SYLLABUS (NEP)

For

M.Sc. Course in Chemistry

To be effective from the session 2026-2027

BANKURA UNIVERSITY

BANKURA - 722155

WEST BENGAL, INDIA

COURSE STRUCTURE

SEMESTER-I

Category of Course	Course Code	Course Title	Marks				Credit
			IA	ESE		TOTAL	
				TH	PR		
Theoretical Papers							
DSC	CHEM 101C	Inorganic Chemistry I	10	40	-	50	4
DSC	CHEM 102C	Organic Chemistry I	10	40	-	50	4
DSC	CHEM 103C	Physical Chemistry I	10	40	-	50	4
Practical Papers							
DSC	CHEM 104C(PR)	Inorganic Chemistry Practical	10	-	40	50	4
DSC	CHEM 105C(PR)	Organic Chemistry Practical	10	-	40	50	4
		Total	**250**				**20**

SEMESTER-II

Category of Course	Course Code	Course Title	Marks				Credit
			IA	ESE		TOTAL	
				TH	PR		
Theoretical Papers							
DSC	CHEM 201C	Inorganic Chemistry II	10	40	-	50	4
DSC	CHEM 202C	Organic Chemistry II	10	40	-	50	4
DSC	CHEM 203C	Physical Chemistry II	10	40	-	50	4
Practical Papers							
DSC	CHEM 204C(PR)	Physical Chemistry Practical	10	-	40	50	4
#Generic Elective Paper (Interdisciplinary)							
GE	CHEM 205G	General Chemistry	10	40	-	50	4
		Total	**250**				**20**

SEMESTER-III

Category of Course	Course Code	Course Title	Marks				Credit
			IA	ESE		TOTAL	
				TH	PR		
Theoretical Papers							
DSC	CHEM 301C	Advanced General Chemistry I	10	40	-	50	4
DSC	CHEM 302C	Research Methodology	10	40	-	50	4
DSE	CHEM303E (IS/OS/PS)	Special Theory I	10	40	-	50	4
Practical Paper							
DSE	CHEM304E (IS/OS/PS)	Special Practical	10	-	40	50	4
##Term Paper/Project							
DSC	CHEM 305C	Research thesis/Project/Patent/Term Paper	Project work-50, Presentation-25 Viva-voce-25				8
		Total	**300**				**24**

SEMESTER-IV

Category of Course	Course Code	Course Title	Marks				Credit
			IA	ESE		TOTAL	
				TH	PR		
Theoretical Papers							
DSC	CHEM 401C	Advanced General Chemistry II	10	40	-	50	4
DSE	CHEM 402E (IS/OS/PS)	Special Theory II	10	40	-	50	4
DSE	CHEM 403E (IS/OS/PS)	Special Theory III	10	40	-	50	4
Skill Based Course (Non-Credit)	CHEM 404C	IKS	10	40		50	0
##Term Paper/Project							
DSC	CHEM 405C	Dissertation	Project work-50, Presentation-50 Viva-voce-50				12
		Total	**300**				**24**
		Grand Total	**1100**				**88**

IS: Inorganic Special; OS: Organic Special; PS: Physical Special; DSC = Discipline Specific Course; DSE = Discipline Specific Elective; GE = Generic Elective (Interdisciplinary); TH = Theory; PR = Practical; IA = Internal Assessment; ESE = End Semester Examination.

*The foundation courses are to be conducted by the University. The course shall have internal assessment only and so, credit earned for these courses shall not be considered while preparing the final result. However, the candidates are required to obtain 'satisfactory' or 'not satisfactory' remark to obtain eligible for the final semester examination/award of the PG degree.

Semester I (Total Marks - 250, Credits - 20)

Theoretical Papers

CHEM 101C: Inorganic Chemistry I **Marks: 50, Credits: 4**

1. Chemical Bonding – a quantum chemical approach (15 Lectures)

The Born-Oppenheimer Approximation, Molecular Orbitals of Diatomic Systems (homonuclear and heteronuclear), MO of polynuclear ABn type molecules, Molecular Term Symbol, Koopmans' theorem, Walsh diagram. Isolobal Analogy, Frontier Molecular Orbital (FMO) Interactivity, Molecular term symbols, Hückel Molecular Orbital (HMO) Framework and p-MO profiles of ethylene, allyl system, aromatics and conjugated systems.

2. Coordination chemistry: bonding, stereochemistry and structure (20 Lectures)

Fundamentals of coordination chemistry, Molecular orbital theory of complexes, Jahn-Teller and Renner-Teller effects on energy levels, Term Symbols and Interelectronic Repulsion, Racah Parameters, Nephelauxetic effect. Symmetry-Based Graphical Representations: Orgel diagram, Tanabe-Sugano diagram, Spectral Transition Selection Rules, Vibronic Coupling, band broadening, spin-forbidden transition, intensity stealing, magnetic properties, lowering of symmetry, electronic, steric, Chelation Dynamics and Conformational analysis, Structural equilibrium and implication, Correlation of CFSE with spectroscopy.

3. Molecular Magnetism (25 Lectures)

Fundamentals of Molecular Magnetism, Microstates and Term Symbols, Multiplets and Splitting, Crystal Field Effects, Spin–Orbit Coupling (SOC), Quenching of Orbital Angular Momentum, Magnetic Susceptibility and Van Vleck equation, Temperature-Independent Paramagnetism (TIP), Magnetic Exchange Interactions: Mechanisms of magnetic exchange (direct exchange, superexchange, double exchange and spin polarization); Magnetic interactions in di, polynuclear clusters and cluster system; Bleaney–Bowers equation; Magnetization (magnetization versus temperature (M vs. T) and magnetic field (M vs. H); Curie and Curie-Weiss laws) and Variable Temperature Magnetism, Long-Range Ordering, Single-molecule magnets (SMMs), Single Chain magnets (SCMs) etc., Magnetic material synthesis and their modern applications.

4. Advanced Bioinorganic Chemistry **(20 Lectures)**

Metal ion homeostasis, transport and biological functions; structure and function of metalloproteins and metalloenzymes, including porphyrins, hemoglobin, myoglobin, hemocyanin, hemerythrin, cytochrome c and Cytochrome P450, blue copper proteins, nitrogenase, hydrogenase, superoxide dismutase, catalase and peroxidase; oxygen transport and activation, electron-transfer reactions, role of metallochaperones, siderophores, transferrin, and ferritin. Homeostatic Regulation (e.g., iron-responsive element-binding proteins, zinc fingers). Photosystems and Solar Energy Conversion; Biological Electron Transfer and Proton-Coupled Electron Transfer (PCET) (basic concepts); Biomimetic Inorganic Chemistry, Metal Complexes in Medicine, Bio-inspired Catalysis and Renewable Energy

Reference Books:

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

- P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Shriver & Atkins Inorganic Chemistry, 4th Edn, Oxford, 2006.
- R. L. Carlin, Magnetochemistry, Springer-Verlag, New York, 1986. O. Kahn, Molecular Magnetism,
- VCH, New York, 1993. 66
- P. Day and A. E. Underhill (Eds), Metal-organic and Organic Molecular Magnets, RSC, London, 2000.
- P. M. Lathi (Ed), Magnetic Properties of Organic Materials, Marcel Dekker, New York, 1999.
- J. S. Miller and M. Drillon (Eds), Magnetism: Molecules to Materials, V; Molecule-based Magnets, Wiley-VCH, Weinheim, 2005.
- P. Gutlich and H. A. Goodwin, Spin Crossover in Transition Metal CompoundsI, Springer, Berlin, 2004.
- F. E. Mabbs and D. J. Machin, Magnetismand Transition Metal Complexes, Dover Publications, 2008.
- R. Winpenny (Ed), Single-Molecule Magnets and Related Phenomena, Structure and Bonding Series, Vol. 122, Springer, Berlin, 2010.
- D. Cullity and C. D. Graham, Introduction to Magnetic Materials, 2nd Edn, John Wiley & Sons, New York, 2011.
- K. H. J. Buschow, Handbook of Magnetic materials, Vol 20, Elsevier, New York, 2012.
- Gatteschi, R Sessoli and J. Villain, Molecular Nanomagnets, Oxford University Press, Oxford, 2006.
- Bertini, H. B. Gray, E. I. Stiefel, J. S. Valentine, Biological Inorganic Chemistry: Structure and Reactivity, University Science Books, Sausalito, 2007.
- R. H. Holm, P. Kennepohl, E. I. Solomon (Eds.), Chemical Reviews: Bioinorganic Chemistry, American Chemical Society, Washington, D.C., 1996.
- R. R. Crichton, Biological Inorganic Chemistry: A New Introduction to Molecular Structure and Function, 3rd Edition, Academic Press (Elsevier), London, 2019.
- L. Que Jr., W. B. Tolman (Eds.), Nature's Catalysts: The Science of Metalloenzymes, Royal Society of Chemistry, Cambridge, 2022.
- I. Solomon, R. K. Szilagyi, S. DeBeer George, L. Basumallick, Electronic Structures of Metal Sites in Proteins and Models: Contributions to Function in Blue Copper Proteins and Heme–Copper Oxidases, Chemical Reviews, American Chemical Society, 2004. (Selected review articles.)

CHEM 102C: Organic Chemistry I **Marks: 50, Credits: 4**

1. Bonding in Organic Molecules & Structure-Reactivity Relationship (20 Lectures)

Qualitative MO treatment to acyclic and cyclic conjugated systems, Huckel treatment-applications to ethylene, allyl, cyclopropenyl, butadiene, cyclobutadiene and benzene; concept of aromaticity in benzenoid and nonbenzenoid systems, graphical method-Frost diagram, linear free energy relations, Hammett equation; equilibria and rates in organic reactions; separation of polar, steric and resonance effects: Taft equation, Grunwald-Winstein equation.

2. NMR Spectroscopy (20 Lectures)

Principles, instrumentation and different techniques (CW and FT) of NMR spectroscopy, factors influencing chemical shift, spin-spin interactions, coupling constant (J); spin-decoupling; cross polarization, peak integration, first-order and non first-order spectra, spin system notations; introduction to ^{13}C: proton decoupled ^{13}C spectra, NOE, off resonance ^{13}C.

3. Mass Spectroscopy (20 Lectures)

Mass spectroscopy principles, instrumentation and applications of mass spectrometry-methods of generation of ions in EI, CI, FD and FAB, MALDI-TOF; detection of ions, ion analysis, ion abundance, molecular ion peak, meta-stable peak, isotope, ion-molecule interaction and analysis of fragmentation patterns; calculation of MF from mass, introduction to GC-MS, LC-MS and MS-MS.

Applications of mass, UV-VIS, IR and NMR spectroscopy to structural and mechanistic problems.

4. Stereochemistry and Conformational Analysis (20 Lectures)

Molecular symmetry, chirality and point group; stereoisomerism: definitions, classifications; configuration and conformation; relative and absolute configuration; determination of relative configuration: Prelog's rule, Cram's rule, Sharpless rule; conformations of acyclic and cyclic system (3 to 8 membered rings), fused (5/5 and 6/6), spiro and bridged bicyclo systems; stability, reactivity and mechanism; allylic strain; reactions of 5/6-membered ring containing one or more trigonal carbon(s).

Reference Books:

- E. V. Anslyn, D. A. Dougherty. Modern Physical Organic Chemistry, University Science Books, 2006.
- S. Shaik, P. C. Hiberty. Valence Bond Theory, its History, Fundamentals and Applications: a Primer, Reviews in Computational Chemistry, Volume 20 (Eds. K. B. Lipkowitz, R. Larter, T. R. Cundari), John Wiley & Sons, Hoboken, NJ, USA, 2004.
- F. A. Caroll. Perspectives on Structure and Mechanism in Organic Chemistry, 2nd Edn. Wiley-VCH, 2011.
- E. L. Eliel, S. H. Wilson, L. N. Mander. Stereochemistry of Organic Compounds, John Wiley & Sons, 2003.
- E. L. Eliel. Stereochemistry of Carbon Compounds, Tata McGraw-Hill Edition, New Delhi, 1988.
- D. Nasipuri. Stereochemistry of Organic Compounds (Principles and Applications), 2nd Edn. Wiley Eastern Limited, New Delhi, 1994.
- E. L. Eliel, N. L. Allinger, S. J. Angyal, G. A. Morrison. Conformational Analysis, John Wiley & Sons, 1967.
- J. Eames, J. Peach. Stereochemistry at a Glance, Blackwell Science, 2003.
- K. Mislow, W. A. Benjamin. Introduction to Stereochemistry, New York, 1965.
- B. Testa. Principles of Organic Stereochemistry, Marcel Dekker, New York, 1979.
- E. Juaristi. Stereochemistry and Conformational Analysis, John Wiley & Sons, 1991.
- M. Nogradi. Stereochemistry: Concepts and Applications, Pergamon press, New York, 1981.
- H.-J. Zhu. Organic Stereochemistry: Experimental and Computational Methods, Wiley-VCH, 2015.
- M. B. Smith, J. March. March's Advanced Organic Chemistry (Reactions, Mechanisms and Structure), 5th Edn. John Wiley & Sons, 2001.
- L. N. Ferguson. The Modern Structural Theory of Organic Chemistry, Prentice-Hall of India Pvt. Ltd., New Delhi, 1963.
- R. H. Grubbs, D. J. O'leary. Handbook of Metathesis - Volume 1 & 2, Wiley-VCH, 2015.
- D. L. Pavia, G. M. Lampman, G. S. Kriz. Introduction to Spectroscopy, 3rd Edn. Harcourt, 2001.
- R. M. Silverstein, G. C. Bassler, T. C. Morrill. Spectroscopic Identification of Organic Compounds, 5th Edn. John Wiley & Sons, 1991.

- D. H. Williams, I. Fleming. Spectroscopic Methods in Organic Chemistry, 5th Edn. Tata McGraw-Hill edition, New Delhi, 2004.
- W. Kemp. Organic Spectroscopy, 3rd Edn. Macmillan press Ltd. 1991.
- G. Siuzdak. Mass Spectrometry for Biotechnology, Academic press, 2005.
- H. Budzikiewicz, C. Djerassi, D. H. Williams. Interpretation of Mass Spectra of Organic Compounds. Holden-Day Inc., 1965.
- J. S. Splitter, F. Turećek. Applications of Mass Spectrometry to Organic Stereochemistry, Wiley-VCH, 1994.
- Atta-ur-Rahman, Md. Iqbal Choudhary. Solving Problems with NMR Spectroscopy, Academic press, 1996.
- N. S. Bhacca, D. H. Williams. Applications of NMR Spectroscopy in Organic Chemistry, Holden-Day Inc., 1964.
- L. M. Jackman, S. Sternhell. Applications of Nuclear Magnetic Resonance Spectroscopy in Organic Chemistry, 2nd Edn. Pergamon Press, Oxford, 2nd Edn. 1969.
- R. G. Linington, P. G. Williams, J. B. Macmillan. Problems in Organic Structure Determination: a Practical Approach to NMR Spectroscopy, CRC press, Taylor & Francis group, 2016.
- Y. R. Sharma. Elementary Organic Spectroscopy (Principles and Chemical Applications) S. Chand & Company ltd., New Delhi, 5th Edn. 2013.

CHEM 103C: Physical Chemistry I **Marks: 50, Credits: 4**

1. Quantum Mechanics I **(16 Lectures)**

Introduction, properties of sets of wave functions; operators - linear and nonlinear operators, Laplacian operator, Hermitian operators and their properties, eigen-functions and eigenvalues of an operator; eigenvalue equation, eigen-functions of commuting operators; expectation values; time-dependent Schrödinger equation of motion, conservative systems and time independent Schrödinger equation; particle in a one and three-dimensional boxes with infinite potential walls, important features, Bohr's correspondence principle.

2. Symmetry & Group Theory I **(16 Lectures)**

Introduction, symmetry, symmetry elements and symmetry operations, definition of a group, point symmetry groups, group multiplication tables, theorems of groups, conjugate elements and class,

symmetry operators and their matrix representation, function space, reducible and irreducible representations, equivalent representations, characters of representations.

3. Electrochemistry (12 Lectures)

Introduction, ion-solvent interaction: Born model and Born equation, enthalpy of ion-solvent interaction and its calculation, solvation and solvation number, ion association, Bjerrum equation, fraction of ions associated, ion association constant; electrode kinetics: relation between current and rate of electrode reaction, current-overpotential relationship, Tafel equation and its importance.

4. Biophysical Chemistry (18 Lectures)

Introduction, adsorption of solids, micelles, reverse micelles, microemulsion, thermodynamics of micellization, hydrophobic hydration, interaction; stabilization and denaturation of protein, transport of ions, ion channels, configuration and conformation of biological macromolecules, membrane structure; applications of spectroscopic techniques: UV-Vis, CD, fluorescence, separation techniques: gel electrophoresis; macromolecule ligand binding and co-operativity.

5. Chemical Kinetics I (18 Lectures)

Introduction, theories of reaction rates: applications to uni-, bi- and ter-molecular reactions, thermodynamic formulation of reaction rate, reactions in solution; cage effect, 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, Curtin-Hammett principle, linear free energy relationship, Hammett and Taft equations; fast reactions: flow process and relaxation techniques.

Reference Books:

- L. Pauling, E. B. Wilson. Introduction to Quantum Mechanics, McGraw-Hill, New York, 1939.
- H. Eyring, J. Walter, 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, New Delhi, 1989.

- F. L. Pilar. Elementary Quantum Chemistry, Tata McGraw-Hill, New Delhi, 1990.
- D. A. McQuarrie. Quantum Chemistry, Viva books (P) Ltd. New Delhi, 2003.
- S. C. Rakshit. Molecular Symmetry Group and Chemistry, The New Book Stall, Kolkata, 1988.
- F. A. Cotton. Chemical Applications of Group Theory, 3rd Edn. John Wiley & Sons. New York, 1999.
- D. M. Bishop. Group Theory and Chemistry, Oxford University Press, 1993.
- J. Vincent. Molecular Symmetry and Group Theory, John Wiley & Sons. New York, 1998.
- S. Glasstone. An Introduction to Electrochemistry, D. Van Nostrand Company, 1962.
- J. O'M. Bockris, A. K. N. Reddy. Modern Electrochemistry, Volume I, Plenum Press, New York, 1970.
- J. Albery. Electrode Kinetics, Oxford Chemistry Series, Clarendron Press, Oxford, 1975.
- G. W. Castellan. Physical Chemistry, 3rd Edn. Narosa Publishing House, New Delhi, 1995.
- R. A. Alberty, R. J. Silbey. Physical Chemistry, 1st Edn. John Wiley & Sons. New York, 1995.
- R. S. Berry, S. A. Rice, J. Ross. Physical Chemistry, Oxford University Press, London, 1970.
- K. V. Van Holde, W. C. Johnson, P. S. Ho. Principles of Physical Biochemistry, Prentice Hall, 1998.
- D. L. Nelson, M. Cox. Lehninger Principles of Biochemistry, 8th Edn. Macmillan Learning, 2017.
- C. Tanford. Physical Chemistry of Macromolecules, John Wiley & Sons. New York, 1961.
- P. J. Flory. Principles of Polymer Chemistry, Cornell University Press, Ithaca & London, 1995.
- K. J. Laidler. Reaction Kinetics, Volume I & II, Pergamon Press, London, 1970.
- K. J. Laidler. Chemical Kinetics, Tata McGraw-Hill Publishing Company Ltd. New Delhi, 1988.
- M. R. Wright. Fundamental Chemical Kinetics, Horwood Publishing, 1999.

Practical Paper

CHEM 104C(PR): Inorganic Chemistry Practical **Marks: 50, Credits: 4**

1. Determination of amount of Ca^{2+} in milk by complexometric titration.
2. Estimation of Ca^{2+}, Mg^{2+} and Fe^{3+} in Dolomite by complexometry

3. Estimation of phosphoric acid in cola drinks by molybdenum blue method
4. Estimation of iron in minute quantities by UV-vis spectrophotometry
5. Estimation of fluoride in water by SPADNS Method.
6. Analysis of brass (Cu and Zn) by iodometry and complexometry.
7. Preparation and characterization (FTIR, UV-Vis) of hexamminenickel(II) chloride: estimation of ammonia and nickel by titrimetric and gravimetric methods
8. Computer application in chemistry-Exposure to available standard application packages like: chemdraw, generation of graphs using Origin, data sheet creation, tables using excel programme, etc.

Reference Books:

- Vogel's Textbook of Quantitative Chemical Analysis - Jeffery, Bassett, Mendham and Denney
- Practical Inorganic Chemistry, Preparations, reactions and instrumental methods, Geoffrey Pass, Haydn Sutcliffe, Springer Dordrecht, 2013.
- Experimental Inorganic Chemistry, W. G. Palmer, 1954.
- Advanced Experiments in Inorganic Chemistry-G. N. Mukherjee
- Practical Inorganic Chemistry-Dr. L. Rakesh Sharma

CHEM 105C(PR): Organic Chemistry Practical **Marks: 50, Credits: 4**

Chemical separation, purification and identification of organic compounds in binary mixture (two solids) using chemical tests and TLC.

(At least 6 samples are to be worked up during the lab session).

Reference Books:

- B. S. Furniss, A. J. Hannaford, P. W. G. Smith, A. R. Tatchell. Vogel's Textbook of Practical Organic Chemistry, 5th Edn. John Wiley & Sons. New York, 1989.
- A. I. Vogel. A Textbook of Practical Organic Chemistry, 3rd Edn. Longman group ltd. London, 1956.
- R. C. Bhattacharyya. A Manual of Practical Chemistry, 11th Edn. Studies book sellers & publishers, Calcutta, 1992.
- Roberts, Gilbert, Rodewaid, Wingrove. An Introduction to Experimental Organic Chemistry, 3rd Edn. Holt, Rinehart & Winston Publishers, New York, 1969.

- H. T, Clarke. Handbook of Organic Analysis, 4th Edn. Hodder & Stoughton Educational, London, 1926.
- H. Middleton. Systematic Qualitative Organic Analysis, 2nd Edn. Hodder & Stoughton Educational, London, 1943.
- V. K. Ahluwalia, R. Aggarwal. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press, 2001.
- E. Stahl. Thin Layer Chromatography, 2nd Edn. Springer, 1969.
- R. M. Silverstein. Spectrometric Identification of Organic Compounds, 6th Edn. John Wiley & Sons, New York, 1997.

Semester II (Total Marks -250, Credits- 20)

Theoretical Papers

CHEM 201C: Inorganic Chemistry II **Marks: 50, Credits: 4**

1. Main Group Chemistry **(20 Lectures)**

Fundamentals of electronic structure, periodic trends, allotropy, synthesis, structure and bonding of main-group compounds; electron-deficient, electron-precise and hypervalent compounds, multicentre bonding and multiple bonding in heavier main-group elements. Boron Cluster Chemistry: boranes, carboranes, Wade–Mingos rules and organoboron compounds; Low-valent main-group compounds: N-heterocyclic carbenes (NHCs), silylenes, germylenes, and phosphinidenes. Frustrated Lewis Pairs (FLPs) and small-molecule activation: Concept, mechanism of activation and small molecule transformations. Industrially important compounds of boron, silicon and phosphorus, and selected applications in catalysis, materials chemistry and green chemistry.

2. Advanced organometallic Chemistry **(20 Lectures)**

Synthesis, bonding, structure and reactivity of organometallic compounds; metal–ligand bonding, Advanced electron counting methods, the 18-electron rule considering important ligand systems (phosphines, cyclopentadienyl (Cp/Cp*) and N-heterocyclic carbenes (NHCs)); Elementary organometallic reactions including ligand substitution, oxidative addition, reductive elimination,

migratory insertion, β-hydride elimination and transmetallation; Principles of homogeneous catalysis and catalytic cycles with applications in hydrogenation, hydroformylation, carbonylation, olefin metathesis and transition-metal-catalysed cross-coupling reactions; Brief overview of heterogeneous catalysis, olefin polymerization (Ziegler-Natta catalysis) and green organometallic catalysis.

3. Nuclear Chemistry **(20 Lectures)**

Introduction to nuclear stability, formulation of semi-empirical binding energy equation, mass parabola and application of binding energy equation; nuclear reactions, Calculation of Q value, threshold energies and cross section of nuclear reaction. The liquid drop model, Fermi gas model, Magic numbers and its derivation from nuclear potential well. Nuclear fission and nuclear fusion. Nuclear reactors and particle accelerators. Interaction of radiation with matter, radio-analytical techniques and activation analysis, dosimetry (physical and chemical dosimetry), Applications of Nuclear Chemistry in Neutron activation analysis (NAA), isotope dilution analysis. Waste management and nuclear safety.

4. Electroanalytical Methods **(20 Lectures)**

Fundamentals of Electroanalytical Chemistry: Electrochemical cells; electrode potentials; reference electrodes, indicator and working electrodes; three-electrode system; electrode–solution interface and electrical double layer; mass transport (diffusion, migration and convection); supporting electrolytes; choice of solvent and electrolyte; electrochemical instrumentation. Dropping mercury electrode (DME) and mercury film electrodes; Cottrell, Ilkovič and Ilkovič–Heyrovský equations; current–potential curves; reversible, quasi-reversible and irreversible electrode processes; DC and AC polarography; linear sweep voltammetry (LSV); cyclic voltammetry (CV); differential pulse voltammetry (DPV); square-wave voltammetry (basic concepts); stripping voltammetry (anodic and cathodic); interpretation of voltammograms and reaction mechanisms (EE, EC, ECE and CE pathways), determination of diffusion coefficients, electron-transfer kinetics and catalytic rate constants; electrogravimetry and amperometric titrations; electrochemical impedance spectroscopy (EIS) (basic concepts); Electrocatalysis; electrochemical water oxidation (OER), proton reduction (HER), oxygen reduction (ORR) and carbon dioxide reduction (CO_2RR); rechargeable batteries (Li-ion, Na-ion, Ni–Cd, Ni–MH and Ag–Zn).

Reference Books:

- W Henderson, Main Group Chemistry, RSC publishing, 2007
- Thomas Baumgartner, Frieder Jäkle, Main Group Strategies towards Functional Hybrid Materials, Wiley, 2017
- Joseph Casanova, The Borane, Carborane, Carbocation Continuum, Wiley, 1998
- 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.
- H. J. Arnikar, Essentials of Nuclear Chemistry, 4th Edn Reprint, New Age International (P) Ltd Publications,New Delhi, 2001.
- R. D. Evans, The Atomic Nucleus, McGraw-Hill, New York, 1979.
- B. Harvey, Introduction to Nuclear Physics and Chemistry, Prentice Hall, 1965.
- S. Glasstone, Source Book of Atomic Energy, East-West Press Pvt. Ltd, New Delhi, 1967.
- 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.
- J. Bard and L. F. Faulkner, Electrochemical Methods–Fundamentals and Applications, 2nd Edn, Wiley, New York, 1998.
- G. Zoski (Ed) Handbook of Electrochemistry, Elsevier, New York, 2007.
- Ed. By R.Kellner, J.-M.Mermet, M.Otto,M.Valcarcel,H.M.Widmer, Analytical Chemistry, Wiley VCH

CHEM 202C: Organic Chemistry II **Marks: 50, Credits: 4**

1. Organic Name Reaction and Reagents **(20 Lectures)**

Moffat oxidation; Swern oxidation; Dess-Martin Periodinane; Shapiro reaction; Barton reaction; McMurry reaction; Peterson reaction; Sharpless asymmetric epoxidation; Luche reduction; Yamaguchi esterification; hydride transfer reagent: Boranes, trialkyl borohydrides, Diimide, Baker's yeast, trialkyl tin hydride; DIBAL, $Na(CN)BH_3$, Red-Al; Selectrides; Woodward and Prevost hydroxylation; Sharpless epoxidation; PCC, PDC, Mn(IV) oxide; RuO_4 (TRAP); OsO_4.

2. Heterocyclic Chemistry I **(20 Lectures)**

Systematic nomenclature (Hantzch-Widman system) for monocycle system, general approach to heterocyclic synthesis- cyclisation and cycloaddition routes, heterocycles in organic synthesis-masked functionalities, umpolong, Stork annulations reaction; rearrangement and ring transformation involving 5- and 6- membered heterocycles with one heteroatom.

3. Asymmetric Synthesis I **(15 Lectures)**

Introduction to asymmetric synthesis, preliminary idea about different methods of asymmetric synthesis with special reference to the chiral pool strategy, asymmetric Diels-Alder reaction, enantioselective organocatalysis, biocatalysis

4. Pericyclic Reactions **(25 Lectures)**

The Woodward-Hoffmann selection rules and stereochemistry of electrocyclic reactions, cycloadditions, sigmatropic rearrangements, cheleotropic reactions and group transfer reaction, rationalization based on frontier MO approach, correlation diagrams, Dewer-Zimmermann approach, Mobius and Huckel systems, Sommelet-Hauser, aza-Cope and Ene reaction, Wittig rearrangement, suitable examples of [(2Π+2Π), (4Π+2Π), (4Π+4Π), (2Π+2Π+2Π)] and metal catalysed cycloaddition reactions.

Reference Books:

- T. L. Gilchrist, R. C. Storr. Organic Reactions and Orbital Symmetry, 2nd Edn. Cambridge University Press, 1979.
- N. J. Turro. Modern Molecular Photochemistry, The Benjamin Cummings Publishing, 1978.
- S. Sankararaman. Pericyclic Reactions - A Textbook, Wiley-VCH Verlag, 2005.
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- R. Bruckner. Advanced Organic Chemistry (Reaction Mechanisms), Harcourt Academic Press, 2002.
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- T. G. Graham, C. B. Fryhle. Organic Chemistry, 8th Edn. John Wiley & Sons, 2004.
- J. Moody. Reactive Intermediates, Oxford University Press, 1992.
- R. T. Morrison, R. N. Boyd, S. K. Bhattacharjee. Organic Chemistry, 7th Edn. Pearson Education, 2013.

- W. Carruthers, I. Coldham. Modern Methods of Organic Synthesis, Cambridge University Press, 4th Edn. 2012.

CHEM 203C: Physical Chemistry II **Marks: 50, Credits: 4**

1. Quantum Mechanics II **(14 Lectures)**

Free particle in one dimension; particle in one-dimensional box with finite potential walls (or particle in a rectangular well), step potential and tunneling; solution of Schrodinger equation of a Harmonic oscillator using the operator method; selection rules for Harmonic oscillator; rigid rotator; elementary discussion of the H-atom solution; Heisenberg's uncertainty principle.

2. Photo-excited Processes **(16 Lectures)**

Introduction, Jablonski diagram, photoexcitation, fluorescence, phosphorescence, photosensitization, delayed fluorescence: E- and P-type, quantum yield and its determination, fluorescence quenching: static and dynamic, application of Stern-Volmer equation/plot (linear and non-linear); absorption, emission and excitation spectra - mirror symmetry, excited state processes, Marcus theory, solvent effect in spectroscopy, solvation dynamics, sensing of biologically relevant cations, anions and neutral molecules, chemosensors.

3. Nanotechnology: Principles and Applications **(16 Lectures)**

Introduction, fundamental principles of nanoparticles (0D, 1D, 2D and 3D) and their physical, optical, electronic, magnetic properties; metallic and semiconducting nanoparticles; density of states, some special nanomaterials - quantum wire, thin film, fullerenes, carbon nanotubes and nanodiamonds; nanolithography; material characterization techniques: transmission electron microscopy (TEM), scanning electron microscope (SEM) and atomic force microscopy (AFM); applications of nanotechnology.

4. Thermodynamics and Statistical Mechanics **(16 Lectures)**

Introduction, Legendre transformation with applications; Maxwell-Boltzmann distribution with degeneracy (distinguishable and indistinguishable particles), partition function and its properties, interpretation of thermodynamic laws, thermodynamic functions in terms of partition functions, molecular partition functions (translational, rotational, vibrational and electronic) for ideal gas, Sackur-Tetrode equation, calculation of thermodynamic functions for mono- and diatomic gases, equipartition principle, equilibrium constant in terms of partition functions.

5. Symmetry & Group Theory II **(18 Lectures)**

The Great Orthogonality Theorem (GOT) - statement and interpretation, proof of its corollaries; character table and its construction, number of times an irreducible representation occurs in a reducible one; the reduction of reducible representations, notation of irreducible representations, representations and quantum mechanics, the invariance of Hamiltonian operator under symmetry transformations, direct product representation, molecular vibrations, symmetry species of vibrational mode, selection rules for Infrared and Raman spectra, crystal field splitting.

Reference Books:

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- H. Eyring, J. Walter, 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, 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.
- J. R. Lakowicz. Principles of Fluorescence Spectroscopy, 3rd Edn. Springer, 2010.
- N. J. Turro. Modern Molecular Photochemistry, The Benjamin Cummings Publishing, 1978.
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- K. Rohatgi-Mukherjee, Fundamentals of Photochemistry, New Age International (P) Ltd, India, 2007.
- C. Bréchignac, B. P. Houdy, M. Lahmani. Nanomaterials and Nanochemistry, Springer, London, 2006.

- C. N. R. Rao, A. Muller, A. K. Cheetam. The Chemistry of Nanomaterials: Synthesis, Properties and Applications, Wiley-VCH verlog, Germany, 2005.
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- R. W. Kelshell, I. W. Hameley, M. Geoghegan. Nanoscale Science and Technology, John Wiley & Sons, England, 2005.
- C. P. Poole, F. J. Owens. Introduction to Nanotechnology, Wiley Interscience, 2003.
- T. Pradeep. A Textbook of Nanoscience and Nanotechnology, Tata McGraw-Hill India, 2012.
- P. Diwan, A. Bharadwaj. The Nanoscope: Encyclopedia of Nanoscience and Nanotechnology. Pentagon Press, 2005.
- N. Levine. Physical Chemistry, Tata McGraw-Hill, New Delhi, 1978.
- K. Denbigh. Principles of Chemical Equilibrium, Cambridge University Press, Cambridge, 1981.
- M. Klotz, R. M. Rosenberg. Chemical Thermodynamics, John Wiley & Sons, New York, 1994.
- G. W. Castellan. Physical Chemistry, 3rd Edn. Narosa Publishing House, 1995.
- N. A. Gokcen, R. G. Reddy. Thermodynamics, Plenum Press, New York, 1996.
- P. W. Atkins. Physical Chemistry, Oxford University Press, Oxford, 1998.
- R. S. Berry, S. A. Rice, J. Ross. Physical Chemistry, Oxford University Press, Oxford, 2000.
- S. C. Rakshit. Molecular Symmetry Group and Chemistry, The New Book Stall, Kolkata, 1988.
- F. A. Cotton. Chemical Applications of Group Theory, 3rd Edn. John Wiley & Sons. New York, 1999.
- D. M. Bishop. Group Theory and Chemistry, Oxford University Press, 1993.
- J. Vincent. Molecular Symmetry and Group Theory, John Wiley & Sons. New York, 1998.

Practical Paper

CHEM 204C (PR): Physical Chemistry Practical **Marks: 50, Credits: 4**

1. To determine the rate constant of acid catalyzed hydrolysis of an ester in a micellar media.
2. To verify Ostwald dilution law and determine the K_a of a weak acid.
3. To determine the rate constant and salt effect on the rate constant of the reaction between $K_2S_2O_8$ and KI.
4. To determine the composition of a mixture of acetic acid, sodium acetate and ammonium acetate by conductometry.
5. To study the titration of H_3PO_4 by NaOH using potentiometry.
6. To determine the composition of metal-ligand complex by Job's method.

Reference Books:

- B. Viswanathan, P. S. Raghavan. Practical Physical Chemistry, Viva Books, 2009.
- J. Mendham. Vogel's Quantitative Chemical Analysis, 6th Edn. Pearson Education, 2009.
- D. C. Harris. Quantitative Chemical Analysis, 6th Edn. W. H. Freeman, 2007.
- S. R. Palit, S. K. De. Practical Physical Chemistry, Science Book Agency.
- University Hand Book of Undergraduate Chemistry Experiments, edited by G. N. Mukherjee. University of Calcutta.
- B. P. Levitt. Findlay's Practical Physical Chemistry, 9th Edn. Longman Group Ltd. 1973.
- J. N. Gurtu, R. Kapoor. Advanced Experimental Chemistry, S. Chand & Co. Ltd.

CHEM 205G: **General Chemistry** **Marks: 50, Credits: 4**

1. Structure and Properties of Organic Molecules **(35 Lectures)**

Nature of bonding in aliphatic, alicyclic, aromatic and heterocyclic compounds; bond length, bond strength, bond angle and their variations in compounds with sp^3, sp^2 and sp hybridized carbon atoms; orbital pictures of methane, ethane, ethene, ethyne, allene and benzyne; delocalized bonds, inductive effect, resonance, steric inhibition of resonance, hyperconjugation, tautomerism,

aromaticity, Huckel's rules, aromatic, nonaromatic and antiaromatic compounds, non-benzenoid aromatic compounds; formation, structure, stability and reactions of classical and non-classical carbocations, carbanions, free radicals, arynes, ylides, carbenes and nitrenes.

2. Atomic Structure **(25 Lectures)**

Bohr's model, Sommerfeld's extension, de Broglie's wave particle duality; Heisenberg's uncertainty principle and Schrödinger's equation (qualitative); significance of ψ and ψ^2; radial density, angular probability, characteristics of s-/p-/d-orbital, Aufbau principle, Pauli's exclusion/antisymmetry principle (statement and implication), Hund's rules, Slater's rules, quantum defect; Mendeleev-Seaborg's periodic table: basis and possible extension; periodic properties: atomic radius, ionic radius, covalent radius, van der Waals radius, ionization energy, electron affinity, electronegativity and its different scales, orbital/group electronegativity, ionic potential, diagonal relationship, work function; aperiodicity.

3. Kinetic Theory of Gases **(20 Lectures)**

Idea of distribution functions, properties of gamma functions, Maxwell's speed and energy distributions in one-, two- and three- dimensions, distribution curves, different types of speeds and their significance, principle of equipartition of energy and its application to calculate the classical limit of molar heat capacity of gases.

Reference Books:

- I. L. Finar. Organic Chemistry, Volume I, 6th Edn, Addison Wesley Longmann, London, 1998.
- I. L. Finar. Organic Chemistry, Volume II, 5th Edn, ELBS, London, 1995.
- W. J. I. Noble. Highlights of Organic Chemistry, Mercel Dekker, New York, 1974.
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- G. Brahmachari. Organic Name Reactions: A Unified Approach, Narosa Publishing House Pvt. Ltd., New Delhi, 2012.
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- J. Clayden, N. Greeves, S. Warren, P. Wothers. Organic Chemistry, Oxford University Press, 2001.

- F. A. Carry, R. J. Sundberg. Advanced Organic Chemistry - Part-A and B, 5th Edn, Springer, 2007.
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- J. Moody. Reactive Intermediates, Oxford University Press, 1992.
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- J. E. Huheey, E. A. Keiter, R. L. Keiter, O. K. Medhi. Inorganic Chemistry: Principles of Structures and Reactivity, 4th Edn, Pearson, New Delhi, 2006.
- F. A. Cotton, G. Wilkinson, C. M. Murillo, M. Bochmann. Advanced Inorganic Chemistry, 6th Edn, John Wiley & Sons Inc. New York, 1999.
- P. Atkins, T. Overton, J. Rourke, M. Weller, F. Armstrong. Shriver & Atkins Inorganic Chemistry, 4th Edn, Oxford, 2006.
- P. C. Rakshit (Revised by S. C. Rakshit), Physical Chemistry, Sarat Book Distributers, Kolkata.
- P. W. Atkins, Julio De Paula. Physical Chemistry, Oxford University Press, Oxford.
- D. A. Mc-Quarie, J .D. Simon. Physical Chemistry: A Molecular Approach, Viva Book Pvt. Ltd.