Murshidabad Maharaja Krishnanath University

Syllabus

Chemistry (Major and Minor Course)

SEM-III and IV

Semester – III

Course Code	Course Type	Course Name	Credit	Lectures / Week	Internal Assessment	End Semester	Total Marks
CHE-M-301(T)	Major (Theory)	Inorganic Chemistry - I	3	3	15 + 5	40	80
CHE-M-301(P)	Major (Practical)	Inorganic Chemistry Practical- I	1	2	–	20	
CHE-M-302(T)	Major (Theory)	Organic Chemistry – I & Physical Chemistry-I	4	4	15 + 5	60	80
CHE-Mi-301(T)	Minor (Theory)	General Chemistry-II	3	3	15 + 5	40	80
CHE-Mi-301(P)	Minor (Practical)	Organic Chemistry-I	1	2	–	20	
CHE-MDC-301 (T)	MDC*	Chemistry in Daily Life	3	3	15	45	60
CHE -SEC -301 (T)	Skill Enhancement Course (SEC)	IT Skills for Chemist	3	3	15	45	60
	Value Added Course (VAC)		2	2	15 + 5	20	40
Total			**20**	**22**	**110**	**290**	**400**

*** Students who have not studied chemistry in H. S. level may opt for MDC (Chemistry in Daily Life).**

Semester – IV

Course Code	Course Type	Course Name	Credit	Lectures/ Week	Internal Assessment	End Semester	Total Marks
CHE-M-401 (T)	Major (Theory)	Inorganic Chemistry - 2	4	4	15 + 5	60	80
CHE-M-402 (T)	Major (Theory)	Organic Chemistry - 2	4	4	15 + 5	60	80
CHE-M-403 (T)	Major (Theory)	Physical Chemistry-2	4	4	15 + 5	60	80
CHE-M-404 (P)	Major (Practical)	Practical Chemistry (Inorganic-2, Organic-2 and Physical-2)	4	4	20	60	80
CHE-Mi-401(T)	Minor (Theory)	General Chemistry-II	3	3	15 + 5	40	80
CHE-Mi-401(P)	Minor (Practical)	Organic Chemistry-I	1	2	–	20	
Total			**20**	**21**	**100**	**300**	**400**

Semester-III
Chemistry MAJOR Course

Course Code	Course Name	Credit: 3
CHE-M-301(T)	Inorganic Chemistry-I	F.M. = 60

Chemical Bonding-II (Advanced part): **(25 hours)**

Molecular orbital concept of covalent bonding:

The major drawbacks of VBT and introduction of MOT. The approximations of MO theory, Linear combination of atomic orbitals (LCAO) method (elementary pictorial approach). Sigma (σ)-,Pi (π)- and Delta (δ)-Molecular Orbitals, HOMO, LUMO. MO diagrams of simple homo nuclear diatomic molecules like H_2, He_2, Li_2, Be_2, B_2, C_2, N_2, O_2, F_2, and their ions wherever possible. MO diagrams of hetero nuclear molecules and ions: CO, NO, NO^+, CN^-, HF, BeH_2, CO_2 and H_2O. Bond properties: bond order, bond length and bond energy. Limitations of the Simple Molecular Orbital Model.

Metallic Bond: Electron sea model, Qualitative idea of valence bond and band theories, Differences among Conductor, Semiconductor and Insulator in the light of band theory, Defects in crystal.

Weak Chemical Forces: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Hydrogen bonding.

Chemistry of s and p-block elements: **(20 hours)**

Diagonal relationship (Li-Mg; B-Si) and anomalous behavior of first member of each group, Allotropy and catenation (examples of C, P and S compounds). Study of the following compounds with emphasis on preparation, properties, structure and bonding: Berylium hydrides and halides; diborane; borazine; boron nitride, boric acid, borax, fluorocarbons (with environmental effect); oxides and oxy acids of nitrogen, phosphorous, sulphur and chlorine; Peroxo acids of sulphur; tetrasulphurtrtranitride; interhalogens, pseudohalogens, polyhalides, fluorides and oxides of xenon. Noble gas clathrates; basic properties of iodine. Synthesis, structural aspects and applications of silicones and phosphazines. Structural properties of various silicates.

Course Code	Course Name	Credit: 1
CHE-M-301(P)	Inorganic Chemistry Practical-I	F.M. = 20

Inorganic Quantitative Analysis: **(30 hours)**

1. Standardization of $KMnO_4$ using standard oxalic acid solution.
2. Estimation of Fe(II) using standard $KMnO_4$ solution.
3. Estimation of Fe(III) using standard $K_2Cr_2O_7$ solution.
4. Estimation of Cu(II) iodometrically.

Course Code	Course Name	Credit: 4
CHE-M-302(T)	Organic Chemistry-I & Physical Chemistry-I	F.M. = 80

Unit-1: Organic Chemistry-I

Reaction Mechanism I: **(20 hours)**

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

***Concept of organic acids and bases*:** Effect of structure, substituent and solvent on acidity and basicity; proton sponge; gas-phase acidity and basicity; comparison between nucleophlicity and basicity; HSAB principle; application of thermodynamic principles in acid-base equilibria.

***Tautomerism*:** Prototropy (keto-enol, nitro - aci-nitro, nitroso-oximino, diazo-amino and enamine-imine systems); valence tautomerism and ring-chain tautomerism; composition of the equilibrium in different systems (simple carbonyl; 1,2- and 1,3-dicarbonyl systems, phenols and related systems), factors affecting keto-enol tautomerism; application of thermodynamic principles in tautomeric equilibria.

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

Reaction Mechanism II*:* Substitution and Elimination Reactions: **(15 hours)**

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

Nucleophilic substitution reactions: Substitution at sp^3centre: mechanisms (with evidence), relative rates & stereochemical features: S_N1, S_N2, S_N2', S_N1' (allylic rearrangement) and S_Ni; effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite); substitutions involving NGP; role of crown ethers and phase transfer catalysts; [systems: alkyl halides, allyl halides, benzyl halides, alcohols, ethers, epoxides]. Concept of aliphatic electrophilic substitution reactions (S_E1, S_E2, S_Ei).

Elimination reactions: E1, E2, E1cb and Ei (pyrolytic syn eliminations); formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity; comparison between substitution and elimination; importance of Bredt's rule relating to the formation of C=C.

Unit-2: Physical Chemistry-I:

Chemical kinetics: **(15 hours)**

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

Role of Temperature and theories of reaction rate: Temperature dependence of rate constant; Arrhenius equation, energy of activation; Rate-determining step and steady-state approximation –explanation with suitable examples; Collision theory; Lindemann theory of unimolecular reaction; outline of Transition State theory (classical treatment).

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

Liquid State: **(10 hours)**

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

Multidisciplinary Course		
Course Code	**Course Name**	**Credit: 3**
CHE-MDC-301 (T)	**Chemistry in Daily Life**	**F.M. = 60**

1. Food Additives **(6 hours)**

Food flavour, food colour, food preservatives, artificial sweeteners, acidulants, alkalies, edible emulsifiers and edible foaming agents, sequestrants – uses and abuses of these substances in food beverages.

2. Drugs and Pharmaceuticals **(8 hours)**

Structure and function, antipyretic and analgesic drugs - aspirin, paracetamol, ibuprofen, sulphadiazine, quinine, chloroquine, phenobarbital, metronidazole.

3. Vitamins **(4 hours)**

Basic idea on vitamins, uses of some vitamins: Vit-A, Vit-K, Vit-E, Vit-C, Vit-D and Vit-B12

4. Fats and Oils **(8 hours)**

Natural fat, edible and inedible oil of vegetable origin; common fatty acids; glycerides; hydrogenation of unsaturated oil, production of vanaspati and margarine.

5. Soaps and Detergents **(6 hours)**

Production of toilet and washing soaps; enzyme-based detergents, detergent powder; liquid soaps.

6. Pesticides **(5 hours)**

Common pesticides: production, applications and residual toxicity of gammaxane, aldrin, parathion, malathion, DDT, paraquat, decamethrin.

7. Chemistry of Fuels: **(8 hours)**

Conventional and non-conventional energy sources, classification of fuels, calorific values of fuels like kerosene, coal, coal gas, petrol, liquefied petroleum gas, octane number, bio gas.

Reference Books:

1. Textbook of Food Chemistry, Gayatri Vaidya, Book Rivers, 2022
2. Food Chemistry, H. Thapar, Pacific Book International, 2011.
3. Application Oriented Chemistry, S. Sengupta, Book Syndicate Pvt. Ltd., 2000.
4. Chemistry in Daily Life, K. Singh, Third Edition, Prentice Hall India Learning Private Limited, 2012.
5. Chemistry in Daily Life, Lassar-Cohn, Publisher, Read Books, 2007.
6. Conceptual Organic Chemistry, A. Sethi, New Age International Publisher, 2017.
7. Organic Chemistry, R. L. Madan, S. Chand & Sons, 2013
8. General Chemistry, S. Ekambaram, Pearson, 2013

Skill Enhancement Course		
Course Code	**Course Name**	**Credit: 3**
CHE-SEC-301 (T)	**IT Skills for Chemist**	**F.M. = 60**

1. Mathematics for Chemist **(15 hours)**

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

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

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

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

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

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

2. Computer programming (10 hours)

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

3. Hands On (20 hours)

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

ii. Handling numeric data: Spreadsheet software (Excel), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs. Incorporating tables and graphs into word processing documents. Simple calculations, plotting graphs using a spreadsheet (Planck's distribution law, radial distribution curves for hydrogenic orbitals, gas kinetic theory- Maxwell-Boltzmann distribution pressure-volume curves of van der Waals gas (van der Waals isotherms), data from phase equilibria studies. Graphical solution of equations.

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

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

v. Presentation: Presentation graphics

Reference Books

1. Mathematics for Physical Chemistry, D. A. McQuarrie, University Science Books (2008).

2. Mathematics for Physical Chemistry, R. Mortimer, 3rd Ed. Elsevier (2005).

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

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

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

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

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

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

Semester-III
Chemistry MINOR Course

Course Code	**Course Name**	**Credit: 3**
CHE-Mi-301(T)	**General Chemistry-II**	**F.M. = 60**

Unit-1: Inorganic Chemistry: **(15 hours)**

Chemical Bonding and Molecular Structure

Ionic Bonding: General characteristics of ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Born-Haber cycle and its applications. Fajan's rules, bond moment, dipole moment.

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

MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s- p mixing).

Coordination Chemistry

Double salt, complex compound, Werner's coordination theory, IUPAC nomenclature of coordination compound, classification of ligands, Inner and outer orbital complexes. Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

Unit-2: Organic Chemistry: (15 hours)

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

Substitution: Free-radical substitution reaction: Halogentaion of alkanes, mechanism; Nucleophilic substitution reactions: Substitution at sp^3 centre: mechanisms, relative rates & stereochemical features: S_N1, S_N2; effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite).

Elimination reactions: E1, E2, E1cb and Ei (pyrolytic eliminations); formation of alkenes and alkynes; mechanisms, reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity; comparison between substitution and elimination; importance of Bredt's rule relating to the formation of C=C.

Concept of organic acids and bases*:* Effect of structure, substituent and solvent on acidity and basicity; proton sponge; gas-phase acidity and basicity; comparison between nucleophlicity and basicity; HSAB principle; application of thermodynamic principles in acid-base equilibria.

Unit-3: Physical Chemistry: (15 hours)

Chemical Energetics

a. Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics; Concept of heat, work, internal energy and statement of first law; enthalpy, H; relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases

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

Chemical Kinetics*:*

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

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

Course Code	Course Name	Credit: 1
CHE-Mi-301(P)	Organic Chemistry Practical-I	F.M. = 20

Qualitative Analysis of Single Solid Organic Compound(s) **(30 hours)**

1. Detection of special elements (N, Cl, and S) in organic compounds.

2. Solubility and Classification (solvents: H_2O, dil. HCl, dil. NaOH, dil. $NaHCO_3$)

3. Detection of functional groups: Aromatic-NO_2, Aromatic-NH_2, -COOH, carbonyl (no distinction of –CHO and >C=O needed), -OH (phenolic) in solid organic compounds.

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

Semester-IV

Chemistry MAJOR Course

Course Code	Course Name	Credit: 4
CHE-M-401(T)	Inorganic Chemistry-2	F.M. = 80

Coordination Chemistry: Preamble **(15 hours)**

Idea about double and complex salts. Basic postulates of Werner's Coordination Theory; Characteristic features of the Primary and Secondary Valencies. Coordination numbers, IUPAC nomenclature of coordination complexes (up to two metal centers). Ligand: Definition and Classification of ligands based on the nature of metal-ligand bonding and number of donor sites (denticity),chelating ligands including trans-chelate, Ambidentate and Flexidentate ligands, Innocent and non-innocent ligands. Stability constant (stepwise and overall), Isomerism in Coordination Compounds: Constitutional and Stereoisomerism, Geometrical and Optical Isomerism in Square Planar and Octahedral Complexes.

Coordination Chemistry: Bonding Theory **(15 hours)**

VB description and its limitations. Elementary Crystal Field Theory: splitting of *dn* configurations in octahedral, square planar and tetrahedral fields, crystal field stabilization energy (CFSE) in weak and strong fields; pairing energy. Spectrochemical series. Jahn- Teller distortion. Octahedral site stabilization energy (OSSE). Metal-ligand bonding (MO concept, elementary idea), sigma- and pi-bonding in octahedral complexes (qualitative pictorial approach) and their effects on the oxidation states of transitional metals (examples).

Metal extraction and purification: Basic Metallurgy **(5 hours)**

Idea about ores and minerals, operations involved in metallurgy, Flow chart diagram for the extraction of pure Ti, Ni and U (including reactions) from their important ores and their uses.

Redox Chemistry: **(25 hours)**

Electronic theory of Redox reaction. Oxidation number and Rules for calculating oxidation number. Balancing of redox reactions by ion-electron method, Oxidative Addition and Reductive Elimination reaction, Equivalent Weight of Oxidants and Reductants. Disproportionation and Comproportionation reactions (typical examples).

Electrode Potentials: Elementary idea on standard redox potentials with sign conventions. Standard Electrode Potentials of Metals, Electrochemical series and its Applications, Nernst equation (without derivation), Periodic trends of electrode potential. Effect of Different Factors on Electrode Potential: Influence of complex formation, precipitation and change of pH (due to participation of H^+ and OH^- in electrode process) on redox potential, formal potential. Application of such effects in Analytical Chemistry.

Redox titrations: Feasibility of a redox titration, redox potential at the equivalence point, redox indicators.

EMF diagrams: Latimer and Frost diagrams of common elements such as Manganese, Nickel, Copper and their applications.

Course Code	Course Name	Credit: 4
CHE-M-402 (T)	Organic Chemistry-2	F.M. = 80

Chemistry of alkenes and alkynes: **(25 hours)**

Addition to C=C: Mechanism (with evidence wherever applicable), reactivity, regioselectivity (Markownikoff and anti-Markownikoff additions) and stereoselectivity; reactions: hydrogenation, halogenations, iodo-lactonisation, hydro-halogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, syn- and anti-hydroxylation, ozonolysis, addition of singlet and triplet carbenes; electrophilic addition to diene (conjugated dienes and allene); radical addition: HBr addition; mechanism of allylic and benzylic bromination in competition with brominations across C=C; use of NBS; dissolving metal reduction of alkenes; interconversion of E - and Z - alkenes; contra-thermodynamic isomerization of internal alkenes.

Addition to C≡C (in comparison to C=C):

Mechanism, reactivity, regioselectivity (Markownikoff and anti-Markownikoff addition) and stereoselectivity; reactions: hydrogenation, halogenations, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, dissolving metal reduction of alkynes (Birch); reactions of terminal alkynes by exploring its acidity; interconversion of terminal and non-terminal alkynes.

Aromatic Substitution: **(10 hours)**

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

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

Carbonyl and Related Compounds: **(25 hours)**

Addition to C=O: structure, reactivity and preparation of carbonyl compounds; mechanism (with evidence), reactivity, equilibrium and kinetic control; Burgi-Dunitz trajectory in nucleophilic additions; formation of hydrates, cyanohydrins and bisulphite adduct; nucleophilic addition-elimination reactions with alcohols, thiols and nitrogen- based nucleophiles; reactions: benzoin condensation, Cannizzaro and Tischenko reactions, reactions with ylides: Wittig and Corey-Chaykovsky reaction; Rupe rearrangement, oxidations and reductions: Clemmensen, WolffKishner, $LiAlH_4$, $NaBH_4$, MPV, Oppenauer, Bouveault-Blanc, acyloin condensation; oxidation of alcohols with PDC and PCC; periodic acid and lead tetraacetate oxidation of 1,2-diols.

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

Course Code	Course Name	Credit: 4
CHE-M-403 (T)	Physical Chemistry-2	F.M. = 80

Applications of Thermodynamics –I **(30 hours)**

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

Chemical Equilibrium: Thermodynamic conditions for equilibrium, degree of advancement; Van't Hoff's reaction isotherm (deduction from chemical potential); Variation of free energy with degree of advancement; Equilibrium constant and standard Gibbs free energy change; Definitions of K_P, K_C and K_X; Van't Hoff's reaction isobar and isochore from different standard states; Shifting of equilibrium due to change in external parameters e.g. temperature and pressure; variation of equilibrium constant with addition to inert gas; Le Chatelier's principle. Nernst's distribution law; Application-(finding out K_{eq} using Nernst distribution law for $KI+I_2 = KI_3$ and dimerization of benzene.

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

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

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

Application of Thermodynamics – II (30 hours)

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

Phase rule: Definitions of phase, component and degrees of freedom; Phase rule and its derivations; Definition of phase diagram; Phase diagram for water, CO_2, Sulphur. First order phase transition and Clapeyron equation; Clausius-Clapeyron equation –derivation and use; Liquid vapour equilibrium for two component systems; Phenol-water system. Three component systems, water-chloroform-acetic acid system, triangular plots.

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

Course Code	Course Name	Credit: 4
CHE-M-404(P)	Practical Chemistry (Inorganic-2, Organic-2 and Physical-2)	F.M. = 80

Inorganic Chemistry Practical-2 **(40 hours)**

1. Estimation of Fe(II) and Fe(III) in a given mixture using standard $K_2Cr_2O_7$ solution
2. Estimation of Fe(III) and Cu(II) in a given mixture using standard $K_2Cr_2O_7$ solution
3. Estimation of Fe(II) and Mn(II) in a given mixture using standard $KMnO_4$ solution
4. Estimation of Fe(III) and Cr(VI) in a given mixture using standard $K_2Cr_2O_7$ solution

Organic Chemistry Practical-2 **(40 hours)**

Organic Preparations:

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

1. Nitration of aromatic compounds
2. Condensation reactions
3. Hydrolysis of amides/imides/esters
4. Acetylation of phenols/aromatic amines
5. Benzoylation of phenols/aromatic amines
6. Side chain oxidation of aromatic compounds
7. Diazo coupling reactions of aromatic amines
8. Bromination of anilides using green approach (Bromate-Bromide method)
9. Selective reduction of m-dinitrobenzene to m-nitroaniline

Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

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

C. Melting point of the purified product is to be noted.

Physical Chemistry Practical-1 **(40 hours)**

1. Determination of partition coefficient for the distribution of I2 between water and CCl_4.
2. Determination of Keq for $KI + I_2 = KI_3$, using partition coefficient between water and CCl_4.
3. Conductometric titration of an acid (strong, weak, monobasic, dibasic) against strong base.
4. Study of saponification reaction conductometrically.
5. Perform the following potentiometric titrations:

i. Weak acid vs. strong base

ii. Potassium dichromate vs. Mohr's salt

Semester-IV
Chemistry MINOR Course

Course Code	Course Name	Credit: 3
CHE-Mi-401(T)	General Chemistry-II	F.M. = 60

Unit-1: Inorganic Chemistry: **(15 hours)**

Chemical Bonding and Molecular Structure

Ionic Bonding: General characteristics of ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Born-Haber cycle and its applications. Fajan's rules, bond moment, dipole moment.

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

MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s- p mixing).

Coordination Chemistry

Double salt, complex compound, Werner's coordination theory, IUPAC nomenclature of coordination compound, classification of ligands, Inner and outer orbital complexes. Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

Unit-2: Organic Chemistry: **(15 hours)**

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

Substitution: Free-radical substitution reaction: Halogenation of alkanes, mechanism; Nucleophilic substitution reactions: Substitution at sp^3centre: mechanisms, relative rates & stereochemical features: S_N1, S_N2; effects of solvent, substrate structure, leaving group and nucleophiles (including ambident nucleophiles, cyanide & nitrite)

Elimination reactions: E1, E2, E1cb and Ei (pyrolytic eliminations); formation of alkenes and alkynes; mechanisms, reactivity, regioselectivity (Saytzeff/Hofmann) and stereoselectivity; comparison between substitution and elimination; importance of Bredt's rule relating to the formation of C=C.

***Concept of organic acids and bases**:* Effect of structure, substituent and solvent on acidity and basicity; proton sponge; gas-phase acidity and basicity; comparison between nucleophlicity and basicity; HSAB principle; application of thermodynamic principles in acid-base equilibria.

Unit-3: Physical Chemistry: **(15 hours)**

Chemical Energetic

a. Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics; Concept of heat, work, internal energy and statement of first law; enthalpy, H; relation between heat capacities, calculations of q, w, U and H for reversible, irreversible and free expansion of gases

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

***Chemical Kinetics**:*

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

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

Course Code	Course Name	Credit: 1
CHE-Mi-401 (P)	Organic Chemistry Practical-1	F.M. = 20

Qualitative Analysis of Single Solid Organic Compound(s)

1. Detection of special elements (N, Cl, and S) in organic compounds.
2. Solubility and Classification (solvents: H_2O, dil. HCl, dil. NaOH, dil. $NaHCO_3$)
3. Detection of functional groups: Aromatic-NO_2, Aromatic-NH_2, -COOH, carbonyl (no distinction of –CHO and >C=O needed), -OH (phenolic) in solid organic compounds.

Reference Chemistry Books:

Inorganic Chemistry Books:

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

2. Concise Inorganic Chemistry, J. D. Lee, Wiley India Pvt. Ltd., 5thEdn., 2008.

3. Inorganic Chemistry, Weller, Overton, Rourke, Amstrong, Oxoford University Press, 6thEdn., 2015

4. Inorganic Chemistry, G. L. Miessler, D. A. Tarr, Pearson India, 3rd Edition, 2008.

5. Fundamental Concept of Inorganic Chemistry (Vol. 2) by Asim K. Das CBS Publishers and Distributors Pvt. Ltd,, 2ndEdn., 2011

6. Fundamental Concept of Inorganic Chemistry (Vol. 3) by Asim K. Das CBS Publishers and Distributors Pvt. Ltd,, 2ndEdn., 2011

7. Fundamental Concept of Inorganic Chemistry (Vol. 4) by Asim K. Das and Mahua das, CBS Publishers and Distributors Pvt. Ltd,, 1stEdn., 2014

8. Inorganic Chemistry: Part-1 Principles, R. L. Dutta, The New Book Stall, 5thEdn., 2003.

9. Introduction to Coordination Chemistry, Geoffrey A. Lawrance, John Wiley & Sons Ltd, 2010.

10. Inorganic Chemistry, Catherine E. Housecroft and Alan G. Sharpe, Pearson Education Limited, 4thEdn., 2012

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

12. Inorganic Chemistry: Part-II Chemistry of Elements, R. L. Dutta, The New Book Stall, 5thEdn., 2003.

13. Advanced Inorganic Chemistry, F.A. Cotton and G. Wilkinson, Wiley–Blackwell, 3rdEdn., 1972.

14.Concepts & Models of Inorganic Chemistry, B.E. Douglas, and D.H. McDaniel, Wiley India Pvt Ltd, 3rdEdn., 2011.

15. Theoretical Inorganic Chemistry, M.C. Day, and J. Selbin, ACS Publications, 1962.

Organic Chemistry Books:

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

2. A guidebook to Mechanism in Organic Chemistry, P. Sykes, Pearson Education, 2003.

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

4. Organic Chemistry, F. A. Carey, &R. M. Guiliano, McGraw Hill Education, Eighth edition, 2012.

5. Organic Chemistry, G. M. Loudon, Fourth edition, Oxford University Press, 2008.

6. Stereochemistry of Organic Compounds, E. L. Eliel, &S. H. Wilen, Wiley: London, 1994.

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

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

9. Organic Chemistry (Volume 1 and 2), I. L. Finar, Pearson Education.

10. Organic Chemistry, T.W. Graham Solomons, C. B. Fryhle, John Wiley & Sons, Inc.
11. Stereochemistry at a Glance, J. Eames, J. M. Peach, Blackwell Publishing, 2003.
12. Stereochemistry, M. J. T. Robinson, Oxford University Press, 2005.
13. Mechanisms of Organic Reactions, H. Maskill, Oxford Chemistry Primers, Oxford University Press, 1996.
14. Advanced Organic Chemistry, J. March, Fourth edition, WileyIndiaEdn., 2006.
15. Principles of Organic Synthesis, R.O. C. Norman, J. M. Coxon, Third Edition, Nelson Thornes, 2003.
16. Basic Stereochemistry of Organic molecules, S. Sengupta, Oxford University Press, 2014.
17. Stereochemistry: Conformation and Mechanism, P. S. Kalsi, Eighth edition, New Age International, 2014.

Physical Chemistry Books:

1. Atkins' Physical Chemistry, P. W. Atkins, J. de Paula, Oxford University Press, 2014.
2. Physical Chemistry, G. W., Castellan, Narosa, 2004.
3. Physical Chemistry: A Molecular Approach, D. A. McQuarrie, &J. D. Simons, Viva Press, 2019.
4. Physical Chemistry, I. N. Levine, Tata McGraw-Hill, 2001.
5. Physical Chemistry, P.C. Rakshit, Sarat Book House, 7thEdn., 2014.
6. Physical Chemistry, W. J. Moore, Orient Longman, 1972.
7. Physical Chemistry, R. G. Mortimer, Elsevier, 2008.
8. The Principles of Chemical Equilibrium, K. Denbigh, Cambridge University Press, 1981.
9. Physical Chemistry, T. Engel, &P. Reid, Pearson Education, 2013.
10. Quantum Chemistry, I. N. Levine, Pearson. 2008.
11. Molecular Quantum Mechanics, P. W. Atkins, 5thEdn., Oxford University Press, 2010.
12. Heat and Thermodynamics, M. W. Zemansky, &R.H. Dittman, 8thEdn.,McGraw Hill Education, 2017.
13. An Introduction to Chemical Thermodynamics, R. P. Rastogi, &R.R. Misra, 6thEdn., Vikas Publishing House Pvt Ltd. 2018.
14. Chemical Thermodynamics:Basic Concepts and Methods, I.M. Klotz, R. M. Rosenberg, 7thEdn.,Wiley-Interscience, 2010.
15. An Introduction to Electrochemistry, S. Glasstone, East-West Press (Pvt.) Ltd., 2006.

Practical Chemistry Books

1. A. I. Vogel's Quantitative Chemical Analysis, J.Mendham, 6th Ed., Pearson, 2009.
2. Elementary Practical Organic Chemistry, Part 1: Small scale Preparations, A. I. Vogel, 2ndEdn., Pearson India, 2010.

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

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

5. Practical Organic Chemistry, B.S.Furniss, A.J.Hannaford, P.W.G. Smith&A.R. Tatchell, 5thEdn. Pearson, 2012.

6. Practical Organic Chemistry: Preparation and Quantitative Analysis, V.K. Ahluwalia, &R.Aggarwal, Comprehensive University Press, 2000.

7.Practical Physical Chemistry,B.Viswanathan,P.S. Raghavan, Viva Books, 2009.

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

9. Practical Physical Chemistry, S.R.Palit, S. K. De, Science Book Agency.

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

11. Chemistry in Laboratory (SEM I –VIII), S. Ghosh, M. Das Sarma, D. Majumdar, S. Manna, Santra Publication, 2022.