THE UNIVERSITY OF BURDWAN

SYLLABUS OF TWO -YEAR POSTGRADUATE PROGRAMME

IN

CHEMISTRY

Under

Curriculum and Credit Framework for Postgraduate Programme (CCFPP), as per N.E.P. 2020

w.e.f. 2026 – 2027

2- Year PG Programme

Semester I and II

Semester-wise and Course-wise Distribution of Credit & Marks under CCFPP as per NEP, 2020

SEMESTER	Course Type	Code & Level	Name of the Course	Credit	L – T - P	Marks	Marks Dist. Th. – Pr. - IA
I	Major/Core Course	**PG2CHEM1011 (400-499)**	Inorganic General	6	4 – 0 – 2	75	40 – 20 – 15
	Major/Core Course	**PG2CHEM1012 (400-499)**	Nuclear-Analytical General	6	4 – 0 – 2	75	40 – 20 – 15
	Major/Core Course	**PG2CHEM1013 (400-499)**	Organic General	6	4 – 0 – 2	75	40 – 20 – 15
	Major/Core Course	**PG2CHEM1014 (400-499)**	Physical General	6	4 – 0 – 2	75	40 – 20 – 15
	Minor Course	**PG2CHEM1021 (300-399)**	Industrial Chemistry	4	3 – 1 – 0	75	60 – 00 – 15
	Total			**28**		**375**	
II	Major/Core Course	**PG2CHEM2011 (400-499)**	Research Methodology, Ethics & Indian Knowledge System (IKS)	6	5 – 1 – 0	75	60 – 00 – 15
	Major/Core Course	**PG2CHEM2012 (400-499)**	Inorganic & Nuclear Analytical General	4	3 – 1 – 0	75	60 – 00 – 15
	Major/Core Course	**PG2CHEM2013 (400-499)**	Physical & Organic General	4	3 – 1 – 0	75	60 – 00 – 15
	Major/Core Course	**PG2CHEM2014 (400-499)**	Practical General	4	0 – 0 – 4	75	00 – 60 – 15
	Minor Course	**PG2CHEM2021 (300-399)**	Medicinal Chemistry	4	3 – 1 – 0	75	60– 00– 15
	Total			**22**		**375**	
	Grand total (Sem. I -II)			**50**		**750**	

SEMESTER I

Chemistry Major/Core Course

Paper Code: **PG2CHEM1011**
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-Duncanson bonding 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 color centers. 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

Recommended 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.

A. B. P Lever, *Inorganic Electronic Spectroscopy*, Elsevier, New York, 1984.

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.

J. G. Verkade, *A Pictorial Approach to Molecular Bonding*, 2nd Edn, Springer-Verlag, New York, 1997. A. Vincent, *Molecular Symmetry and Group Theory*, John Wiley & Sons, New York, 1998.

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,*

4th Edn, Pearson, New Delhi, 2006.

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

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

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.

A. Das and G. N. Mukherjee, *Elements of Bioinorganic Chemistry*, 2nd Edn, U. N. Dhur and Sons, Kolkata, 2002.

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

Recommended 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: **PG2CHEM1012**
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

Recommended 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 by using anion-exchange resin
4. Estimation of chloride ion (Cl^-) by adsorption and elution over anion-exchange resin

Recommended 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: **PG2CHEM1013**
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.
- Understandthestructure-activityrelationshipsinquantifyingkineticparametersofaromatic 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; 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

Recommended 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 + m-nitroaniline, acetophenone + salicylic acid, cyclohexanol + p-nitroaniline

Recommended Books/ Journals

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

Paper Code: **PG2CHEM1014**
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 tunneling, 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 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 13 Hours

Theories of reaction rates: applications to uni-, bi- and ter-molecular 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 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.

Thermodynamics and statistical mechanics 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

Recommended Books

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

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.

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.

I. N. Levine, *Quantum Chemistry*, Pearson, New York, 2014.

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 bases for 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

Recommended 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: **PG2CHEM1021**
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

Recommended 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*, 3rd Edn, Narosa Publishing House, 1995.

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

I. N. Levine, *Physical Chemistry*, 4th Edn, 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–II

Chemistry Major/Core Course

Paper Code: **PG2CHEM2011**
Paper Title: **Research Methodology, Ethics & Indian Knowledge System (IKS)**

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, to get acquainted with the Indian knowledge system, 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
- get acquainted with the Indian knowledge system

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 10 Hours

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

The Research Report 10 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); material safety data sheet (MSDS); 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 outputs 10 Hours

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

Historical perspective of Indian Knowledge System (IKS) 15 Hours

Composition of the universe- matter and its forms; metals, alloys, minerals, alkalis and acids; atom & atomic theories under various schools of thoughts; arrangement of atoms, chemical action & heat, fermentation & traditional food chemistry, indigenous water purification methods, natural dyes, pigments & medicines from plants and chemicals, post-era decline of scientific activity.

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.

Priyadaranjan Ray, *History of Chemistry in Ancient and Medieval India*, Indian Chemical Society, Kolkata, 1952

Prafulla Chandra Ray and Haris Chandra Kaviratna (Ed.), *Rasarnava*, The Asiatic Society, Kolkata, 1910 (reprinted in 1985).

Brajendranath Seal, The Positive Sciences of Ancient Hindus, Sahitya Samsad, Kolkata, 2001 (first published in 1915 by Longmans, Green and Co, London)

Priyadaranjan Ray, The theory of chemical combinations in ancient Indian Philosophies, Indian J. Hist. Sci., 1966, Vol 1, pp 1-14.

Priyadaranjan Ray, Origin and tradition of alchemy, *Indian J. Hist. Sci.*, 1967, Vol 2, pp 1-21 Priyadaranjan Ray, Medicine - as it evolved in ancient and mediaeval India, *Indian J. Hist. Sci.*, 1970, Vol 5, pp 85-100

Priyadaranjan Ray, Chemistry in ancient India, *J. Chem. Edu.*, 1948, Vol 25, pp 327-335

Paper Code: **PG2CHEM2012**
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

Recommended 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.

Paper Code: **PG2CHEM2013**
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

Principles of molecular spectroscopy 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 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

Recommended 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.

Paper Code: **PG2CHEM2014**
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 data processing and elementary numerical techniques used in chemistry
- Acquireskillswithconfidenceandaccuracyindesigningexperimentsand/ortheirneedbasedextensions

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

Verification of Beer's law using $KMnO_4$ solution and estimation of manganese from an unknown sample

Estimation of sugar

Estimation of amino acid

Estimation of phosphate in a supplied sample

Unit III: Physical Practical General

Computer programming for:

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

Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations)

Numerical integration (e.g. entropy/ enthalpy changes from heat capacity data), probability distributions (gas kinetic theory) and mean values

Matrix operations: addition, multiplication, transpose, etc.

Curve fitting using supplied data sets

Unit IV: Organic Practical General

Isolation of natural products: casein from milk, caffeine from tea leaves

Recommended 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: **PG2CHEM2021**
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

Recommended 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