rd Ed., 2010.

Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).

Finar, I. L. Organic Chemistry (Volume 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Loudon, G. M. Organic Chemistry, Fourth edition, Oxford University Press.

Davis, B. G., Fairbanks, A. J., Carbohydrate Chemistry, Oxford Chemistry Primer, Oxford University Press.

Kar, R. K. Fundamentals of Organic Synthesis: The Retrosynthetic Analysis, New Central Book Agency, 2007.

Practical (F.M. 20) **Credit: 1**

I. Volumetric Estimation:

(i) Estimation of glucose using Fehling's solution

(ii) Estimation of ascorbic acid (Vitamin-C) in reduced form

(iii) Estimation of aniline using $KBrO_3$-KBr mixture

(iv) Estimation of phenol using $KBrO_3$-KBr mixture

(v) Estimation of saponification value of oil/fat/ester

II. Chromatographic Separations

(i) TLC separation of a mixture containing 2/3 amino acids

(ii) TLC separation of a mixture of dyes (fluorescein & methylene blue)

(iii) Column chromatographic separation of mixture of dyes

(iv) Paper chromatographic separation of a mixture containing 2/3 amino acids

Reference Books / Journals

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

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

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

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

Mukhopadhyay, R & Chatterjee, P, Advanced Practical Chemistry, Books & Allied (P) Ltd., 3rd Ed., 2007.

Manna, A.K., Practical Organic Chemistry, Books & Allied (P) Ltd., 2nd Ed., 2020.

Chemistry MAJOR
Course code: CHEM5013 (3 and 4 Years)
Course title: Physical Chemistry
F.M. 75 (40+20+15)
Credit: 5

Course objective

- Development of theoretical and practical knowledge for several basic and advanced topics of physical chemistry

Course outcome

- The course will help the students to develop a complete knowledge on crystal structure, polymers, dipole moment, polarizability, applications of quantum mechanics, statistical thermodynamics and surface phenomena

Theory (F.M. 40) **Credit: 4**

Crystal Structure I *10 Hours*

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.

Crystal planes: Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of d_{hkl}; Relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation) *Determination of crystal structure*: Powder method; Structure of NaCl and KCl crystals

Macromolecular Polymers I *8 Hours*

Classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers, Criteria for synthetic polymer formation; classification of polymerization processes, Functionality, Extent of reaction and Degree of polymerization – relationship.

Kinetics of Polymerization – Condensation and free-radical Addition Polymerization (only), Molecular weights of polymers, Determination of molecular weights by viscometry and osmometry methods, Molecular weight distribution and its significance. Polydispersity index

Preparation, Structures, Properties of few polymers (Physical, Thermal, Flow & Mechanical Properties) - polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride), Polyamides, Phenol formaldehyde resins (Bakelite, Novalac)

Dipole moment and Polarizability *6 Hours*

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

Surface phenomena *12 Hours*

Adsorption: Physical and chemical adsorption; Freundlich and Langmuir adsorption isotherms; multilayer adsorption and BET isotherm (no derivation required); Gibbs adsorption isotherm and surface excess; Heterogenous catalysis (single reactant); Zero order and fractional order reactions

Colloids: Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, Coagulation and Schultz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electrokinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrin's method; Stability of colloids and zeta potential; Micelle, surfactants, reverse micelleand emulsions

Quantum mechanics-II *16 Hours*

Particle in a box: setting up of Schrödinger equation for one-dimensional particle in 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.

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

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 solutions
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)

Statistical Thermodynamics I *8 Hours*

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

Reference Books/ Journals

Rakshit, P.C., Physical Chemistry, Sarat Book Distributors, 7th Ed.
Kapoor, K. L., A Textbook of Physical Chemistry, Volume-4, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.
Kapoor, K., A Textbook of Physical Chemistry, Volume-5, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.
Castellan, G. W. Physical Chemistry, Narosa
Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press.
McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.
Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
Moore, W. J. Physical Chemistry, Orient Longman.
Mortimer, R. G. Physical Chemistry, Elsevier.
Engel, T. & Reid, P. Physical Chemistry, Pearson.
Maron, S.H., Prutton, C. F., Principles of Physical Chemistry, McMillan.
Puri, B.R., Sharma, L.R., and Pathania, M.S., Principles of Physical Chemistry, Vishal Publishing Co.
Levine, I. N. Quantum Chemistry, PHI.
Atkins, P.W. Molecular Quantum Mechanics, Oxford.

Practical (F.M. 20) **Credit: 1**

1. Conductometric titration with standardization of
   (i) Strong acid-strong base
   (ii) Weak acid-strong base
   (iii) Precipitation reaction
2. Kinetics of saponification of ester by conductometric method
3. Conductometric verification of Ostwald dilution law and determination K_a for a weak acid
4. Determination of solubility product of a sparingly soluble salt by titrimetric method
5. Determination of Equilibrium constant (K_c) of the reaction $KI + I_2 = KI_3$ by partition method
6. Determination of partition co-efficient (K_d) of a solute in two immiscible solvents

Reference Books/ Journals

Nad, A.K., Mahapatra, B. &Ghosal, A.An Advanced Course in Practical Chemistry, New Central Book Agency, 2007.

Das, S.C. Advanced Practical Chemistry, The World Press Pvt. Ltd., 4th Ed. 2010.

Mukhopadhyay, R. & Chatterjee, P. Advanced Practical Chemistry, Books &Allied (P) Ltd., 3rd Ed., 2007.

Maity, S. K. & Ghosh, N. K. Physical Chemistry Practical, New Central Book Agency (P) Ltd. 2012

Semester-VI

Chemistry MAJOR
Course code: CHEM6011 (3 and 4 Years)
Course title: Inorganic Chemistry (Theory)
Credit: 4

Course objective

- Development of knowledge for several basic and advanced topics of inorganic chemistry

Course outcome

- The course will help the students to develop a complete knowledge on metallurgy, lanthanides & actinides, bio-inorganic chemistry, organometallic chemistry as well as reaction kinetics & mechanism

Theory **Credit: 4**

General Principles of Metallurgy *10 Hours*

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

Lanthanoids and Actinoids *8 Hours*

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

Bioinorganic Chemistry *10 Hours*

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 *20 Hours*

(i) 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.

(ii) *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 *12 Hours*

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/ Journals

Arnikar, H. J. Essentials of Nuclear Chemistry, New Age International, 1995.

Lee, J. D. Concise Inorganic Chemistry 5th Ed., John Wiley and sons 2008.

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

Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India.

Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.

Banerjee, S. P., Comprehensive Coordination Chemistry, Books & Allied Pvt. Ltd., 2019

Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

Atkins, P., Overton, T., Rourke, J., Weller, M., Armstrong, F,. Shriver & Atkins, Inorganic Chemistry, Fifth Edition, Oxford University Press.

Chemistry MAJOR
Course code: CHEM6012 (3 and 4 Years)
Course title: Organic Chemistry (Theory)
Credit: 4

Course objective

- Development of knowledge for several basic and advanced topics of organic chemistry

Course outcome

- The course will help the students to develop a complete knowledge on organic spectroscopy, cyclic stereochemistry, heterocyclic chemistry as well as introductory concept on green chemistry

Theory **Credit: 4**

Organic Spectroscopy *30 Hours*

(i) *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 λmax considering conjugative effect, steric effect, solvent effect, effect of pH; effective chromophore concentration: keto-enol systems; benzenoid transitions.

(ii) *IR Spectroscopy*: introduction; modes of molecular vibrations (fundamental and nonfundamental); 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.

(iii) *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, anisotropic effects in alkene, alkyne, aldehydes and aromatics;; significance of the terms: up-/downfield, shielded and deshielded protons; spin coupling and coupling constant (1st order spectra); relative intensities offirst-order multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR; elementary idea about non-first-order splitting; 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.

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

Cyclic Stereochemistry *10 Hours*

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 (S_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic syn elimination and fragmentation reactions.

Heterocyclic chemistry *10 Hours*

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 itsvariation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis;benzo-fused 5- and 6-membered rings with one heteroatom: reactivity, orientation and importantreactions (with mechanistic details) of indole, quinoline and isoquinoline; synthesis (includingretrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert; quinoline: Skraup, Doebner- Miller, Friedlander; isoquinoline: Bischler-Napieralski synthesis.

Green Chemistry *10 Hours*

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.

Examples of Green Synthesis / Reactions and some real-world cases

Green synthesis of adipic acid, Hofmann Elimination, oxidation of toluene and alcohols; Diels-Alder reaction and Decarboxylation reaction, Simmons-Smith reaction, Aldol

condensation reaction, Friedel-Crafts, Michael, Knoevenagel, Cannizzaro, Benzoin condensation and Dieckmann condensation.

Reference Books/ Journals

Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley, London.

Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.

Sengupta, S., Basic Stereochemistry of Organic Molecules, Oxford University Press, 2014.

Kalsi, P. S. Stereochemistry Conformation and Mechanism, Eighth edition, New Age International, 2014.

Joule, J. A. & Mills, K. Heterocyclic Chemistry, Blackwell Science.

Gilchrist, T. L. Heterocyclic Chemistry, 3rd edition, Pearson.

Bansal, R. K. Heterocyclic Chemistry, New Age International Publishers.

Davies, D. T., Heterocyclic Chemistry, Oxford Chemistry Primer, Oxford University Press.

Ahluwalia, V.K., Heterocyclic Chemistry, Narosa Publishing House, 2012.

Anastas, P.T. & Warner, J.K., Green Chemistry-Theory and Practical, Oxford University Press (1998).

Ryan, M.A. & Tinnesand, M. Introduction to Green Chemistry, American Chemical Society, Washington, 2002.

Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2nd Edition, 2010.

Ahluwalia, V.K., Green Chemistry: A Textbook, 1st Ed., Narosa Publishing House, 2013

Jag Mohan, Organic Spectroscopy: Principles and Applications, 2nd Ed., Narosa Publishing House, 2010.

Sharma, YY.R., Elementary Organic Spectroscopy: Principles and Chemical Applications, S. Chand & Company Ltd.

Manna, A.K., Organic Molecular Spectroscopy, Books & Allied (P) Ltd.2nd Ed., 2020.

Kalsi, P.S., Spectroscopy of Organic Compounds, New Age International Publisher

Chemistry MAJOR
Course code: CHEM6013 (3 and 4 Years)
Course title: Physical Chemistry (Theory)
Credit: 4

Course objective

- Development of knowledge for several basic and advanced topics of physical chemistry

Course outcome

- The course will help the students to develop a complete knowledge on thermodynamic applications, electrical properties of molecules, molecular spectroscopy and photochemistry

Theory **Credit: 4**

Applications of Thermodynamics *18 Hours*

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.

Colligative properties: Vapour pressure of solution; ideal solutions, ideally diluted solutions and colligative properties; Raoult's law; thermodynamic derivation using chemical potential for the four colligative properties, relative lowering of vapour pressure, elevation of boiling point, depression of freezing point and osmotic pressure; applications in calculating molar masses of solutes; abnormal colligative properties for dissociated and associated solutes in solution.

Heterogenous equilibria: Definitions of phase, component and degrees of freedom; phase rule and its derivations; phase diagram for water, CO_2, sulphur

1st order phase transition and Clapeyron equation; Clausius-Clapeyron equation - derivation and use; liquid vapour equilibrium for two component systems.

Binary solutions: ideal solution at fixed temperature and pressure; Nernst distribution law and its applications, 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.

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

Electrical Properties of Molecules (Electrochemistry II) *18 Hours*

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.

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 (a) free energy, enthalpy and entropy of a cell reaction, (b) equilibrium constants, and (c) pH values, using hydrogen, quinone-hydroquinone and glass electrodes.

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

Molecular Spectroscopy I *14 Hours*

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

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

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

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

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

Photochemistry *10 Hours*

Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry,

StarkEinstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields Photochemical Processes: Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; Fluorescence and phosphorescence, Jablonski diagram

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

Reference Books/ Journals

Castellan, G. W. Physical Chemistry, Narosa

Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press.

McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press.

Levine, I. N. Physical Chemistry, Tata McGraw-Hill.

Moore, W. J. Physical Chemistry, Orient Longman.

Mortimer, R. G. Physical Chemistry, Elsevier.

Engel, T. & Reid, P. Physical Chemistry, Pearson.

Maron, S.H., Prutton, C. F., Principles of Physical Chemistry, McMillan.

Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics: Basic Concepts and Method, Wiley.

Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas Publishing House.

Glasstone, S. An Introduction to Electrochemistry, East-West Press.

Rakshit, P.C., Physical Chemistry, Sarat Book Distributors, 7th Ed.

Kapoor, K.., A Textbook of Physical Chemistry, Volume-4, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.

Kapoor, K.., A Textbook of Physical Chemistry, Volume-5, McGraw Hill Education (India) Pvt. Ltd., 5th Ed.

Chemistry MAJOR
Course code: CHEM6014 (3 and 4 Years)
Course title: Inorganic & Physical Chemistry (Practical)

F.M. 75 (60+ 15)
Credit: 4

Course objective

- Development of practical knowledge for several basic and advanced topics of inorganic and physical chemistry

Course outcome

- The course will help the students to develop a complete practical knowledge on inorganic as well as physical chemistry

Practical **Credit: 4**

Inorganic Chemistry experiments (F.M. 30)

I. Volumetric estimation using redox titration:

(a) Estimation of Mohr's salt with standard $KMnO_4$ and $K_2Cr_2O_7$ solution

(b) Estimation of Fe^{+2} and Fe^{+3} (total iron) with standard $KMnO_4$ and $K_2Cr_2O_7$ solution

(c) Estimation of one of the metal ions such as iron, copper, chromium and manganese in a binary mixture using dichromometry/permanganometry/iodometry as applicable

II. Volumetric estimation using complexometric titration:

Complexometric titration using EDTA for estimation of (a) Ca(II) or Mg(II) in a mixture and (b) total hardness of water sample

III. Colorimetric analysis of (i) Mn(II) in permanganate solution and (ii) Cr(III) in dichromate solution

Physical Chemistry Experiments (F.M. 30)

(i) Verification of Beer-Lambert's law for aqueous $KMnO_4$ and $K_2Cr_2O_7$ solutions.

(ii) Determination of Indicator Constant (K_{In}) of an acid-base indicator colorimetrically.

(iii) Potentiometric titration of a solution of strong acid with a solution of strong alkali using quinhydrone electrode.

(iv) Potentiometric titration of a solution of weak acid with a solution of strong alkali and determination of pKa of the weak acid.

(v) Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$ solution

(vi) Determination of hydrolytic constant (K_h) of ammonium chloride solution pH-metrically.

(vii) Study the phase diagram of a binary system (phenol-water) and the effect of impurities (e.g., NaCl)

Reference Books/ Journals

Mendham, R.C., Denney, J.D., Baines, M. Thomas and Siva Sankar, B. Vogel's Text Book on Quantitative Chemical Analysis, 6/e, Pearson.

Nad, A. K., Mahapatra, B. & Ghosal, A. An Advanced Course in Practical Chemistry, New Central Book Agency, 2007.

Das, S.C. Advanced Practical Chemistry, The World Press Pvt. Ltd., 4th Ed. 2010

Mukhopadhyay, R. & Chattejee, P. Advanced Practical Chemistry, Books & Allied (P) Ltd., 3rd Ed., 2007.

Maity, S. K. & Ghosh, N. K. Physical Chemistry Practical, New Central Book Agency (P) Ltd. 2012

SEMESTER VII

Chemistry Major/Core Course

Paper Code: **CHEM7011**

Paper Title: **Inorganic General**

Credit: 6

Course Objective:

- The objective is to impart into the students (i) theoretical the idea and understanding of chemical bonding and properties through a quantum chemical approach, chemical structures, bonding, stereochemistry and properties of elements and coordination complexes and organometallics, structures and properties of

crystalline and amorphous solids, and (ii) practical knowledge and skills for quantitative estimation and analysis of pyrolusite, dolomite and brass.

Course outcome:

On completion of the course the students will be able to:

- Learn and apply quantum mechanics in understanding chemical bonding with molecular orbital (MO) theory formalism and thereby predict the structures and properties of several homo- and heteronuclear molecules
- Learn and understand the chemistry of elements (nontransition, transition, lanthanides, and actinides) and their compounds of different sizes in varying ligands sites
- Understand and predict the chemical bonding and structures of coordination complexes, and their stereo-chemical, magnetic and spectral properties.
- Analyzeandcharacterizeseveralorganometaliccompoundsinvaryingligandsystemsaswell as the interactions therein.
- ions and their compounds as well as to apprehend their applicability in biological and material sciences
- Understand the fundamentals of ionic, covalent, hydrogen bonded and molecular solids and thereby to explain structural, magnetic and conducting behaviors of different kinds of solids

Theory **Credit: 4**

Bonding and properties in chemical system – a quantum chemical approach 15 Hours

The Born-Oppenheimer approximation, the hydrogen molecular ion (H_2^+), Molecular Orbital (MO) theory, Linear Combination of Atomic Orbitals (LCAO), LCAO-MO method, MO of homo- and heteronuclear diatomic molecules, MO of polynuclear AB_n type molecules, Molecular electronic terms, the hydrogen molecule (H_2), electron probability density, dipole moment, Semiemperical treatment of polyatomic molecules: Hückel method of π-MO calculation, Frost diagram of carbocyclic π-systems

Chemistry of elements and Coordination chemistry – structure, bonding, stereochemistry and properties 15 Hours

Chemistry of elements

Elements – structural versatility and related properties; compounds – design and syntheses, isolation, characterization, solution structure, molecular aggregate, crystalline architecture,

spectral, magnetic and catalytic properties and application in chemistry, biology and materials science

Non-transition and transition metal ion homoleptic/heteroleptic and homonuclear/ heteronuclear complexes of different dimensions with varied mono- and polydentate blockers containing carbon, nitrogen, phosphorus, chalcogen, halogen donors with/without mono-/polydentate bridges and counter ions

Inner-transition metals: Ionization energy, electrode potential, metallic and ionic radii, peculiarities in electronic and magnetic properties, coordination chemistry, formation constant, actinyl ion

Coordination chemistry – structure, bonding, stereochemistry and properties

Fundamentals, Orgel diagram, Tanabe-Sugano diagram, ligand symmetry orbital, molecular orbital, spectral properties, Nephelauxetic effect, Racah parameter, vibronic coupling, band broadening, spin-orbit coupling, spin-forbidden transition, intensity stealing, magnetic properties, anomalous and subnormal magnetic moments, lowering of symmetry, electronic, steric, Jahn-Teller and Renner-Teller effects on energy levels, conformation of chelator/congregator, structural equilibrium and implication, Correlation of CFSE with spectroscopy

Organometallic chemistry-I 15 Hours

Overview and striking difference, valence electron count, oxidation number and formal ligand charge; carbonyl ligand, pi-ligands: linear pi systems and cyclic pi systems, complexes containing M-C, M=C and M≡C bonds, hydride and dihydrogen complexes, phosphines and related ligands, spectral analysis and characterization, Dewar-Chatt-Duncansonbonding model, isolobal analogy, Agostic interaction

Structure and properties of solids 15 Hours

Crystalline and amorphous solids, lattice, basis, unit cell, symmetry elements, Bravais lattices, close packing in solids (hcp, ccp), voids in close packing, types of bonding in solids, ionic, covalent, metallic, molecular and hydrogen-bonded solids, lattice energy, Born–Haber cycle, Madelung constant, radius ratio rules, crystal field considerations in solids, structure–property correlations. AB and AB_2 type structures, Perovskite structure, Ilmenite structure, Rutile structure, tolerance factor and structural distortion, normal and inverse Spinel structure, cation distribution and magnetic implications, Diamond cubic crystal structure, zinc blende and wurtzite structures, structural comparison and applications. Classification based on SiO_4 tetrahedral linkage, single chain silicates (pyroxenes), double chain silicates (amphiboles), sheet silicates (talc, mica, clay minerals), three-dimensional framework silicates (zeolites), isomorphous substitution, ion exchange properties,

structural chemistry and industrial applications. Point defects, Schottky and Frenkel defects, line defects and dislocations, surface defects and grain boundaries, non-stoichiometric compounds, metal excess and metal deficiency defects, defect equilibria, defect chemistry and its influence on electrical and optical properties, F-center and colorcenters. Free electron theory, band theory of solids, conductors, insulators and semiconductors, intrinsic and extrinsic semiconductors, n-type and p-type semiconductors, superconductivity, critical temperature, Meissner effect, type I and type II superconductors, diamagnetism, paramagnetism, ferromagnetism, antiferromagnetism, ferrimagnetism, cooperative magnetism and magnetic domains. Polarization mechanisms in solids, ferroelectricity, antiferroelectricity, pyroelectricity, piezoelectricity, dielectric properties, liquid crystals (nematic, smectic, cholesteric phases), order parameter and phase transitions, structure–property relationships and technological applications

Reference Books/ Journals

H. E. White, *Introduction to Atomic Spectra*, McGraw-Hill Kogakusha Ltd, Tokyo, 1934.

B. N. Figgis, *Introduction to Ligand Field Theory*, Interscience, New York, 1966.

C. J. Ballhausen, *Molecular Electronic Structure of Transition Metal Complexes*, McGraw-Hill, London, 1979.

R. McWeeney, *Coulsons' Valence*, 3rd Edn, Oxford University Press, Oxford, 1979.

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B. E. Douglas and C. A. Hollingsworth, *Symmetry in Bonding and Spectra, An Introduction*, Academic Press, New York, 1985.

T. A. Albright, J. K. Burdett and M. H. Whangbo, *Orbital Interactions in Chemistry*, Wiley, New York, 1985.

V. Heine, *Group Theory in Quantum Mechanics: An Introduction to Its Present Usage*, Dover Publication, New York, 1991.

K. Fukui and H. Fujimoto, *Frontier Orbital and Reaction Paths,* World Scientific, Singapore, 1995.

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F. A. Cotton, *Chemical Applications of Group Theory*, 3rd Edn, John Wiley & Sons, New York, 1999.

F. A. Cotton, G. Wilkinson, C. M. Murillo and M. Bochmann, *Advanced Inorganic Chemistry*, 6th Edn, John Wiley & Sons, Inc, New York, 1999.

B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models of Inorganic Chemistry*, 3rd Edn, John Wiley & Sons, Inc., New York, 2001.

G. Wulfsberg, *Inorganic Chemistry*, Viva Books Pvt Ltd, New Delhi, 2001.

J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorgnic Chemistry: Principles of Structures and Reactivity,*

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D. A. McQuarrie, P. A. Rock and E. B. Gallogly, *General Chemistry*, 4th Edn, University Science Books, Mill Valley, Canada, 2011.

A. K. Mukherjee, B. C. Ghosh, Group theory in Chemistry: Bonding and molecular spectroscopy, Universities press, 2018

R. S. Drago, *Physical Methods for Chemists*, Saunders, Philadelphia, 1992.

C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, Tata McGraw-Hill Publishing Company Ltd, New Delhi, 1994.

J. M. Hollas, *Modern Spectroscopy*, Wiley, New York, 1996.

D. N. Sathyanarayana, *Electronic Absorption Spectroscopy and Related Techniques*, University Press, 2001.

M. Cox, *Optical Properties of Solids*, Oxford University Press, Oxford, 2001.

G. Aruldhas, *Molecular Structure and Spectroscopy*, 2nd Edn, Prentice-Hall of India, New Delhi, 2007.

C. Trindle and D. Shillady*, Electronic Structure Modeling: Connection between Theory and Software*, CRC Press, Boca Raton, FL, 2008.

P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Shriver & Atkins Inorganic Chemistry,* 4th Edn, Oxford, 2006. 7

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O. Kahn, *Molecular Magnetism*, VCH, New York, 1993.

G. W. Parshall, *Homogeneous Catalysis*, Wiley, New York, 1980.

C. N. Satterfield, *Heterogeneous Catalysis in Practice*, McGraw-Hill, New York, 1980.

P. Powell, *Principles of Organometallic Chemistry*, 2nd Edn, Chapman and Hall, London, 1988.

J. D. Atwood, *Inorganic and Organometallic Reaction Mechanisms*, 2nd Edn, VCH, New York, 1997.

R. H. Crabtree, *The Organomettalic Chemistry of the Transition Metals*, 4th Edn, Wiley, New York, 2005.

C. Elschenbroich, *Organometallics*, 3rd Edn, Wiley-VCH, Weinheim, 2006.

R. A. van Santen and M. Neurock, *Molecular Heterogenous Catalysis,* Wiley-VCH, Weinheim, 2006.

G. O. Spessard and G. L. Miessler, *Organometallic Chemistry*, International 2nd Edn, Oxford University Press, Oxford, 2010.

J. F. Hartwig, *Organotransition Metal Chemistry. From Bonding to Catalysis*, University Science Books, Sausalito, CA, 2010.

S. J. Lippard and J. M. Berg, *Principles of Bioinorganic Chemistry*, University Science Books, Mill Valley, CA, 1993.

W. Kaim and B. Schwederski, *Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life,* Wiley, New York, 1994.

I. Bertini, H. B. Gray, S. J. Lipperd and J. S. Valentine, *Bioinorganic Chemistry*, Viva Books Pvt. Ltd., New Delhi, 1998.

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A. K. Das, Bioinorganic Chemistry, Books & Allied (P) Ltd. Kolkata 2007.

E. Ochiai*, Bioinorganic Chemistry: A Survey*, Academic Press, Elsevier, 2009.

R. R. Crichten, *Biological Inorganic Chemistry: A New Introduction to Molecular Structure,* 2nd Edn, Elsevier, New York, 2012.

R. M. Roat-Malone, *Bioinorganic Chemistry: A short Course*, 2nd Edn, Wiley, New York, 2013.

G. Patrick, *Instant Notes: Medicinal Chemistry*, Viva Books, New Delhi, 2002.

G. L. Patrik, *An Introduction to Medicinal Chemistry,* 3rd Edn*,* Oxford University Press, 2006.

A. Kar, *Medicinal Chemistry*, 4th Edn, New Age International (P) Ltd, New Delhi, 2007.

C. G. Wermuth (Ed), *The Practice of Medicinal Chemistry*, Academic Press, Noida, India, 2008.

D. Sriram and P. Yogeeswari, 2/e, Medicinal Chemistry, Pearson

G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3/e, Pearson.

A. G. Sharpe, Inorganic Chemistry, 3/e, Pearson

A. F. Hill, *Organotransition Metal Chemistry*, Royal Society of Chemistry, London, 2002.

A. F. Wells, *Structural Inorganic Chemistry,* 5th Edn, Oxford University Press, Oxford, 1984.

W. A. Harrison, *Electronic Structure and the Properties of Solids: The Physics of the Chemical Bonds*, Dover Publications, New York, 1989.

D. M. Adams, *Inorganic Solids*, Wiley, New York, 1992.

T. C. W. Mak and G. -D. Zhou, *Crystallography in Modern Chemistry*, Wiley, New York, 1992.

S. R. Elliot, *The Physics and Chemistry of Solids*, John Wiley& Sons, Chichester, 1998. 17

M. Cox, *Optical Properties of Solids*, Oxford University Press, Oxford, 2001.

L. E. Smart and E. A. Moore, *Solid State Chemistry: An Introduction,* 4th Edn, CRC Press, Boca Raton, FL, 2012.

A. R. West, *Solid State Chemistry and Its Application*, 2nd Edn, Wiley-VCH, Weinheim, 2014.

Practical **Credit: 2**

Quantitative estimation of pyrolusite (estimation of available oxygen along with other metal ions), dolomite and brass

Reference Books/ Journals

J. Mendham, R. C. Denney, J. D. Barnes, M. Thomas, Vogel's Text Book of Quantitative Chemical Analysis 6th Edition, Pearson Education Asia, Singapore (2002).

P. Karmakar, S. Ray, R. Sarkar (Sain), A. K. Ghosh, Concise Practical Chemistry, New Book Stall, Kolkata (2018).

Chemistry Major/Core Course

Paper Code: **CHEM7012**

Paper Title: **Nuclear Analytical General**

Credit: 6

Course Objective:

- The objective is to impart into the students (i) theoretical idea and understanding of nuclear structures and properties, radioactive equilibrium, matter-radiation interaction, statistical methods in analytical chemistry, several thermal methods of analysis, separation techniques, environmental chemistry and cosmochemistry, and (ii) practical knowledge and skills for the estimation of molecular weights, cations and anions, and separation of cations in mixtures by using resins.

Course outcome:

On completion of the course the students will be able to:

- Acquire knowledge on the structure, stability and properties of atomic nucleus along with different disintegration series, their kinetics and activation processes.
- Understand the radioactive radiations, their interaction with matters and related phenomena.
- Realize the radioactivity as a statistical phenomenon and thereby to grasp the importance of statistical methods in the analytical measurement of radioactivity and the related properties.
- Learn and explore different types of methods of elemental analysis, various types of titrations and their applications
- Assimilate ideas on green chemistry and cosmochemistry
- Understand the chemistry behind the separation and estimation of different compounds using ion-exchange resins and thereby acquire skills in designing experiments and/or their need-based extensions.

Theory **Credit: 4**

Nuclear properties and structure I 15 Hours

Liquid drop model, formulation of semi-empirical binding energy equation, mass parabola and application of binding energy equation; nuclear reactions, Q-value and cross section of nuclear reaction, compound nucleus theory (qualitative approach), calculation of fission probability using binding energy equation nuclear angular momentum, magnetic dipole

moment and electronic quadruple moment, parity of nuclear energy states; nuclear size and root mean square radius of atomic nucleus

Radioactive equilibrium 7 Hours

Successive disintegration, Bateman equation, secular and transient equilibrium, no equilibrium; analysis of special types of successive disintegration, formation of radioelement in a nuclear reaction, activation analysis (introductory)

Interaction of radiation with matter 10 Hours

Different radiations, interactions of heavy charged particles, charged particles and photons, energy loss, stopping power and related semi-emperical calculations, Bethe formula, collisional and radiative stopping power, mean excitation energy, range, slowing down time, Cerenkov radiation, attenuation coefficient

Statistical methods in analytical chemistry 7 Hours

Application of counting statistics in analytical and nuclear measurements: probability and binomial distribution, radioactivity as a statistical phenomenon, standard deviation of counting data, Poisson distribution, optimization of counting experiments

Thermal methods 5 Hours

Different methods of analysis: thermogram, TGA, DTA and their applications

Separation techniques 7 Hours

Chromatography: band broadening, column efficiency; column resolution, numerical problems, gas chromatography, high performance chromatography. Ionic liquids: synthesis, properties and applications, green solvent.

Environmental chemistry 4 Hours

Hazardous and Radioactive wastes, treatment, waste management, fertilizer industries

Cosmochemistry 5 Hours

Different geological systems, age of rocks and earth, cosmic rays and its effect in meteorites, comets, black hole, nuclear reactions in stars, solar neutrino hypothesis

Reference Books/ Journals

B. Harvey, *Introduction to Nuclear Physics and Chemistry*, Prentice Hall, New York, 1965.

S. Glasstone, *Source Book of Atomic Energy*, East-West Press Private Ltd, New Delhi, 1967.

R. D. Evans, *The Atomic Nucleus*, McGraw-Hill, New York, 1979.

G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller, *Nuclear and Radiochemistry*, 3rdEdn, Jhon Wiley & Sons Inc, New York, 1981.

H. J. Arnikar, *Essentials of Nuclear Chemistry*, 4thEdn, New Age International (P) Ltd Publications, New Delhi, 2001.

W. D. Loveland, D. J. Morrissey and G. T. Seaborg, *Modern Nuclear Chemistry*, Wiley Interscience, New Jersey, 2006.

C. Duval, *Inorganic Thermogravimetric Analysis*, Elsevier Publishing Co, New York, 1963.

P. Tundo, A. V Perosa and F Zecchimi (Eds), *Methods and Reagents for Green Chemistry: An Introduction*, Wiley Interscience, New Jersey, 2007.

R. Sanghi and V. Singh, *Green Chemistry for environmental remediation*, Wiley, New York, 2012.

A. K. De, *Environmental Chemistry*, 4thEdn, New Age International (P) Ltd Publications, New Delhi, 2000.

Practical **Credit: 2**

1. Determination of equivalent weight of different salts (NaCl, $MgSO_4$, $ZnSO_4$, etc) using cation-exchange resin
2. Determination of the amount of Na^+ and Mg^{2+} in a mixture using cation-exchange resin
3. Separation and estimation of Zn^{2+} and Mg^{2+} in a mixture byusing anion-exchange resin
4. Estimation of chloride ion (Cl^-) by adsorption and elution overanion-exchange resin

Reference Books/ Journals

G. H. Jeffery, J. Bassett, J. Mendham, R. C. Denney, Vogel's Textbook of Quantitative Chemical Analysis (5 th Edition), 1989.

J. S. Fritz and S. K. Karraker, Ion Exchange Separation of Metal Cations, Anal. Chem., 32, 8, 957–960 (1960).

Frederick C. Nachod, Ion Exchange: Theory and Application, Academic Press, 1940.

Dr. Inamuddin and Mohammad Luqman, Ion Exchange Technology II: Applications, Springer Netherlands, 2014.

Chemistry Major/Core Course

Paper Code: **CHEM7013**

Paper Title: **Organic General**

Credit: 6

Course Objective:

- The objective is to impart into the students (i) theoretical idea and understanding of conformation and reactivity of cyclic systems, structure-reactivity relationship, heterocycles, polymers of principles and synthesis, proteins, and (ii) practical knowledge and skills for separation of a binary mixture of liquid-solid/liquid-liquid of organic compounds and identification of functional groups of liquid components

Course outcome:

On completion of the course the students will be able to:

- Learn and accumulate ideas on stereo-chemical conformations and stereo-selective reactivity of various ring systems.
- Understand the structure-activity relationships in quantifying kinetic parameters of aromatic and aliphatic compounds and the role of several factors like conjugation, steric, and solvents, etc. on the parameters.
- Acquire knowledge for the synthesis, reactivity and uses of several heterocycles and their derivatives.
- Understand the classification of proteins, their quality evaluation with some well defined indices, amino acid analysis, and their molar mass determination.
- Grasp the basic ideas of polymers, their structural units, formations and reactions

Theory **Credit: 4**

Conformation and reactivity of cyclic systems 15 Hours

Introduction; reactions on small rings (four and five membered rings); six-membered rings (cyclohexanone, cyclohexene, cyclohexenone, epoxycyclohexane): stereoselectivity in reactions, conformational control in ring formation; Stereoselective reactions of bicyclic compounds: bridged, fused and spiro

Structure-reactivity relationship 8 Hours

A quantitative approach to Linear free energy relations: Hammett equation, Hammett's σ_x and ρ values and their physical significance through conjugation; deviations from straight line plots; steric effects: Taft equation; solvent effects: Grunwald-Winstein equation

Heterocycles 15 Hours

Synthesis and reactions of 5-memberded heterocycle containing two hetero-atoms: imidazole, pyrazole, oxazole, isooxazole, thiazole, isothiazole, triazole and their derivatives

Polymers: principles and synthesis 10 Hours

Monomer, dimer, dendrimer and polymer; mechanism of formation: carbonyl substitution reactions, electrophilic aromatic substitution, the SN^2 reaction and nucleophilic attack on isocyanates; polymerization of alkenes; co-polymerization; biodegradable polymers and plastics; reactions on polymers

Proteins 12 Hours

Classification, evaluation quality: biological value, digestibility co-efficient, PER and NPU; denaturation, structure elucidation; amino acid analysis, molecular weight determinations, tertiary and quaternary structures

Reference Books/ Journals

D. Nasipuri, *Stereochemistry of Organic Compounds*, 2nd Edn, Wiley Eastern, New Delhi, 1993.

E. L. Eliel, S.H. Wilen and L.N. Mander, *Stereochemistry of Organic Compounds*, John Wiley & Sons, New York, 1994.

R. S. Ward, *Selectivity in Organic Synthesis*, John Wiley & Sons, New York, 1999.

F. A. Carey and R. J. Sundberg, *Advanced Organic Chemistry Part A and Part B*, 4th Edn, Plenum Press, New York, 2001.

J. Clayden, N. Greeves, S. Warren and P. Wothers, *Organic Chemistry*, Oxford University Press, Oxford, 2001.

J. R. Hanson, *Organic Synthetic Methods*, Royal Society of Chemistry, London, 2002.

J. H. Fuhrhop and G. Li, *Organic Synthesis*, Concepts and Methods, Wiley-VCH, New York, 2003.

P. Sykes, *A Guidebook to Mechanism in Organic Chemistry*, 6th Edn, Pearson Education Ltd, New Delhi, 2011.

R. Kartritzky, *Handbook of Heterocyclic Chemistry*, Pergamon Press, London, 1986.

R. R. Gupta, M. Kumar, V. Gupta, *Heterocyclic Chemistry II*, Springer Pvt Ltd, India, 2005.

R. K. Bansal, *Heterocyclic Chemistry*, 4th Edn, New Age International (P) Ltd, India, 2005.

J. A. Joule, K. Mills, *Heterocyclic Chemistry*, 5th Edn, John Wiley & Sons Ltd, UK, 2010.

K. Nakanishi, T. Goto, S. Ito, S. Natori and S. Nozoe, *Natural Products Chemistry*, Vol I, Academic Press, New York, 1974.

M. P. Stevens, *Polymer Chemistry*: An Introduction, 3rd Edn, Oxford University Press, USA, 1998.

G. R. Newkome, C. N. Moorefield and F. Vogtle, *Dendrimers and Dendron*: Concepts, Syntheses, Applications, Wiley-VCH, Weinheim, 2001.

G. Odian, *Principles of Polymerization*, 4th Edn, Wiley Interscience, New Jersey, 2004.

P. C. Hiemenz and T. P. Lodge, *Polymer Chemistry*, 2nd Edn, CRC Press, Boca Raton, FL, 2007.

Practical **Credit: 2**

Separation of following binary mixtures of liquid-solid and liquid-liquid organic compounds by solvent extraction technique and functional group identification of liquid components

Liquid-liquid mixture: aniline + diethyl malonate, aniline + ethyl benzoate, aniline + benzyl alcohol, m-toluidine + cyclohexanol, m-anisidine + cyclohexanol

Liquid-solid mixture: benzyl alcohol + p-nitrobenzoic acid, aniline + benzanilide, diethyl malonate + p-nitrophenol, acetophenone + salicylic acid, cyclohexanol + p-nitroaniline

Reference Books/ Journals

A. I. Vogel, Elementary Practical Organic Chemistry: Qualitative Organic Analysis Part 2, CBS Publishers and Distributors

Chemistry Major/Core Course

Paper Code: **CHEM7014**

Paper Title: **Physical General**

Credit: 6

Course Objective:

- The objective is to impart into the students (i) theoretical idea and understanding on symmetry and group theory with applications, fundamentals quantum mechanics, theories and applications of chemical kinetics, electrochemistry; thermodynamics and statistical mechanics, and (ii) practical knowledge and understanding of the experiments on kinetics and equilibrium and develop skills in handling instruments (like, conductivity-bridge, potentiometer, colorimeter, polarimeter, etc.)

Course outcome:

On completion of the course the students will be able to:

- Learn and identify the symmetry elements and operations and hence the point group of an object including fullerene, construct representations and hence character table of a point group and use it in analyzing and solving physicochemical problems
- Get hold of projection operator and hence its use in calculating SALCs and MOs under Hückel approximations for some simple system
- Analyze the quantum mechanical postulates, understand conversion of orthonormal functions from degenerate functions, Heisenberg uncertainty principle and its consequences
- Understand quantum mechanical equation of motion and related theorems and handle several exactly solvable problems, like step potential and tunnelling, the Virial theorem, harmonic oscillator, rigid rotator, Dirac delta function, Fourier Transform, etc.
- Get the ideas behind the theories of reaction rate and thereby derive the corresponding rate expressions.
- Apply the theories in thermodynamic formation of reaction rates in studying uni-, bi-and ter-molecular reaction rates, and other consequences thereof.
- Understand statistical interpretation of thermodynamics, express thermodynamic functions, specific heats of solids, and equilibrium constant of a reaction in terms of partition functions and interpret equipartition principle.
- Realize ion-solvent interaction in reference with several models and hence calculate the change of thermodynamic parameters, salvation number, ion-association, ion association constant, factors responsible for.
- Understand concept of electrode kinetics relating current with rates of electrode reactions and hydrogen electrode with its application in charge transfer reaction.

Theory **Credit: 4**

Symmetry and group theory 15 Hours

Point symmetry operations, groups and group multiplication tables, similarity transformation and conjugate classes, identification of point groups and stereographic projection, symmetry elements and symmetry operations of the Platonic solids, symmetry of the fullerene [60] structure; representation of symmetry operators and groups; characters of symmetry operators in a representation, invariance of character under similarity transformation, rules (without derivation) for construction of character tables with illustrations

The Great Orthogonality Theorem: statement and interpretation, proof of important corollaries; construction of character tables, cyclic groups and construction of their character tables, direct product groups, direct product representations, projection operators (without derivations) and vanishing of integrals, invariance of the Hamiltonian operator and eigenfunctions of Hamiltonian operator (H) as bases of irreducible representations, SALCs and their use in calculating π MOs under the Hückel approximations for some simple systems, outlines of symmetry aspects of molecular spectra

Quantum mechanics III 12 Hours

Analysis of quantum mechanical postulates - pictures and representations; properties of sets of functions, operators and related theorems; degeneracy, spread of observation and uncertainty principle; Schmidt orthonormalisation; Fourier transformation, delta function with examples, free particle normalization, matrix formulation, bound states, the Virial theorem

Equation of motion, constants of motion; Ehrenfest's theorem, exactly solvable problems: step potential and tunneling, bound states, the Virial theorem, harmonic oscillator, rigid rotator; elementary discussion of the H-atom solution

Chemical kinetics III 13 Hours

Theories of reaction rates: applications to uni-, bi- and termolecular reactions, thermodynamic formulation of reaction rate, reactions in solution cage effect, diffusion and activation controlled reactions (elementary idea), dielectric effect on ion-ion reaction, electrostriction, volume of activation, effect of pressure on reaction rate, classification of reactions on the basis of volume of activation, study of fast reactions flow process and relaxation techniques; Curtin-Hammett principle, linear free energy relationship, Hammett and Taft equations

Electrochemistry III 10 Hours

Introduction, ion-solvent interaction: Born model and Born equation, enthalpy, entropy and free energy of ion-solvent interaction and their calculations, Eley-Evan model, solvation number and methods for determination of solvation number, ion association: Bjerrum equation, fraction of ions associated, ion association constant, factors responsible for ion association; effect of ion association over conductivity; ion-dipole and ion-quadrupole interactions; electrode kinetics: relation between current and rate of electrode reaction, current-overpotential relationship, Tafel equation and its importance; Hydrogen electrode and its application in charge transfer reaction.

Statistical Thermodynamics II 10 Hours

Legendre transformation with applications; Maxwell-Boltzmann distribution with degeneracy (for both distinguishable and indistinguishable particles), partition function and its properties, interpretation of thermodynamic laws, thermodynamic function in terms of partition functions,

molecular partition functions (translational, rotational, vibrational and electronic) for ideal gas, calculation of thermodynamic functions for monoatomic and diatomic gases, equipartition principle, equilibrium constant, theories of specific heat of solids

Reference Books/ Journals

S. C. Rakshit, *Molecular Symmetry Group and Chemistry*, The New Book Stall, Kolkata, 1988.

V. Heine, *Group Theory in Quantum Mechanics: An Introduction to Its Present Usage*, Dover Publication, New York, 1991.

D. M. Bishop, *Group Theory and Chemistry*, Oxford University Press, 1993.

A. K. Mukherjee and B. C. Ghosh, *Group Theory in Chemistry: Bonding and Molecular Spectroscopy*, Universities Press (India) Private Ltd., Hyderabad, 2018

A. Vincent, *Molecular Symmetry and Group Theory*, John Wiley & Sons, New York, 1998.

F. A. Cotton, *Chemical Applications of Group Theory*, 3rdEdn, John Wiley & Sons, New York, 1999.

L. Pauling and E. B. Wilson, *Introduction to Quantum Mechanics*, McGraw-Hill, New York, 1939.

H. Eyring, J. Walter and G. F. Kimball, *Quantum Chemistry*, Wiley, New York, 1944.

P. W. Atkins, *Molecular Quantum Mechanics*, Clarendon Press, Oxford, 1980.

L. I. Schiff, *Quantum Mechanics*, McGraw-Hill, New York, 1985.

A. K. Chandra, *Introductory Quantum Chemistry*, Tata McGraw-Hill Publishing Co, New Delhi, 1989.

F. L. Pilar, *Elementary Quantum Chemistry*, Tata McGraw-Hill, New Delhi, 1990.

D. A. McQuarrie, *Quantum Chemistry,* Viva Books Pvt Ltd, New Delhi, 2003.

S. Glasstone, *An Introduction to Electrochemistry*, D. Van Nostrand Company, 1962.

J. O'M. Bockris and A. K. N. Reddy, *Modern Electrochemistry*, Vol I, Plenum Press, New York, 1970.

I. N. Levine, *Physical Chemistry*, Tata McGraw-Hill, New Delhi, 1978.

K. J. Laidler*, Reaction Kinetics,* Vols I and II, Pergamon Press, London, 1970.

L. P. Hammett*, Physical Organic Chemistry*, McGraw-Hill Book Company, New Delhi, 1970.

J. Albery, *Electrode Kinetics*, Oxford Chemistry Series, Clarendron Press, Oxford, 1975.

K. J. Laidler*, Chemical Kinetics,* Tata McGraw-Hill Publishing Company Ltd, New Delhi, 1988.

M. R. Wright, *Fundamental Chemical Kinetics*, Horwood Publishing, 1999.

K. Denbigh, *Principles of Chemical Equilibrium*, Cambridge University Press, Cambridge, 1981.

I. M. Klotz and R. M. Rosenberg, *Chemical Thermodynamics*, John Wiley, New York, 1994.

G. W. Castellan*, Physical Chemistry,* 3rdEdn, Narosa Publishing House, 1995.

N. A. Gokcen and R. G. Reddy, *Thermodynamics*, Plenum Press, New York, 1996.

G. K. Vemulapalli, *Physical Chemistry*, Prentice-Hall, India, 1997.

P. W. Atkins, *Physical Chemistry*, Oxford University Press, Oxford, 1998.

R. S. Berry, S. A. Rice and J. Ross, *Physical Chemistry*, Oxford University Press, Oxford, 2000.

D. A. McQuarrie and J. D. Simon, *Molecular Thermodynamics,* University Science Books, California, 1999.

Practical **Credit: 2**

1. **Experiments on kinetics:**
   (a) Decomposition H_2O_2 by $FeCl_3$
   (b) Reaction between $K_2S_2O_8$ and KI analytically and/ or spectrophotometrically
   (c) Activation energy of clock reaction
   (d) Inversion kinetics of cane sugar (polarimetrically)
2. **Experiments on equilibrium:**
   (a) Conductometric and potentiometric titrations of (i) weak acid and (ii) mixtures of weak acids and basesfor determination of pK_a values of the concerned acid(s)
   (b) Potentiometric titration of $AgNO_3$ solution by KCl solution for the determination of K_{sp} of AgCl
   (c) Hydrolysis constant (K_h) of aniline hydrochloride by conductometric method
   (d) Ternary phase diagram for (water-chloroform-acetic acid) system
   (e) Coordination number of copper in cuproammonium complex by partition method

Reference Books/ Journals

P. B. Levitt, *Findlays Practical Physical Chemistry*, Longman's London (1966).

D. Shoemaker and C. Garland, Experiments in Physical Chemistry, McGraw Hill International Edition (1966).

H. W. Salberg J. I. Morrow, S. R. Cohen and M. E. Green, Physical Chemistry Laboratory Principles and Experiments, Macmillan publishing Co., New York (1978)

D. Farrington, Experimental Physical Chemistry, McGraw Hill, New York (1956).

A.M James and P. E. Pritchard, Practical Physical Chemistry, Longman's Group Ltd. (1968).

J. M. Wilson, R. J. Newcombe, A. R. Denaro and R. M. W. Rickett, Experimental Physical Chemistry, Pergamon Press, New York (1962).

J. C. Ghosh, Experiments in Physical Chemistry, Bharati Bhawan (P & D), Patna (1988).

J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishers, Meerut (1988).

B. C. Kosla, Senior Practical Physical Chemistry, Simla Printers, New Delhi (1987).

R.C. Behra & B Behra, Experimental Physical Chemistry, Tata McGraw, ND (1983)

V. D. Atavale and Parul Mathur, Experimental Physical Chemistry, New Age International, New York (2001).

Chemistry Minor Course

Paper Code: **CHEM7021**

Paper Title: **Industrial Chemistry**

Credit: 4

Course Objective:

- The objective is to impart into the students the theoretical idea and understanding on classification and characteristics of fuels and combustion, macromolecular polymers**,** glass with classification and structures, spectroscopic techniques like, UV–Visible, atomic absorption, fluorescence and mass spectrometry, and analytical data analysis

Course outcome:

On completion of the course the students will be able to:

- Grasp the general ideas on various kinds of fuels, their combustion, calorific values, etc.
- Learn and understand polymers, their preparations, characteristics, average molar masses and different methods of determinations, etc.
- Acquire knowledge on glass and ceramics, methods of fabrication of different wares, porcelain and vitreous enamels, etc.
- Develop understanding on various analytical tools, techniques and analysis of data obtained from instruments like, UV-Vis., IR, AAS, Fluorescence, NMR, Mass spectroscopy.

Theory **Credit: 4**

Fuels and combustion 14 Hours

classification of fuels, characteristics of good fuel, combustion reactions, air requirement, calorific value, bomb calorimeter, Dulong's formula, solid fuels, coal, coke, carbonization, proximate analysis, ultimate analysis, liquid fuels, petroleum, refining, fractional distillation, cracking, octane number, cetane number, synthetic petrol, gaseous fuels, natural gas, LPG, CNG, producer gas, water gas, petrochemicals,

feedstocks, olefins, aromatics, nuclear fuels, fission, fusion, uranium, thorium, nuclear reactor, bio-fuels, bioethanol, biodiesel, biogas, transesterification

Macromolecular Polymers 14 Hours

Classification, polymerization - addition polymerization, condensation polymerization, ring opening, etc., polymerization techniques; degree and extent of polymerization, molecular weights and its determination- osmometry, viscometry, light scattering, sedimentation, thermoplastics, thermosetting polymers, elastomers, fibers, biopolymers, conducting polymers,polymer characterization, glass transition temperature, thermal analysis, mechanical properties, industrial polymers

Glass 6 Hours

Classification and structure, soda-lime glass, borosilicate glass, lead glass, manufacture, clays, kaolin, ball clay, fire clay, silica, ceramics, slip casting, dry pressing, isostatic pressing, sintering, porcelain, vitreous enamels

Spectroscopic techniques 20 Hours

UV–Visible spectroscopy: Beer–Lambert law, electronic transitions, instrumentation
IR spectroscopy: Molecular vibrations: functional group analysis
Atomic absorption spectroscopy: Flame method, graphite furnace
Fluorescence spectroscopy: Fluorescence, phosphorescence, nuclear magnetic resonance, chemical shift, spin–spin coupling
Mass spectrometry: Ionization methods, mass analyzer, fragmentation

Analytical data analysis 6 Hours

Calibration curve, accuracy, precision, standard deviation, limit of detection, limit of quantification, error analysis

Reference Books/ Journals

J. Griswold, Fuels, combustion and furnaces, McGraw-Hill Book Company, Inc., London (1946).
J R. Puskar, Fuel and Combustion Systems Safety, John Wiley & Sons, Inc. (2014).
S. Sarkar, FUELS AND COMBUSTION (3/E), Universities Press (2009).
O.P. Gupta, Elements of Fuel & Combustion Technology, Khanna Book Publishing Company (P) Ltd., New Delhi (2018).
C. Tanford, *Physical Chemistry of Macromolecules*, John Wiley & Sons, Inc, New York, 1961.
F. W. Billmeyer, *Text Book of Polymer Science*, 2nd Edn, Wiley-Interscience, New York, 1971.
G. S. Mishra, *Introductory Polymer Chemistry*, Wiley Eastern, New Delhi, 1993.

P. Ghosh, *Polymer Science and Technology of Plastic and Rubber*, Tata McGraw-Hill Publishing Company Limited, New Delhi, 1993.

S. F. Sun, *Physical Chemistry of Macromolecules: Basic Principles and Issues*, John Wiley & Sons, New York, 1994.

G. W. Castellan, *Physical Chemistry*, 3rdEdn, Narosa Publishing House, 1995.

R. A. Alberty and R. J. Silbey, *Physical Chemistry*, 1stEdn, John Wiley and Sons, Inc, New York, 1995.

I. N. Levine, *Physical Chemistry*, 4thEdn, Tata McGraw-Hill, New Delhi, 1995.

F. W. Fifield &D. Keatey,Principles and practice of analytical chemistry, Blackwell Science Ltd., Berlin (2000).

D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch, Fundamentals of analytical chemistry 9/E, Brooks/Cole Pub Co. (2003).

G. D. Christian, Analytical chemistry 6/E, Wiley India (1999).

A. K. Srivastava and P. C. Jain, Chemical Analysis: An Instrumental Approach, S. Chand & Co. (2000).

W. Kemp, Organic spectroscopy 3/E, Palgrave Macmillan (2008)

John R. Dyer, Applications of absorption spectroscopy of organic compounds, PHI learning Pvt. Ltd., New Delhi (1969).

R. M. Silverstein, F. X. Webster and D. L. Bryce, Spectrometric identification of organic compounds 8/E, John Wiley & Sons Inc. (2014).

D. L. Pavia, D.L., Lampman, G.M., Kriz, G.S. and Vyvyan, J.R., Infrared Spectroscopy. In: Introduction to Spectroscopy, Cengage Learning, Washington DC, (2009).

R. K. Das, Industrial chemistry, Asia Publishing House (1967).

S.M. Rao, A.B. Majali, R.G. Deshpande, T.S. Murthy (eds.), Industrial Applications of Radioisotopes and Radiation. A record of the contributions at the International Conference on Applications of Radioisotopes and Radiation in Industrial Development (March 1-3, 1984 Bombay, India), John Wiley & Sons Inc. (1986).

SEMESTER VIII

(Hons. with Research Project/ Dissertation)

Chemistry Major/Core Course

Paper Code: **CHEM8011**

Paper Title: **Research Methodology & Ethics**

Credit: 6

Course Objective:

- The objective is to impart into the students the theoretical idea and understanding on research and its methodology particularly of reviewing and surveying literature, writing research report with required format; testing of hypotheses and sampling for analysis and quantification research outputs, etc.

Course outcome:

After completion of the course the students will be able to

- describe important ideas, concepts, and research styles, such as mixed, qualitative, and quantitative approaches
- create testable hypotheses or research questions, outline research challenges, and identify research gaps
- create a well-thought-out research plan that includes sampling strategies, data gathering procedures, and the right instruments for data processing
- use citing tools correctly, synthesize current research findings, and critically evaluate academic literature
- plan and carry out investigations involving human or animal subjects by applying ethical principles and comprehending the ethical issues in research
- evaluate data and interpret the findings in a meaningful way by using fundamental statistical or thematic analysis and approaches
- compose well-organized research papers or reports and explain their findings either orally or visually. Students will gain the capacity to evaluate research papers and procedures critically for validity, reliability, and limitations.
- maintain research ethics throughout his/her research activities

Theory **Credit: 6**

Introduction to Research Methodology 20 Hours

Meaning of Research, Objectives of Research, Motivations in Research, Types of Research, Criteria of good Research, What is Research Problem? Basic and Applied research

Review of Literature and Literature survey 15 Hours

Meaning and Purpose of the Literature Review & Literature Survey, Identification of the related Literature.

The Research Report 15 Hours

General format of the Research report, style and formatting of writing, typing of the research report

Testing of Hypotheses and Sampling design 15 Hours

Definition, Concepts Concerning Testing of Hypotheses, Formulation of hypotheses and related difficulties; Needs of sampling, Sampling for chemical analysis, Random sampling

Research Ethics 15 Hours

Research Ethics: Ethical principles and responsible conduct of research (RCR); integrity, transparency, and accountability in scientific research. Scientific misconduct (fabrication, falsification, plagiarism), publication ethics, authorship, peer review, and data management. Ethical issues in human and animal research, informed consent, confidentiality, IEC/IRB approval, conflict of interest, and researcher responsibilities

Quantification of research output 15 Hours

Impact Factor, *h*-index, *i10*-index and *i20*-index, G-index

Reference Books/ Journals

C R Kothari, Research Methodology: Methods and Techniques, New Age International (P)Ltd. (2010), New Delhi

Garg, B.L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. *An introduction to Research Methodology*, RBSA Publishers.

Handbook of Communication and Social Interaction Skills by John O. Greene, Brant Raney Burleson.

W. M. K. Trochim, 2005. *Research Methods: the concise knowledge base*, Atomic Dog Publishing. 270p.

Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, SAGE Publications

Inderpal Singh, Research Methodology and Statistical Methods, Kalyani Publishers, Ludhiana.

G Kanji, 100 statistical tests, Sage Publications.

R.A. Day (1992) How to write and publish a scientific paper. Cambridge University Press. London.

Chemistry Minor Course

Paper Code: **CHEM8021**

Paper Title: **Medicinal Chemistry**

Credit: 4

Course Objective:

- The objective is to impart into the students the theoretical idea and understanding on supramolecular photochemistry, medicinal chemistry and drug discovery, radiopharmaceuticals, medicinal inorganic chemistry, pharmacokinetics, photodynamic medicine, and drug targets and drug delivery, etc.

Course outcome:

On completion of the course the students will be able to:

- Comprehend the applicability of supramolecular chemistry in photodynamic therapy as well as in medicinal prospect.
- Acquire idea and understanding on antibacterial, anticancer, antitussive, antiviral agents and structure-activity relationships (SARs).
- Understand the specific radiopharmaceuticals for diagnostic and therapeutic purposes, principle and instrumentation of gamma/PET camera for detection, methods (SPECT, PET, 18FDG etc.) of administration of radionuclides (nuclear medicines).
- Characterize biomolecules in the discovery and development of newer generation anti-tumour and anti-cancer agents
- Get hold of the ideas about drug absorption, drug distribution, drug metabolism, drug excretion, drug administration and drug dosing, etc.
- Grasp basic principle of photodynamic therapy and photochemotherapy and photodynamic medicine with their mode of action, etc.

Theory **Credit: 4**

Supramolecular Photochemistry 10 Hours

Mechanism of energy and/ electron transfer process(es), various supramolecular devices: electronic, ionic and switching devices, application of supramolecular chemistry in photodynamic therapy, some examples of self-assembly in supramolecular chemistry with prospect in medicinal applications

Medicinal Chemistry and Drug Discovery 8 Hours

Antibacterial, Anticancer, Antitussive, and Antiviral agents; Opium analgesics, Antibiotics, New drugs from old poisons; Drug discovery, Structure-Activity Relationships (SARs)

Radiopharmaceuticals 12 Hours

Nuclear pharmacy: concept, pharmaceuticals and radiopharmaceuticals; type of radionuclides, neutral/charged particle emitters, radionuclide generators; ideal radiopharmaceuticals, methods of radiolabeling, biodistribution, specific radiopharmaceuticals for diagnostic and therapeutic purposes, SPECT, PET, 18FDG etc. method of administration, principle and instrumentation of gamma/PET camera for detection, quality control, Principle, method and application of radioimmuassay(RIA)

Medicinal Inorganic Chemistry 10 Hours

Biomedical significance and inorganic chemistry, Characterization of biomolecules using spectroscopic methods, mechanistic aspects of heavy metal toxicity, platinum anti-cancer drugs (from laboratory to clinic), discovery and development of newer generation anti-tumour and anti-cancer agents

Pharmacokinetics 5 Hours

Drug absorption, drug distribution, drug metabolism, drug excretion, drug administration, drug dosing

Photodynamic medicine 10 Hours

Introduction, early days of photodynamic therapy (PDT), basic principle, photodynamic action, photochemotherapy, photosensitizing molecule, incubation period, light activation, light exposure, total light dose and its fluence rate**,** application of photosensitizer drug

Drug Targets and Drug Delivery 5 Hours

Enzymes, receptors, carrier proteins, structural proteins, nucleic acids, lipids, carbohydrate, targeted drug delivery, novel delivery modalities, Future considerations

Reference Books/ Journals

Radiopharmaceutical Chemistry, by Jason S. Lewis, Albert D. Windhorst, Brian M. Zeglis, Springer, 2019

Photodynamic Therapy: Basic Principles and Clinical Applications 1st Edition, by B.W. Henderson and T.J. Daugherty, ISBN-13: 978-0824786809, CRC Press; 1 edition (June 19, 1992)

Radiopharmaceuticals for Therapy, by Ashutosh Dash and F. F. (Russ) Knapp, 2016, Springer

The Handbook of Radiopharmaceuticals, by Azuwuike Owunwanne, Mohan Patel and Samy Sadek, Chapman & Hall Medical, 1st Edition, 1995

Handbook of Radiopharmaceuticals: Radiochemistry and Applications, By M.J. Welch and C.S. Redvanly, Wiley, 2005

An Introduction to Medicinal Chemistry, Graham L. Patrick, Oxford (International Student Edition)

Medicinal Inorganic Chemistry, Edited by J.L. Sessler, S. R. Doctrow, T. J. Mcmurry and S. J. Lippard, American Chemical Society, Washington, DC

(Instant Notes) Medicinal Chemistry, G. Patrick, Viva Books Pvt. Ltd.

Medicinal Chemistry, Principles and Practice, edited by F. D. King, Royal Society of Chemistry

The practice of Medicinal Chemistry, Edited by C.G. Wermuth, Academic Press

Medicinal Chemistry, D. Sriram & P. Yogeeswari, Pearson

Paper Code: **CHEM8091**

Paper Title: **Research Project/ Dissertation**

Credit: 12

Course Objective:

- The objective is to impart into the students a research oriented logical mind such that they can choose research problem(s) on their own and develop required theoretical methods/theory and/or design experiment with necessary instrumental set up and thereby to achieve the goal (solution).

Course outcome:

On completion of the course the students will be able to:

- Search literatures and choose scientific problems
- Use required tools with necessary modifications/extensions/ for arriving solving solutions
- Design experiment with necessary as per the research problem(s)
- Set up instrument as per experimental requirement
- Analyze and interpret the outcomes of theory/experiments and come to the final conclusions
- Write research papers/articles
- Present and defend the work at the seminar

OR

SEMESTER–VIII

(Hons.)

Chemistry Major/Core Course

Paper Code: **CHEM8011**

Paper Title: **Research Methodology**

Credit: 6

Course Objective:

- The objective is to impart into the students the theoretical idea and understanding on research and its methodology particularly of reviewing and surveying literature, writing research report with required format; testing of hypotheses and sampling for analysis and quantification research outputs, etc in maintaining research ethics.

Course outcome:

After completion of the course the students will be able to

- describe important ideas, concepts, and research styles, such as mixed, qualitative, and quantitative approaches
- create testable hypotheses or research questions, outline research challenges, and identify research gaps
- create a well-thought-out research plan that includes sampling strategies, data gathering procedures, and the right instruments for data processing
- use citing tools correctly, synthesize current research findings, and critically evaluate academic literature
- plan and carry out investigations involving human or animal subjects by applying ethical principles and comprehending the ethical issues in research
- evaluate data and interpret the findings in a meaningful way by using fundamental statistical or thematic analysis and approaches
- compose well-organized research papers or reports and explain their findings either orally or visually. Students will gain the capacity to evaluate research papers and procedures critically for validity, reliability, and limitations.
- maintain research ethics throughout his/her research activities

Theory **Credit: 6**

Introduction to Research Methodology 15 Hours

Meaning of Research, Objectives of Research, Motivations in Research, Types of Research, Criteria of good Research, What is Research Problem? Basic and Applied research

Review of Literature and Literature survey 15 Hours

Meaning and Purpose of the Literature Review & Literature Survey, Identification of the related Literature.

The Research Report 15 Hours

General format of the Research report, style and formatting of writing, typing of the research report.

Testing of Hypotheses and Sampling design 15 Hours

Definition, Concepts Concerning Testing of Hypotheses, Formulation of hypotheses and related difficulties; Needs of sampling, Sampling for chemical analysis, Random sampling

Research Ethics 15 Hours

Research Ethics: Ethical principles and responsible conduct of research (RCR); integrity, transparency, and accountability in scientific research. Scientific misconduct (fabrication, falsification, plagiarism), publication ethics, authorship, peer review, and data management. Ethical issues in human and animal research, informed consent, confidentiality, IEC/IRB approval, conflict of interest, and researcher responsibilities

Quantification of research output 15 Hours

Impact Factor, *h*-index, *i10*-index and *i20*-index, G-index

Recommended books/ Journals

C R Kothari, Research Methodology: Methods and Techniques, New Age International (P) Ltd. (2010), New Delhi

Garg, B. L., Karadia, R., Agarwal, F. and Agarwal, U.K., 2002. *An introduction to Research Methodology*, RBSA Publishers.

Handbook of Communication and Social Interaction Skills by John O. Greene, Brant Raney Burleson.

W. M. K. Trochim, 2005. *Research Methods: the concise knowledge base*, Atomic Dog Publishing. 270p.

Ranjit Kumar, Research Methodology: A Step-by-Step Guide for Beginners, SAGE Publications

Inderpal Singh, Research Methodology and Statistical Methods, Kalyani Publishers, Ludhiana.

G Kanji, 100 statistical tests, Sage Publications.

R.A. Day (1992) How to write and publish a scientific paper. Cambridge University Press. London.

Chemistry Major/Core Course

Paper Code: **CHEM8012**

Paper Title: **Inorganic & Nuclear Analytical General**

Credit: 4

Course Objective:

The objective is to impart into the students the theoretical idea and understanding on cluster compounds, metal-ion promoted reactions, nuclear properties and structure, synthetic elements, circular dichroism (CD) and hetero-NMR spectroscopy, and electroanalytical methods

Course outcome:

On completion of the course the students will be able to:

- acquire knowledge on cluster compounds and to explain structure-property, electron counts and surface analogies of cluster compounds
- learn and understand several metal ion promoted reactions with their applications
- acquire knowledge and understanding on some nuclear models for calculating semi-empirical binding energy, Q-values and cross section of nuclear reaction, fission probability, nuclear magic number, spin, etc.
- understand the theoretical background for the synthesis and separation of man-made radio isotopes as well elements
- have preliminary idea and understanding on CD and hetero-NMR spectroscopy
- learn the electroanalytical methods and their applicability in reversibility test, current-voltage diagram, DC and AC polarography, stripping voltammetry, amperometric titrations.

Theory **Credit: 4**

Unit I

Cluster compounds 15 Hours

Clusters in elemental states, cluster classification, skeletal electron (Elm) counting, higher boron hydrides-structures and reactions, equation of balance, Lipscomb topological diagrams, polyhedral skeletal electron pair theory (PSEPT), carboranes, metalloboranes and heteroboranes, metallocarboranes, zintl ions, chevrel compounds, infinite metal chains, multidecker molecules, cluster-surface analogy.

Metal-ion promoted reactions 15 Hours

Fundamentals, simple cycle, catalytic cycle, pliancy of substrates, Tolman catalytic loop, homogeneous/heterogeneous catalysis: Wacker-Smidt synthesis, Monsanto acetic acid process, hydrogenation by Wilkinson's catalyst, water gas shift reaction (WGSR), Fischer-Tropsch synthesis, hydrosilation, hydrophosphilynation, hydroamination, hydrocyanation and hydroboration reactions

Unit II

Nuclear properties and structure II 8 Hours

Nuclear angular momentum, magnetic dipole moment and electronic quadruple moment, parity of nuclear energy states; shell model, nuclear magic number and its derivation from nuclear potential well, calculation of nuclear spin, nuclear isomerism and non-optical transitions

Synthetic elements 6 Hours

Man-made elements: theoretical background, production and separation with special reference to actinoids and super heavy elements, separation chemistry

Preliminary CD and hetero-NMR spectroscopy 6 Hours

Instrumentation, presentation of spectra, Applications of heteronuclear NMR spectroscopy; ^{11}B, ^{14}N, ^{17}O, ^{19}F and ^{31}P-NMR, ^{195}Pt. CD/ORD: molecular dissymmetry and chiroptical properties, Cotton effect, magnetic circular dichroism (MCD), vibrational circular dichroism (VCD)

Electroanalytical methods I 10 Hours

Electrochemical cell, electrodes: reference and indicator electrodes, membrane electrodes, electrode-solution interface layer, gas-sensing probe, electrolytic process, three electrode system; supporting

electrolyte, DME; Cottrell equation, Ilkovic equation, Ilkovic-Heyrolsky equation, test of reversibility, current-voltage diagram, DC and AC polarography, stripping voltammetry, amperometric titration

Reference Books/ Journals

J. D. Lee, *Concise Inorganic Chemistry*, Chapman and Hall, London, 1991.

G. Wulfsberg, *Principles of Descriptive Inorganic Chemistry*, University Science Books, Mill Valley, CA, 1991.

A. F. Holleman and E. Wifrg, *Inorganic Chemistry*, Academic Press, New York, 1995.

N. N. Greenwood and A. Earnshaw, *Chemistry of the Elements*, 2nd Edn, Pergamon, New York, 1997.

F. A. Cotton, G. Wilkinson, C. M. Murillo and M. Bochmann, *Advanced Inorganic Chemistry*, 6th Edn, John Wiley & Sons, Inc, New York, 1999.

G. Wulfsberg, *Inorganic Chemistry*, Viva Books Pvt Ltd, New Delhi, 2001.

B. Douglas, D. McDaniel and J. Alexander, *Concepts and Models of Inorganic Chemistry*, 3rd Edn, John Wiley & Sons, Inc, New York, 2001.

P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, *Shriver & Atkins Inorganic Chemistry,* 4th Edn, Oxford, 2006.

J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K. Medhi, *Inorgnic Chemistry: Principles of Structures and Reactivity,* 4th Edn, Pearson, New Delhi, 2006.

R. Xu, W. Pang and Q. Huo (Eds), *Modern Inorganic Synthetic Chemistry*, Elsevier, New York, 2011.

J. Crowe, T. Bradshaw and P. Monk, *Chemistry of Biosciences,* Oxford University Press, Oxford, 2006.

G. L. Miessler and D. A. Tarr, *Inorganic Chemistry*, 3rd Edn, Pearson, New Delhi, 2009.

J. R. Anderson and M. Boudart (Eds), *Catalysis: Science and Technology,* Springer, London, 2012.

G. Cao, *Nanostructures & Nanomaterials, Synthesis, Properties & Applications*, Imperial College Press, London, 2004.

L. Cademartiri and G. A. Ozin, *Concepts of Nanochemistry*, Wiley-VCH, Weinheim, 2009.

D. L. Kepert, *Inorganic Stereochemistry*, Springer, Berlin, 1982.

A. von Zelewsky, *Stereochemistry of Coordination Compounds*, Wiley, New York, 1996.

S. P. Sinha, *Systematics and Properties of Lanthanides*, Riedel, Dordrecht, 1983.

J. J. Katz, G. T. Seaborg and L. R. Morss (Eds), *The Chemistry of the Actinide Elements*, Vols I and II, 2nd Edn, Chapman and Hall, London, 1986.

G. B. Richter-Addo and P. L. Legzdins, *Metal Nitrosyls*, Oxford University Press, New York, 1992.

F. A. Cotton and R. A. Walton, *Multiple Bonds Between Metal Atoms*, 2nd Edn, Clarendon Press, Oxford, UK, 1993.

G. A. Jefferey and W. Saenger, *Hydrogen Bonding in Biological Structures*, Springer, Berlin, 1991.

A. J. Stone, *The Theory of Intermolecular Forces*, Clarendon Press, Oxford, 1996.

G. A. Jeffrey, *An Introduction to Hydrogen Bonding*, Oxford University Press, Oxford, 1997.

J. W. Steed and J. L. Atwood, *Supramolecular Chemistry*, 2nd Edn, John Wiley and Sons, New York, 2009.

P. Powell, *Principles of Organometallic Chemistry*, 2nd Edn, Chapman and Hall, London, 1988.

R. A. van Santen and M. Neurock*Molecular Heterogenous Catalysis,* Wiley-VCH, Weinheim, 2006.

G. O. Spessard and G. L. Miessler, *Organometallic Chemistry*, International 2nd Edn, Oxford University Press, Oxford, 2010.

I. Pelant and J. Valenta, *Luminescence Spectroscopy of Semiconductors, Oxford,* New York, 2012.

D. M. P. Mingos and D. J. Wales, *Introduction to Cluster Chemistry*, Prentice Hall, New York, 1990.

D. F. Shriver, H. D. Kaesz and R. D. Adams (Eds), *The Chemistry of Metal Cluster Complexes*, VCH, New York, 1990.

C. E. Housecroft, *Cluster Molecules of the p-Block Elements,* Oxford University Press, Cambridge, 1994.

K. J. Klabunde, *Free Atoms, Clusters and Nanoscale Particles*, Academic Press, New York, 1994.

D. M. P. Mingos (Ed.), *Structural and Electronic Paradigms in Cluster Chemistry*, Springer, Berlin, 1997.

P. Braunstein, L. A. Oro and P. R. Raithby (Eds), *Metal Clusters in Chemistry*, Wiley-VCH, Weinheim, 1999.

M. Driess and H. Noth (Eds), *Molecular Clusters of the Main Group Elements,* Wiley-VCH, Weinheim, 2004.

T. P. Fehlner, J. -F. Halet and J. -Y. Saillard, *Molecular Clusters - A Bridge to Solid State Chemistry*, Cambridge University Press, Cambridge, 2007.

C. E. Housecraft and A. G. Sharpe, *Inorganic Chemistry*, 3rd Edn, Pearson Education Ltd, Essex, England, 2008.

G. W. Parshall, *Homogeneous Catalysis*, Wiley, New York, 1980.

C. N. Satterfield, *Heterogeneous Catalysis in Practice*, McGraw-Hill, New York, 1980.

O. N. Temkin, *Homogeneous Catalysis with Metal Complexes: Kinetic Aspects and Mechanisms*, John Wiley & Sons, New York, 2012.

M. Beller, A. Renken and R. A. van Santen, *Catalysis,* Wiley, New York, 2012.

R. D. Evans, The Atomic Nucleus, McGraw-Hill, New York, 1979.

G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller, Nuclear and Radiochemistry, 3rd Edn, Jhon Wiley & Sons Inc., New York, 1981.

H. J. Arnikar, Essentials of Nuclear Chemistry, 4th Edn Reprint, New Age International (P) Ltd Publications, New Delhi, 2001.

D. D. Sood, A.V. R Reddy and N. Ramamoorty, Fundumentals of Radiochemistry, Yancas, Mumbai, 2004.

G. R. Choppin, J. O. Liljenjin and J. Rydberg, Radiochemistry and Nuclear Chemistry, Butterworth- Heinmann, Woburu, 2002.

D. G. Peters, J. M. Hayes and G. M. Hieftje, Chemical Separations and Measurements: Theory and Practice of AnalyticalChemistry, Saunders, Wiley Interscience, New York, 1974.

D. A. Skoog, D. M. West and F. J. Holley, Fundamentals in Analytical Chemistry, 5th Edn, Saunders, Philadelphia, 1988.

S. M. Khopkar, Basic Concepts of Analytical Chemistry, Wiley Eastern Ltd., New Delhi, 1998.

D. R. Crow, Polarography of Metal Complexes, Academic Press, London, 1979.

A. J. Bard and L. F. Faulkner, Electrochemical Methods–Fundamentals and Applications, 2nd Edn, Wiley, New York, 1998.

Chemistry Major/Core Course

Paper Code: **CHEM8013**

Paper Title: **Physical & Organic General**

Credit: 4

Course Objective:

- The objective is to impart into the students the theoretical idea and understanding on atomic spectra, molecular spectroscopy with its principles, crystal structure, principle and practices in nanotechnology, reaction intermediates, carbohydrate chemistry, and spectroscopy used in organic chemistry.

Course outcome:

On completion of the course the students will be able to:

- Get hold the ideas of origin of atomic spectra, interpret Zeeman and Paschenback effects, Stern- Gerlach experiment, and calculate atomic energy terms and term symbols
- Recollect the idea of molecular spectra of different kinds, explain quantum mechanically their origin, selection rules, effect of several factors on them, and associated effects therein
- Learn and apply molecular spectroscopy in elucidating structures and properties of molecular systems.
- Understand the symmetry operations and the space groups of crystals, realize the electron density and structure factor relationship and hence the band theory that predicts the

conducting behaviors of crystals

- Acquire knowledge about the generation, detection, stabilities and reactivities of different organic intermediates
- Learn and understand the structures, synthesis and reactions of carbohydrates and their fragments
- Get hold of the ideas of the ^{1}H NMR and mass spectroscopy and thereby use these tools for identification of different organic compounds, ions, radicals as well as in explaining the structure properties of such species along with the effects of environment on them

Theory **Credit: 4**

Unit I

Atomic spectra 5 Hours

Elliptic orbits and space quantization; principal and azimuthal quantum numbers, total energy; orbital and spin angular momentum of electrons; vector model of atom, quantum numbers, orbital and spin angular momentum of electrons, normal and anomalous Zeeman and Paschenback effects, Stern-Gerlach experiment, atomic energy terms and term symbols

Molecular spectroscopy II 15 Hours

Fundamentals; rotational spectra: intensity distribution, effect of non-rigidity on spectral features; vibrational spectra: potential energy of an oscillator, Harmonic Oscillator approximation, energy levels and selection rules, anharmonicity and its effect on energy levels and spectral features: overtones and hot bands, vibration-rotation spectra of diatomics: origin; selection rules; P, Q and R branches; Raman spectra: origin, selection rules, classical and quantum treatment of rotational and vibrational Raman spectra, resonance Raman spectroscopy; NMR spectra: theory, relaxation process, spin interactions - its origin, equivalent protons, qualitative idea of energy levels of AX, AX_2 and AX_3 systems, a few representative examples; Electronic spectra: Electronic absorption spectra of molecules, vibrational structures in electronic spectra, vibronic coupling: Herzberg Teller effect, Jahn-Teller effect, and Renner Teller Effect.

Crystal structure II 5 Hours

Crystal symmetry, translation, glide plane and screw axis, Bravis lattice, space groups and its determination, stereographic projection, Fourier series, electron density and structure factor, methods for solving the phase problems, B-zones and Fermi level in lattice, concept of particle-hole in conduction process, band theory, theory of conductors, semiconductors and insulators.

Nanotechnology: principles and practices 5 Hours

Density of states – zero-dimensional solid, one-dimensional quantum wire, thin film and three-dimensional box, some special nanomaterials – fullerenes, carbon nanotubes and nanodiamonds, optical properties of metallic and semiconducting nanoparticles, nanolithography

Unit II

Reaction intermediates II 10 Hours

Advanced reactions of carbocations, carbanions, free radicals including radical cations and radical anions, carbenes, arynes and nitrenes

Carbohydrates II 8 Hours

Conformational drawing: Fischer projection, zigzag, chair, half chair, boat, envelop, skew; reactions of anomeric centers: nucleophilic substitution, oxidation, reduction, reductive elimination, free radical reaction, Wittig/Horner-Emmons reaction; reactions of hydroxyl groups: protections (cyclic acetal both 5 and 6 membered ring, ether, ester) and deprotections, nucleophilic substitution, oxidation, reduction; disaccharide formation: chemical and enzymatic; chemical glycobiology

Organic spectroscopy II 12 Hours

^{1}H NMR spectroscopy: FT-NMR; concept of FID signal and signal-to-noise ratio; chemical shift of different functional groups; magnetic anisotropic effect in annulenes and bridge systems; mechanism of spin-spin coupling; geminal couplings in acyclic and cyclic systems; vicinal coupling in open chain molecules, cyclic molecules: cycloalkenes, 3- and 6-membered saturated cyclic molecules, Karplus relationship; homoallylic and allylic couplings; couplings in benzene system; First-order and Non-first-order spectra; tree-diagram analysis; spectra of diastereotopic system; Pople notation; solvents used in NMR; chemical shift reagents

Mass Spectrometry: Instrumentation; Vaporization and Ionization process: EI, CI, ESI, MALDI etc.; Fragmentation process; Mass Analysis; Mass spectral data: Isotope peaks, Mass accuracy; Basic concepts of hyphenated mass spectral methods: GC-MS, LC-MS, MS-MS

Reference Books/ Journals

G. K. Vemulapalli, *Physical Chemistry*, Prentice-Hall, India, 1997.

P. W. Atkins, *Physical Chemistry*, Oxford University Press, Oxford, 1998.

R. S. Berry, S. A. Rice and J. Ross, *Physical Chemistry*, Oxford University Press, Oxford, 2000.

H. E. White, *Introduction to Atomic Spectra*, McGraw-Hill Kogakusha Ltd., Tokyo, 1934.

G. M. Barrow, *Introduction to Molecular Spectroscopy*, McGraw-Hill International Book Company, Tokyo, 1982.

C. N. Banwell and E. M. McCash, *Fundamentals of Molecular Spectroscopy*, 4th Edn, Tata McGraw-Hill Publishing Company Ltd, New Delhi, 1994.

J. D. Graybeal, *Molecular Spectroscopy,* McGraw-Hill International Editions, Spectroscopy series, 1998.

C. Kittel, *Introduction to Solid State Physics*, 4thEdn, John Wiley & Sons, New York.

P. A. Cox, *The Electronic Structure & Chemistry of Solids*, Oxford University Press, Oxford, 1987.

M. F. C. Ladd and R. A. Palmer, *Structure Determination by X-ray Crystallography*, 3rdEdn, Plenum Press, New York, 1994.

W. Clegg, *Crystal Structure Determination*, Oxford University Press, Oxford, 2005

J. March, Advanced Organic Chemistry: Reactions, Mechanisms and Structure, 5th Edn, John Wiley, New York, 1999.

S. P. McManus, Organic Reactive Intermediates, Academic Press, New York, 1973.

F. A. Carey and R. J. Sundberg, Advanced Organic Chemistry Part A and Part B, 4th Edn, Plenum Press, New York, 2001.

T. L. Gilchrist and C. W. Rees, Carbenes, Nitrenes and Arynes, Nelson, New York, 1973.

T. H. Lowry and K.C. Richardson, Mechanism and Theory in Organic Chemistry, 3rd Edn, Harper and Row, New York, 1998.

Robert V. Stick, Carbohydrates: The Sweet Molecules of Life, Academic press, 2001

I. L. Finar, Organic Chemistry, Vol I, 6th Edn, Addison Wesley Longmann, London, 1998.

I. L. Finar, Organic Chemistry, Vol II, 5th Edn, ELBS, London, 1995.

W. J. I. Noble, Highlights of Organic Chemistry, Mercel Dekker, New York, 1974.

W. J. I. Noble, Highlights of Organic Chemistry, Mercel Dekker, New York, 1974.

E. A. Davidson, Carbohydrate Chemistry, Holt, Rinehart and Winston, New York, 1967.

R. D. Guthrie and J. Honeyman, An Introduction of Chemistry of Carbohydrate, 3rd Edn, Clarendon Press, Oxford, 1988.

J. Kennedy, Carbohydrate Chemistry, Clarendon Press, Oxford, 1988.

W. Kemp, Organic Spectroscopy, 3rd Edn, McMillan, Hong Kong, 1991.

R. M. Silverstein and F. Webster, Spectrometric Identification of Organic Compounds, 6th Edn, John Wiley, New York, 1998.

D. H. Williams and I. Fleming, Spectroscopic Methods in Organic Chemistry, 5th Edn, Tata McGraw-Hill, New Delhi, 2005.

D. L. Pavia, G. M. Lampman, G. S. Kriz and J. R. Vyvyan, Spectroscopy, Brooks/Cole, a part of Cengage Learning, 2008.

K. Biemann, Mass Spectrometry – Application to Organic Chemistry, McGraw-Hill, New York, 1962.

H. Budzikiewicz, C. Djerassi and D.H. Williams, Mass Spectrometry of Organic Compounds, Holden-Day, 1967.

J. Barker, Mass Spectrometry, 2nd Edn, John Wiley, New York, 2000.

C. Dass, An Introduction to Biological Mass Spectrometry, Wiley, New York, 2002.

K. Downard, Mass Spectrometry: A Foundation Course, Royal Society of Chemistry, UK, 2004.

G. Siurdek, The Expanding Role of Mass Spectrometry in Biotechnology, MCC Press, San Diego, 2004.

Chemistry Major/Core Course

Paper Code: **CHEM8014**

Paper Title: **Practical General**

Credit: 4

Course Objective:

The objective is to impart into the students the practical idea and understanding on synthesis and characterization and estimation of components in coordination complexes, photometric estimation of components in mixtures, isolation of natural products, and data processing and elementary numerical techniques used in chemistry.

Course outcome:

On completion of the course the students will be able to:

- learn and understand the chemistry behind the synthesis and characterization of compounds
- acquire knowledge and understanding on the chemistry behind the separation and estimation of different compounds using photometric techniques
- learn and understand the isolation techniques of isolation of natural products
- acquire knowledge and understanding on dataprocessing and elementary numerical techniques used in chemistry
- acquire skills with confidence and accuracy in designing experiments and/or their need-based extensions

Unit I: Inorganic Practical General

Synthesis and characterization and estimation of several components of copper(I) chloride, manganese(III) phosphate, potash alum, tris(8-hydroxyquinline) aluminium(III) tris(acetylacetonenato)iron(III), potassium tris(oxalate) ferrate(III)

Unit II: Nuclear-Analytical Practical General

(i) Verification of Beer's law using $KMnO_4$ solution and estimation of manganese from an unknown sample

(ii) Estimation of sugar

(iii) Estimation of amino acid

(iv) Estimation of phosphate in a supplied sample

Unit III: Physical Practical General

Computer programming for:

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

(ii) Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations)

(iii) Numerical integration (e.g. entropy/ enthalpy changes from heat capacity data), probability distributions (gas kinetic theory) and mean values

(iv) Matrix operations: addition, multiplication, transpose, etc.

(v) Curve fitting using supplied data sets

Unit IV: Organic Practical General

Isolation of natural products: casein from milk, caffeine from tea leaves

Reference Books/ Journals

Inorganic Experiments, Edited by J. D. Woollins, VCH, Weinheim, Germany, 1994

A Collection of General Chemistry Experiments, A. J. Elias, Universities Press, Hyderabad, India

G. H. Jeffery, J. Bassett, J. Mendham, R. C. Denney, Vogel's Textbook of Quantitative Chemical Analysis (5^{th} Edition), 1989.

M. S. Dunn, Analytical Methods in the Food Industry, 1950

Ajay Kumar Goswami, Spectrophotometric Determination of Vanadium, Chromium and Manganese: Reagents and Methods, 2024

D. A. McQuarrie, Mathematics for Physical Chemistry University Science Books (2008).

R. Mortimer, Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).

D. C. Harris, Quantitative Chemical Analysis. 6th Ed., Freeman (2007) Chapters 3-5.

P. Yates, Chemical Calculations.2nd Ed. CRC Press (2007).

G. W. Collins II, Fundamental Numerical Methods and Data Analysis, Harvard University Press, Harvard (2003)

L. R. Scott, Numerical Analysis, Princeton University Press, Princeton (2011)

J. H. Noggle, Physical Chemistry on a Microcomputer. Little Brown & Co. (1985).

J H Tucker, A Manual of Sugar Analysis: Including the Applications in General of Analytical Methods to the Sugar Industry. With an Introduction on the Chemistry of Cane-Sugar, Dextrose, Levulose, and Milk-Sugar, D. Van Nostrand, New York, 2010.

Tetsuo Onami & Hitoshi Kanazawa, *A Simple Method for Isolation of Caffeine from Black Tea Leaves: Use of a Dichloromethane-Alkaline Water Mixture as an Extractant*, Journal of Chemical Education, **73**, 556-557 (1996).

Raquel Galante, Fernando Cunha & Raúl Fangueiro,'Extraction and properties of casein biopolymer from milk': in *Handbook of Natural Polymers (Vol. 1): Sources, Synthesis, and Characterization (Ch. 19)*, Elsevier, 471-487 (2023).

A. I. Vogel, Elementary Practical Organic Chemistry: Qualitative Organic Analysis Part 2, CBS Publishers and Distributors

Chemistry Minor Course

Paper Code: **CHEM8021**

Paper Title: **Medicinal Chemistry**

Credit: 4

Course Objective:

- The objective is to impart into the students the theoretical idea and understanding on supramolecular photochemistry, medicinal chemistry and drug discovery, radiopharmaceuticals, medicinal inorganic chemistry, pharmacokinetics, photodynamic medicine, and drug targets and drug delivery, etc.

Course outcome:

On completion of the course the students will be able to:

- comprehend the applicability of supramolecular chemistry in photodynamic therapy as well as in medicinal prospect.
- acquire idea and understanding on antibacterial, anticancer, antitussive, antiviral agents and structure-activity relationships (SARs).
- understand the specific radiopharmaceuticals for diagnostic and therapeutic purposes,

principle and instrumentation of gamma/PET camera for detection, methods (SPECT, PET, 18FDG etc.) of administration of radionuclides (nuclear medicines).

- characterize biomolecules in the discovery and development of newer generation anti-tumour and anti-cancer agents
- get hold of the ideas about drug absorption, drug distribution, drug metabolism, drug excretion, drug administration and drug dosing, etc.
- grasp basic principle of photodynamic therapy and photochemotherapy and photodynamic medicine with their mode of action, etc.

Theory **Credit: 4**

Supramolecular Photochemistry 10 Hours

Mechanism of energy and/ electron transfer process(es), various supramolecular devices: electronic, ionic and switching devices, application of supramolecular chemistry in photodynamic therapy, some examples of self-assembly in supramolecular chemistry with prospect in medicinal applications

Medicinal Chemistry and Drug Discovery 8 Hours

Antibacterial, Anticancer, Antitussive, and Antiviral agents; Opium analgesics, Antibiotics, New drugs from old poisons; Drug discovery, Structure-Activity Relationships (SARs)

Radiopharmaceuticals 12 Hours

Nuclear pharmacy: concept, pharmaceuticals and radiopharmaceuticals; type of radionuclides, neutral/charged particle emitters, radionuclide generators; ideal radiopharmaceuticals, methods of radio labeling, biodistribution, specific radiopharmaceuticals for diagnostic and therapeutic purposes, SPECT, PET, 18FDG etc. method of administration, principle and instrumentation of gamma/PET camera for detection, quality control, Principle, method and application of radioimmuassay(RIA)

Medicinal Inorganic Chemistry 10 Hours

Biomedical significance and inorganic chemistry, Characterization of biomolecules using spectroscopic methods, mechanistic aspects of heavy metal toxicity, platinum anti-cancer drugs (from laboratory to clinic), discovery and development of newer generation anti-tumour and anti-cancer agents

Pharmacokinetics 5 Hours

Drug absorption, drug distribution, drug metabolism, drug excretion, drug administration, drug dosing

Photodynamic medicine 10 Hours

Introduction, early days of photodynamic therapy (PDT), basic principle, photodynamic action, photochemotherapy, photosensitizing molecule, incubation period, light activation, light exposure, total light dose and its fluence rate**,** application of photosensitizer drug

Drug Targets and Drug Delivery 5 Hours

Enzymes, receptors, carrier proteins, structural proteins, nucleic acids, lipids, carbohydrate, targeted drug delivery, novel delivery modalities, Future considerations

Reference Books/ Journals

Radiopharmaceutical Chemistry, by Jason S. Lewis, Albert D. Windhorst, Brian M. Zeglis, Springer, 2019

Photodynamic Therapy: Basic Principles and Clinical Applications 1st Edition, by B.W. Henderson and T.J. Daugherty, ISBN-13: 978-0824786809, CRC Press; 1 edition (June 19, 1992)

Radiopharmaceuticals for Therapy, by Ashutosh Dash and F. F. (Russ) Knapp, 2016, Springer

The Handbook of Radiopharmaceuticals, by Azuwuike Owunwanne, Mohan Patel and Samy Sadek, Chapman & Hall Medical, 1st Edition, 1995

Handbook of Radiopharmaceuticals: Radiochemistry and Applications, by M.J. Welch and C.S. Redvanly, Wiley, 2005

An Introduction to Medicinal Chemistry, Graham L. Patrick, Oxford (International Student Edition)

Medicinal Inorganic Chemistry, Edited by J.L. Sessler, S. R. Doctrow, T. J. Mcmurry and S.J. Lippard, American Chemical Society, Washington, DC

Instant Notes: Medicinal Chemistry, G. Patrick, Viva Books Pvt. Ltd.

Medicinal Chemistry, Principles and Practice, edited by F.D. King, Royal Society of Chemistry

The practice of Medicinal Chemistry, Edited by C.G. Wermuth, Academic Press

Medicinal Chemistry, D. Sriram & P. Yogeeswari, Pearson