VIDYASAGAR UNIVERSITY

Midnapore, West Bengal

PROPOSED CURRICULUM & SYLLABUS (DRAFT) OF

BACHELOR OF SCIENCE (HONOURS)

MAJOR IN CHEMISTRY

4-YEAR UNDERGRADUATE PROGRAMME

(w.e.f. Academic Year 2023-2024)

Based on

Curriculum & Credit Framework for Undergraduate Programmes (CCFUP), 2023 & NEP, 2020

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VIDYASAGAR UNIVERSITY
BACHELOR OF SCIENCE (HONOURS) MAJOR IN CHEMISTRY
(under CCFUP, 2023)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. (Hons.)	2nd	III	SEMESTER-III							
			Major-3	CEMHMJ03	T: Physical Chemistry-I; P: Practical	4	3-0-1	15	60	75
			Major-4	CEMHMJ04	T: Organic Chemistry-II; P: Practical	4	3-0-1	15	60	75
			SEC	CEMSEC03	P: Preparation of Household Chemicals (Practical)	3	0-0-3	10	40	50
			AEC	AEC03	Communicative English -2 (***common for all programmes***)	2	2-0-0	10	40	50
			MDC	MDC03	Multidisciplinary Course -3 (***to be chosen from the list***)	3	3-0-0	10	40	50
			Minor-3 (Disc.-I)	CEMMIN03	T: Inorganic Chemistry –II & Organic Chemistry-II; P: Practical	4	3-0-1	15	60	75
					Semester-III Total	20				375
		IV	SEMESTER-IV							
			Major-5	CEMHMJ05	T: Inorganic Chemistry-II; P: Practical	4	3-0-1	15	60	75
			Major-6	CEMHMJ06	T: Physical Chemistry-II; P: Practical	4	3-0-1	15	60	75
			Major-7	CEMHMJ07	T: Organic Chemistry-III; P: Practical	4	3-0-1	15	60	75
			AEC	AEC04	MIL-2 (***common for all programmes***)	2	2-0-0	10	40	50
			Minor-4 (Disc.-II)	CEMMIN04	T: Physical Chemistry –III & Inorganic Chemistry-III; P: Practical	4	3-0-1	15	60	75
			Summer Intern.	INT	Internship/ Apprenticeship - activities to be decided by the Colleges following the guidelines to be given later	4	0-0-4	-	-	50
					Semester-IV Total	22				400
					TOTAL of YEAR-2	42				775

MJ = Major, MI = Minor Course, SEC = Skill Enhancement Course, AEC = Ability Enhancement Course, MDC = Multidisciplinary Course, CA= Continuous Assessment, ESE= End Semester Examination, T = Theory, P= Practical, L-T-P = Lecture-Tutorial-Practical, MIL = Modern Indian Language

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SEMESTER-III

MAJOR (MJ)

Major-3: PHYSICAL CHEMISTRY-I **Credits 04 (Theory-03, Practicals-01)**

MJ3T: PHYSICAL CHEMISTRY-I **Credits 03 (Theory: 45 Lectures)**

A. FITNESS TRAINING FOR PHYSICAL CHEMISTRY **(7 LECTURES)**

(I) Units and Dimensions: Physical quantity, Units and unit systems, Symbols, Basic and Derived units, SI units, Dimensions, Principle of homogeneity of dimensions, Atomic Units. (Examples should be taken from various chapters of Physical Chemistry)

(II) Plots of Simple Functions: linear plots; its slopes and intercepts, choice of proper scale, Plots of polynomial, exponential and trigonometric functions and their combinations. Plots of inverse and hyperbolic functions. . (Examples should be taken from various chapters of Physical Chemistry).

B. CHEMICAL KINETICS: PART-1 **(12 LECTURES)**

(I) Introduction, stoichiometric coefficient, Extent or advancement of reaction, Rate of a reaction in terms of advancement of reaction, Law of mass action, Differential rate law, rate constant and its unit, order and molecularity:

(II) Integrated rate laws for simple reactions involving only one reactant: zero. half, one, two, three and n-th order reactions, Half life time, time of completion, average life time. Integrated rate laws involving more than one reactants: 2nd and third order. Pseudo first order reactions.

(III) Determination of order of a reaction: method of differential rate law, n_t and n_c, method of integrated rate law, method of half-life time, method of isolation.

(IV) Complex reactions: Opposing reactions, Equilibrium Constant; Consecutive reactions, slowest step is the rate determining step. Parallel reactions KCP and TCP

(V) Temperature dependence of rate constant; Arrhenius equation, energy of activation.

(VI) Rate-determining step and steady-state approximation – explanation with suitable examples. Arrhenius Complex and van't Hoff complex.

(VII) Homogeneous catalysis: with reference to acid-base catalysis.

C. THERMODYNAMICS: PART-1 (FIRST LAW OF THERMODYNAMICS & THERMOCHEMISTRY) **(16 LECTURES)**

(I) Mathematics for Thermodynamics: Derivatives, Partial derivatives, State functions and Path functions, Exact and Inexact differentials, Cyclic rule, Chain rule, Legendre transformations, Homogeneous functions, Extremization problems.

(II) Introduction, Some basic concepts; System; isolated, closed and open; Thermodynamic system. Surroundings, Universe, Boundaries and its classifications, Properties of a system: Extensive and Intensive; State property and path property, Different types of processes: reversible and irreversible processes, Isothermal and adiabatic processes. Thermodynamic state, Equation of states, Steady state and Equilibrium state. Thermal equilibrium, Zeroth law of Thermodynamics and its applications. Definition of temperature.

(III) Concept of heat and work: Work in various processes (reversible, irreversible, isothermal, adiabatic), indicator diagrams,

(IV) Joule's experiments, Concept of internal energy (U), First law of thermodynamics; its various statements.

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(V) Joule-Thomson experiment; concept of enthalpy (H); J-T coefficient, Inversion temperature, Expressions of J-T coefficient and inversion temperature for VDW gas. Cooling and heating due to JT expansion.

(VI) Heat capacity relations. General relations, relations for ideal and VDW gas.

(VII) Adiabatic Changes of states: relations among various state properties of ideal and VDW gas for adiabatic reversible process, Expressions of work, adiabatic cooling, its difference from the JT cooling.

(VIII) Thermochemistry: Basic laws of thermochemistry, Standard states; Temperature dependence of enthalpy of a reaction: Kirchhoff's equation. Enthalpy of reactions for various processes; enthalpy of formation, enthalpy of combustion, lattice enthalpy and the Born-Haber cycle, enthalpy of neutralizations, bond dissociation enthalpy and the average bond enthalpy, resonance enthalpy, enthalpy of solution and dilution, adiabatic flame temperature.

D. QUANTUM MECHANICS: PART-1 (HISTORICAL DEVELOPMENTS AND OLD QUANTUM THEORY) (10-LECTURES)

(I) A brief introduction to Quantum Mechanics

(II) Black body radiation: experimental observations, important features, Stefan Boltzmann law, Wien's distribution formula and the Wien's displacement law, Rayleigh-Jeans formula, Planck's hypothesis and the theoretical explanations BB energy distribution.

(III) Particle aspect of light: Photoelectric effect: Experimental observations and Einstein's explanation; Compton effect; Experimental observations and Compton's explanations.

(IV) Wave aspects of particle: de Broglie's wave particle duality

(V) Heisenberg Uncertainty Principle: Position-Momentum Uncertainty principle, Statements and qualitative explanations from the dual nature of light and particle. Various consequences of HUP. Energy-time uncertainty principle.

(VI) Old quantum theory: Bohr, Wilson and Sommerfeld quantization rule and their applications to PIAB, LSHO, RR and H-atom problems.

SUGGESTED BOOKS

Text Books:

1. Physical Chemistry, G.W. Castellan, Narosa, New Delhi
2. Physical Chemisty, I. N. Levine, McGraw Hill, NewYork
3. Physical Chemistry, P. Atkins, J.D Paula and J. Keeler, Oxford University Press, New York
4. Physical Chemistry: A Molecular Approach, D. A. McQuarrie and J. D. Simon, Viva Book Private Limited, New Delhi.
5. Physical Chemistry, T. Engel and P. Reid, Pearson Education,Inc, India.
6. Text Book of Physical Chemistry, S. Glasstone, Macmillan India Limited, New Delhi

Reference Books:

7. Chemical Kinetics, K. J. Laidler, Pearson Education India.
8. Quantum Mechanics, J. L. Powel and B. Crasemann, Dover Publications Inc., UK.
9. Quantum Chemistry, I. N. Levine, Pearson Education India.
10. Mathematics for Physical Chemistry, D. A. McQuarrie, Univ Science Books.
11. Heat & Thermodynamics, M. W. Zemansky & R. H. Dittman, The McGraw-Hill Companies Inc., New York.

MJ3P: PHYSICAL CHEMISTRY LAB- I Credits 01 (30 Hrs.)

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1. Calibration of various apparatus such as burette, pipette, volumetric flux, measuring cylinder etc.
2. Concepts of molecular weight, equivalent weight, various concentration terms, primary and secondary standard solutions and their preparations with proper explanations of types of apparatus to be used to prepare these solutions.

Prepare the following solutions

(i) Primary standard oxalic acid solution by accurate weighing
(ii) Primary standard potassium dichromate solutions by accurate weighing
(iii) Secondary standard sodium hydroxide solutions by approximate weighing
(iv) Secondary standard sodium thiosulphate solutions by approximate weighing
(v) Secondary standard potassium permanganate solution by approximate weighing
(vi) Secondary standard sulphuric acid, hydrochlroric acid and acetic acid solutions of various strength from the supplied concentrated solutions.

3. Study of kinetics of acid-catalyzed hydrolysis of an ester
4. Study of kinetics of decomposition of H_2O_2
5. Determination of specific rotation of cane sugar using polarimeter
6. Study the kinetics of inversion of cane sugar using polarimeter.

SUGGESTED BOOKS

Text Books:

1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015
2. Nad A. K, Mahapatra B. and Ghoshal A., "An Advanced Course In Practical Chemistry'', New Central Book Agency (P) Limited, 2014
3. Maity S.K. and Ghosh N.K, " Physical Chemistry Practicals", New Central Book Agency (P) Limited, 2012
4. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

Reference Books:

5. Practical Physical Chemistry – A.M. James, F.F. Prichard
6. Findlay's Practical Physical Chemistry – B.P. Levitt
7. Experimental Physical Chemistry – Shoemaker and Ga
8. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

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MJ-4: ORGANIC CHEMISTRY-II **Credits 04(Credits: Theory-03, Practicals-01)**

MJ4T: ORGANIC CHEMISTRY-II **Credits 03**

Course content:

Stereochemistry II, General Treatment of Reaction Mechanism II, Substitution and Elimination Reactions and Chemistry of Alkenes and Alkynes **Theory: 45 Lectures**

Stereochemistry II **(8 Lectures)**

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

General Treatment of Reaction Mechanism II **(12 Lectures)**

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.

Substitution and Elimination Reactions **(10 Lectures)**

Free-radical substitution reaction: halogentaion 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 and stereochemical features: SN1, SN2, SN2', SN1' (allylic rearrangement) and SN^i; 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].

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.

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Chemistry of Alkenes and Alkynes **(15 Lectures)**

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

Reference Books

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

MJ4P: ORGANIC CHEMISTRY-III (Lab) **Credits 01 LAB (30 Hrs.)**

Experiment: Qualitative Analysis of Single Solid Organic Compounds

a) Detection of special elements (N, S, Cl, Br) by Lassaigne's test
b) Solubility and classification (solvents: H2O, 5% HCl, 5% NaOH and 5% NaHCO3)
c) Detection of the following functional groups by systematic chemical tests: aromatic amino (-NH2), aromatic nitro (-NO2), amido (-CONH2, including imide), phenolic –OH, carboxylic acid (-COOH), carbonyl (-CHO and >C=O).
d) Melting point of the given compound

[Each student, during laboratory session, is required to carry out qualitative chemical tests for all the special elements and the functional groups of unknown (**at least six)** organic compounds].

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Reference Books

1. Vogel, A. I. *Elementary Practical Organic Chemistry*, Part 1: *Small scale Preparations,* CBS Publishers and Distributors.

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

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

4.Furniss, B.S., Hannaford, A.J., Smith, P.W.G. & Tatchell, A.R. *PracticalOrganic Chemistry, 5th Ed.* Pearson (2012).

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

6. *Practical Workbook Chemistry (Honours), UGBS, Chemistry*, University of Calcutta, 2015.

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MINOR (MI)

Minor 3: (Inorganic Chemistry –II & Organic Chemistry-II) **Credits 04; Full Marks-75**

MI -3T (Theory) **Credits-03**
(45 lectures)

Course Content:

Inorganic Chemistry–II

Chemical Periodicity: **(10 Lectures)**
Classification of elements on the basis of electronic configuration: general characteristics of s-, p-, d- and f-block elements. Positions of hydrogen and noble gases. Atomic and ionic radii, ionization potential, electron affinity, and electronegativity; periodic and group-wise variation of above properties in respect of s- and p- block elements.

Chemical Bonding and Molecular Structure: **(20 Lectures)**
Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability. Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.
***Covalent bonding*:** VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements. Concept of resonance and resonating structures in various inorganic and organic compounds. 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): H_2, B_2, C_2, N_2, O_2, F_2. MO diagram of CO and explanation of its ligating behaviour based on MO approach. Comparison of VB and MO approaches.

Reference Books:

1. Lee, J. D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Cotton, F. A., Wilkinson, G. & Gaus, P.L. *Basic Inorganic Chemistry*, 3rd ed., Wiley.
3. Douglas, B. E., McDaniel, D. H. & Alexander, J. J. *Concepts and Models in Inorganic Chemistry*, John Wiley & Sons.
4. Huheey, J. E., Keiter, E. A., Keiter, R. L. & Medhi, O. K. *Inorganic Chemistry: Principles of Structure and Reactivity*, Pearson Education India.

Organic Chemistry-II

Aromatic Hydrocarbon **(05 Lectures)**
Benzene: Preparation: from phenol, by decarboxylation, from acetylene, from Benzene sulphonic acid. Reactions: electrophilic substitution (general mechanism); nitration (with mechanism), halogenations (chlorination and bromination), sulphonation and Friedel-Craft's reaction (alkylation and acylation) (up to 4 carbons on benzene); side chain oxidation of alkyl benzenes (up to 4 carbons on benzene).

Organometallic Compounds **(05 Lectures)**
Introduction; Grignard reagents: Preparations (from alkyl and aryl halide); concept of umpolung; Reformatsky reaction.

Aryl Halides **(05 Lectures)**
Preparation: (chloro-, bromo- and iodobenzene): from phenol, Sandmeyer reactions. Reactions (Chlorobenzene): nucleophilic aromatic substitution (replacement by –OH group) and effect of nitro substituent (activated nucleophilic substitution).

Reference Book:

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1. Sethi, A. *Conceptual Organic Chemistry;* New Age International Publisher.
2. Parmar, V. S. *A Text Book of Organic Chemistry*, S. Chand & Sons.
3. Madan, R. L. *Organic Chemistry*, S. Chand & Sons.
4. Wade, L. G., Singh, M. S., *Organic Chemistry.*
5. Finar, I. L. *Organic Chemistry* (*Volume 1*), Dorling Kindersley (India) Pvt. Ltd.
6. (Pearson Education).
7. Morrison, R. T. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

MI-3P Practical **Credit-01**

Inorganic Chemistry Laboratory **(10 Hrs.)**

1. Estimation of Fe(II) and Fe(III) in a given mixture.

2. Estimation of Fe(III) and Cu(II) in a mixture.

Organic Chemistry Lab **(20 Hrs.)**

A. Separation, based upon solubility, by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. NaHCO3, etc., of components of a binary solid mixture; purification of any one of the separated components by crystallization.
The composition of the mixture may be of the following types: Benzoic acid/p-Toluidine; p-Nitrobenzoic acid/p-Aminobenzoic acid; p-Nitrotolune/p-Anisidine; etc.
B. Identification of a pure organic compound
Solid compounds: oxalic acid, tartaric acid, succinic acid, resorcinol, urea, glucose, benzoic acid and salicylic acid.
Liquid Compounds: methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and nitrobenzene

Reference Books:

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

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SKILL ENHANCEMENT COURSE (SEC)

SEC 3P: Preparation of Household Chemicals (Practical) **Credits 03 Full Marks: 50**

Part A:

(i) Preparation of liquid disinfectant
(ii) Preparation of Liquid Detergent
(iii) Preparation of Dish wash Liquid Soap
(iv) Preparation of Hand Sanitizer
(v) Preparation of simple organophosphates, phosphonates and thiophosphates

Part B: Field visit and submission of the report

Suggested Readings:

1. Vogel's text book of Qualitative Chemical Analysis (Longman ELBS Edition)
2. Vogel's text book of Quantitative Analysis (Longman ELBS Edition)
3. Practical Organic Chemistry by A.I.Vogel
4. Practical Organic Chemistry by O.P. Agarwal
5. Practical Organic Chemistry by F.G. Mann & B.C. Sounders
6. Comprehensive Practical Organic Chemistry Qualitative Analysis by V.K.Ahluwali
7. Text book of Quantitative inorganic Analysis including elementary instrumental Analysis: A.I.Vogel (Third Ed.)
8. S mall scale industries and house hold industries in developing economy by Shetty M.C.
9. Manufacture of perfume cosmetics and detergents by Prasad Giri Raj
10. Industrial chemistry by B.K.Sharma.

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SEMESTER-IV

MAJOR (MJ)

Major-5: INORGANIC CHEMISTRY-II **Credits 04 (Theory-03, Practical-01)**

MJ5T: INORGANIC CHEMISTRY-II **Credits 03 (Theory: 45 Lectures)**

A. Chemical Bonding-I: **(15 Lectures)**

(i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its application and limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy. Solubility energetics of dissolution process, Defects in solids, line and plane defects, Schottky and Frenkel defects (Elementary idea) non-stoichiometric defect in crystal, Colour centres (F-center) in ionic crystals.

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

B. Chemical Bonding-II: **(12 Lectures)**

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

(ii) Metallic Bond: Qualitative idea of valence bond and band theories, electrical and thermal conductivity of metals, Semiconductors (intrinsic and extrinsic: p-type and n-type) and insulators, Superconductivity (only basic idea).

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

C. Chemistry of s and p Block Elements: **(18 Lectures)**

Group trends in electronic configuration, Common oxidation states, Allotropy and catenation (with example), Oxides of N, P, S and Cl, Oxo/Peroxo acids of P, S and Cl, Basic properties of halogens. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses: Li_2O, Na_2O_2 and KO_2, BeH_2, $BeCl_2$, boric acid, borates, borax, sodium perborate, boron nitrides, borazines, borohydrides (diborane)**,** carbides (covalent and ionic type), diamond, graphite, silanes, silicones, phosphazenes, sulphur-nitrogen binary compounds, interhalogen compounds, polyhalide ions, pseudohalogens, Chlorofluorocarbons (CFCs).

Noble Gases: Separation of Noble gases, Clathrates; Structure and properties of XeF_2, XeF_4, XeF_6, XeO_2F_2 and XeO_3, XeO_4^{2-} and XeO_6^{4-}.

Reference Books

1. Lee, J. D. Concise Inorganic Chemistry, 5th Ed., Wiley India Pvt. Ltd., 2008.

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2. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson, 2006.
3. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
4. Porterfield, H. W., Inorganic Chemistry, Second Edition, Academic Press, 2005.
5. Purecell, K.F. and Kotz, J.C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.
6. Cotton, F.A., Wilkinson, G., &Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India.
7. Gillespie, R. J. and Hargittai, I., The VSEPR Model of Molecular Geometry, Prentice Hall (1992).
8. Albright, T., Orbital interactions in chemistry, John Wiley and Sons (2005).
9. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
10. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, Pearson, 5th Edition.
11. Greenwood, N.N. & Earnshaw A. Chemistry of the Elements, Butterworth-Heinemann, 1997.
12. Cotton, F.A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.
13. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

MJ5P: INORGANIC CHEMISTRY LABORATORY- II (Credit 01) (30 Hrs.)

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

- **Acid Radicals**: Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+},Al^{3+},Cr^{3+}, Mn^{2+}/Mn^{4+}, Fe^{2+}/Fe^{3+}, Co^{2+}/Co^{3+}, Ni^{2+}, Pb^{2+}, Cu^{2+}, Zn^{2+}, Bi^{3+}, NH_4^+, Mg^{2+}.
- **Basic Radicals**: F^-, Cl^-, Br^-, I^-, SCN^- , S^{2-} , SO_3^{2-}, SO_4^{2-} , $S_2O_3^{2-}$, NO_3^- , NO_2^- , PO_4^{3-}, BO_3^{3-}, H_3BO_3.
- **Insoluble Materials**: Al_2O_3, $SrSO_4$, $BaSO_4$, CaF_2.

Suggested Readings:

1. Svehla, G., Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
2. Ghosal, Mahapatra and Nath; An Advanced course in practical Chemistry

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Major-6: PHYSICAL CHEMISTRY-II **Credits 04 (Theory-03, Practicals-01)**

MJ6T: PHYSICAL CHEMISTRY-II Credits 03 **(Theory: 45 Lectures)**

Course contents:

A. STATES OF MATTER: PART-1 (GASEOUS STATE) (LECTURE-15)

(I) Mathematical interlude: Gamma functions, Error and co-error functions, Method of successive approximations, Graphical method of solutions. Concept of probability.

(II) Kinetic Theory of gases: Postulates, Derivation of basic equation of KTG, Concept of pressure and temperature. Derivation of empirical gas laws from the basic equation of KTG.

(III) Maxwell's speed distribution: Maxwell's velocity distribution in 1D, Maxwell's speed distribution in 2D and 3D. Nature of the distributions, graphical representations, calculation of average, RMS, most probable speed and average kinetic energy in each case.

(IV) Maxwell's kinetic energy distribution: Maxwell's kinetic energy distribution in one, two and three dimensions, Nature of the distribution, graphical representations calculations of average kinetic energy in each case. Calculation of probability of finding molecules having energy $\geq$ a threshold value, Importance of the result.

(V) Principle of Equipartition of energy: Statement of the principle, degrees of freedom, Molar heat capacity of gases of different atomicity and structures, Limitations of this principle. .

(VI) Collision of gas molecules; Collision diameter; Collision number and mean free path; Frequency of binary collisions (similar and different molecules); Wall collision. Rate of effusion and Graham's law of effusion.

(VII) Barometric distribution formula.

(VIII) Deviation of gases from ideal behaviour: Liquifaction of gases and Andrew's curve, critical constants. Law of continuity of states, Compressibility factor; Amagat's plots. Kammerling-Onnes or the virial equation of state.

(IX) van der Waals equation and its features; Derivation and application in explaining real gas behaviour, Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; van der Waals equation expressed in virial form and significance of second virial coefficient; Boyle temperature.

(X) Intermolecular interactions among neutral covalent molecules: Dipole-dipole or Keesom interaction, Dipole-induced dipole or Debye interaction, Induced dipole-induced dipole or London interactions. Hard sphere model, Lennard-Jones potential, Buckingham potential.

B. ELECTROCHEMISTRY: PART-1 (CONDUCTANCE) (LECTURE-7)

(I) Transport Phenomena: General law of transport, Examples of various laws of transport

(II) Conductance in a solution: Strong and weak electrolytes, Conductance, Specific Conductance, cell constant, Equivalent and molar conductance and their interrelations.

(III) Variation of specific and equivalent conductance with dilution for strong and weak electrolytes. Ionic mobility, Determination of equivalent conductance at infinite dilution for strong and weak electrolyte. Kohlrausch's law of independent migration of ions. Ionic conductance and transport number. Relation between ionic mobility and ionic conductance. Factors determining ionic and equivalent conductance: concentration, size of the solvated ions, temperature, viscosity of the solvent and the Walden's rule. Abnormally high ionic conductance of H^+ and OH^-.

(IV) Qualitative idea of Debye –Huckel theory of Ion atmosphere -asymmetric or relaxation effect and electrophoretic effect; Kohlrausch equation, Wien effect, Debye-Falkenhagen effect.

(V) Determination by Moving boundary method, Hittorf rule. Abnormal transport number.

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(VI) Application of conductance measurement; Determination of degree of dissociation of weak electrolyte, Determination of ionization constant of weak acid, Determination solubility product of sparingly soluble salts, determination of ionic product of water, determination of rate constant of saponification of ester. Conductometric titrations; principles and various examples.

C. THERMODYNAMICS: PART-2 (SECOND LAW OF THERMODYNAMICS and SYSTEM OF VARIABLE COMPOSITIONS) (LECTURE-12)

(I) Limitations of 1st law of thermodynamics, Spontaneous process and its characteristic features. Need for a Second law.

(II) Engine, its efficiency and the Kelvin Planck statement of 2nd law of thermodynamics. Heat pump and refrigerator, their performance and the Clausius statement of 2nd law of thermodynamics. Equivalence of Kelvin-Planck and Clausius statement of second law of thermodynamics.

(III) Carnot engine: Carnot cycle, Efficiency of Carnot engine taking ideal gas as the working substance, efficiency in terms of P-V diagram. Efficiency of Carnot engine taking VDW gas as the working substance, Carnot's theorem; statements and proofs, Efficiency of Stirling engine. Thermodynamic scale of temperature.

(IV) Introduction to the concept of entropy (S). Properties of entropy. Clausius inequality; Statement of second law of thermodynamics in terms of entropy and the conditions of spontaneity and equilibrium. Limitations of this criteria. Entropy change of systems, surroundings and the universe for various processes and transformations. Carnot's cycle in T-S diagram and expressions of efficiency. Trouton's rule.

(V) Carathedory's statement of 2nd law of thermodynamics (statement only), Two adiabates never intersect, Oneadiabate and one isotherm intersect once, Maxwell's equal area constructions.

(VI) Auxiliary state functions: Legendre transformation. Gibbs free energy (G) and Helmholtz free energy (A) . Their physical significance. Variations of G and A with T, P and V. Thermodynamic criteria for spontaneity and equilibrium in terms of change in G and A. Exergonic and endergonic processes. Coupled reaction.

(VII) Thermodynamic free entropy: Messieu function and Planck's function. Their properties and physical significance.

(VIII) Fundamental equations of thermodynamics, Maxwell's relations; Thermodynamic square, Thermodynamic equations of states, Temperature dependence of free energy functions: Gibbs-Helmholtz equation.

D. QUANTUM MECHANICS: PART-2 (POSTULATES OF QUANTUM MECHANICS AND OPERATOR ALGEBRA) (LECTURE-11)

(I) Postulate-1 of Quantum mechanics: Genesis of Schrodinger equation, Time independent Schrodinger equation and its nature, Wave function, Born's probabilistic interpretation of wave function, acceptability criteria of wave function, Normalized wave functions and normalization procedure, Orthogonal and orthonormal set of wave functions, Degeneracy of wave functions,

(II) Postulate-2 of Quantum Mechanics: Classical observable, concepts of operators, Linear operators, Systematic approach to construct quantum mechanical operator for a classical observable, Various examples.

(III) Postulate-3 of Quantum Mechanics: Eigen value equations, Commutation relations and their physical significance. Important theorems regarding commutations and simultaneous eigen functions. Angular momentum operators and commutation relations associated to them.

(IV) Postulate-4 of Quantum Mechanics: Average values of a classical observable in a quantum state, Representation of quantum mechanics, Bra-ket notations, Hermitian operator; definition

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properties and examples, Theorems of Hermitian operators, Gram-Schmidt orthogonalization techniques, Swartz inequality, Generalized Heisenberg uncertainty principle.

(V) Postulate-5 of Quantum Mechanics: Time dependent Schrodinger equation, Concept of stationary states, Probability current density, Ehrenfest equation of states.

SUGGESTED BOOKS

Text Books:

1. Physical Chemistry, G.W. Castellan, Narosa, New Delhi
2. Physical Chemisty, I. N. Levine, McGraw Hill, NewYork
3. Physical Chemistry, P. C. Rakshit, Sarat Book House, India.
4. Physical Chemistry: A Molecular Approach, D. A. McQuarrie and J. D. Simon, Viva Book Private Limited, New Delhi.
5. Physical Chemistry, R. J. Silbey, R. A. Alberty & M. G. Bawendi, John Wiley & Sons, Inc.
6. Text Book of Physical Chemistry, S. Glasstone, Macmillan India Limited, New Delhi

Reference Books:

1. Heat & Thermodynamics, M. W. Zemansky & R. H. Dittman, The McGraw-Hill Companies Inc., New York.
2. Chemical Thermodynamics: Basic concepts & methods, I. M. Klotz & R. M. Rosenberg, Wiley-Interscience, India.
3. Quantum Mechanics: Concepts and Applications, N. Zettili, A John Wiley and Sons, Ltd., Publication.
4. Introduction to Quantum Mechanics, D. J. Griffiths & D. F. Schroeter, Cambridge University Press.
5. Principles of Physical Chemistry, S. H. Maron & C. F. Prutton, CBS Publishers & Distributors Pvt. Ltd.

MJ6P: PHYSICAL CHEMISTRY LAB- II Credits 01 **(30 Hrs.)**

1. Conductometric titrations
   - (i) Strong acid vs. strong base
   - (ii) Weak monobasic acid vs. Strong base.
   - (iii) Weak dibasic acid vs. Strong base
   - (iv) Mixed acid vs. strong base
   - (v) Silver nitrate vs. potassium chloride
2. Determination of ionization constant and equivalent conductance at infinite dilution of an weak acid.
3. Determination of rate constant of saponification of an ester conductometrically.
4. Determination of solubility product of a sparingly soluble salt.

SUGGESTED BOOKS

Text Books:

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1. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015
2. Nad A. K, Mahapatra B. and Ghoshal A., "An Advanced Course In Practical Chemistry'', New Central Book Agency (P) Limited, 2014
3. Maity S.K. and Ghosh N.K, " Physical Chemistry Practicals", New Central Book Agency (P) Limited, 2012
4. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019

Reference Books:

5. Practical Physical Chemistry – A.M. James, F.F. Prichard
6. Findlay's Practical Physical Chemistry – B.P. Levitt
7. Experimental Physical Chemistry – Shoemaker and Ga
8. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

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MJ-7: ORGANIC CHEMISTRY-III **Credits 04**

MJ7T: ORGANIC CHEMISTRY-III **Credits 03**

Course content:

Stereochemistry III, Aromatic Substitution, Carbonyl and Related Compounds, Organometallics

Theory: 45 Lectures

Stereochemistry III **(10 Lectures)**

Chirality arising out of stereoaxis: stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in allenes, spiro compounds, alkylidenecycloalkanes and biphenyls; related configurational descriptors (*Ra/Sa* and *P/M*); atropisomerism; racemisation of chiral biphenyls; *buttressing* effect.

Concept of prostereoisomerism: prostereogeniccentre; concept of $(pro)^n$-*chirality*: topicity of ligands and faces (elementary idea); *pro-R/pro-S*, *pro-E/pro-Z* and *Re/Si* descriptors; *pro-r* and *pro-s* descriptors of ligands on propseudoasymmetriccentre.

Asymmetric synthesis: stereoselective and stereospecific reactions; diastereoselectivity and enantioselectivity (only definition); enantioselectivity: kinetically controlled MPV reduction; diastereoselectivity: addition of nucleophiles to C=O adjacent to a stereogeniccentre: Felkin- Anh and Zimmermann-Traxler models.

Aromatic Substitution **(5 Lectures)**

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

Nucleophilic aromatic substitution: addition-elimination mechanism and evidences in favour of it; SN1 mechanism; cine substitution (benzyne mechanism), structure of benzyne.

Carbonyl and Related Compounds **(25 Lectures)**

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

Exploitation of acidity of α-H of C=O: formation of enols and enolates; kinetic and thermodynamic enolates; reactions (mechanism with evidence): halogenation of carbonyl compounds under acidic and basic conditions, Hell-Volhard-Zelinsky (H.V.Z.) reaction, nitrosation, SeO2 (Riley) oxidation; condensations (mechanism with evidence): Aldol, Tollens', Knoevenagel, Claisen-Schmidt Claisen ester including Dieckmann, Stobbe; Mannich reaction, Perkin reaction, Favorskii rearrangement; alkylation of active methylene compounds. specific enol equivalents (lithium enolates, enamines, and silyl enol ethers) in connection with alkylation, acylation and aldol type reaction;

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

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Substitution at sp^2 carbon (C=O system): mechanism (with evidence): *B*AC2, *A*AC2, *A*AC1, *A*AL1 (in connection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

Organometallics **(5 Lectures)**

Grignard reagent; Organolithiums; Gilman cuprates: preparation and reactions (mechanism with evidence); addition of Grignard and organolithium to carbonyl compounds; substitution on -COX; directed ortho metalation of arenes using organolithiums, conjugate addition by Gilman cuprates; Corey-House synthesis; abnormal behavior of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky reaction; Blaise reaction; concept of *umpolung* and base-nucleophile dichotomy in case of organometallic reagents.

Suggested Readings:

1. Clayden, J., Greeves, N., Warren, S. *Organic Chemistry*, Second edition, Oxford University Press 2012.
2. Sykes, P. *A guidebook to Mechanism in Organic Chemistry*, Pearson Education, 2003.
3. Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Limited.
4. Carey, F. A., Giuliano, R. M. *Organic Chemistry*, Eighth edition, McGraw Hill Education, 2012.
5. Loudon, G. M. *Organic Chemistry*, Fourth edition, Oxford University Press, 2008.
6. Norman, R.O. C., Coxon, J. M. *Principles of Organic Synthesis*, Third Edition, Nelson Thornes, 2003.
7. Morrison, R. N. & Boyd, R. N. *Organic Chemistry*, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Finar, I. L. *Organic Chemistry (Volume 1)*, Pearson Education.
9. Graham Solomons, T.W., Fryhle, C. B. *Organic Chemistry*, John Wiley & Sons, Inc.
10. March, J. *Advanced Organic Chemistry*, Fourth edition, Wiley.
11. Jenkins, P. R., *Organometallic Reagents in Synthesis*, Oxford Chemistry Primer, Oxford University Press.
12. Ward, R. S., *Bifunctional Compounds*, Oxford Chemistry Primer, Oxford University Press.

MJ7P: ORGANIC CHEMISTRY-III (Lab) **Credits 01**

(30 Lectures)

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 crystallization from water/alcohol, crystallization after charcoal treatment, or sublimation, whichever is applicable.

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

Suggested Readings:

1. Vogel, A. I. *Elementary Practical Organic Chemistry*, Part 2: *Qualitative Organic Analysis*, CBS Publishers and Distributors.
2. *University Hand Book of Undergraduate Chemistry Experiments*, edited by Mukherjee, G. N. University of Calcutta, 2003.
3. Mann, F.G. & Saunders, B.C. *Practical OrganicChemistry*, Pearson Education (2009).
4. Furniss, B.S., Hannaford, A.J., Smith, P.W.G., Tatchell, A.R. *Practical Organic Chemistry*, 5thEd.,Pearson (2012).
5. Clarke, H. T., A *Handbook of Organic Analysis (Qualitative and Quantitative)*, Fourth Edition, CBS Publishers and Distributors (2007).
6. *Practical Workbook Chemistry (Honours), UGBS, Chemistry*, University of Calcutta, 2015.

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MINOR (MI)

MI-4: (Physical Chemistry –III & Inorganic Chemistry-III) Credits 04 (Full Marks: 75)

MI -4T (Theory) **Credits-03**
(45 lectures)

Course Content

Physical Chemistry-III

A. Principles of Thermodynamics (20 Lectures)

(I) Introduction and First Law of Thermodynamics: Introduction, Some basic concepts; System; isolated, closed and open; Surroundings, Universe, Boundaries and its classifications, Properties of a system: Extensive and Intensive; State property and path property, Different types of processes: reversible and irreversible processes, Isothermal and adiabatic processes. Steady state and Equilibrium state. Thermal equilibrium, Zeroth law of Thermodynamics and its applications. Concept of heat and work: p-V type work in various processes, indicator diagrams, Joule's experiments, Concept of internal energy (U), First law of thermodynamics; its various statements. Joule-Thomson experiment; concept of enthalpy (H); J-T coefficient, Inversion temperature, Expressions of J-T coefficient and inversion temperature for VDW gas (without derivation). Cooling and heating due to JT expansion. Heat capacity relations. General relations, relations for ideal gas. Adiabatic changes of states: relations among various state properties of ideal gas for adiabatic reversible process, expressions of work, adiabatic cooling, its difference from the JT cooling.

(II) Thermochemistry: Basic laws of thermochemistry, Standard states; Temperature dependence of enthalpy of a reaction: Kirchhoff's equation. Enthalpy of reactions for various processes; enthalpy of formation, enthalpy of combustion, lattice enthalpy and the Born-Haber cycle, enthalpy of neutralizations, bond dissociation enthalpy and the average bond enthalpy.

(III) 2nd Law of Thermodynamics and Auxiliary State Functions: Limitations of 1st law of thermodynamics, Spontaneous process and its characteristic features. Need for a Second law. Kelvin-Planck statement, Clausius statement of 2nd law of thermodynamics. Carnot engine: Carnot cycle, Efficiency of Carnot engine taking ideal gas as the working substance, efficiency in terms of P-V diagram. Carnot's theorem; statements only. Concept of entropy (S). Properties of entropy. Clausius inequality; Statement of second law of thermodynamics in terms of entropy and the conditions of spontaneity and equilibrium. Entropy change of systems, surroundings and the universe for various processes and transformations.

Gibbs free energy (G) and Helmholtz free energy (A). Their physical significance.. Thermodynamic criteria for spontaneity and equilibrium in terms of change in G and A. Fundamental equations of thermodynamics, Maxwell's relations; Thermodynamic square, Thermodynamic equations of states, Temperature dependence of free energy functions: Gibbs- Helmholtz equation.

B. Chemical and Ionic Equilibrium (10 Lectures)

(I) Chemical Equilibrium: Concept of Chemical Potential, van't Hoff's reaction isotherm, Different kind of true equilibrium constant K_p and K_c. pseudo equilibrium constant K_x. Interrelations among K_p, K_c and K_x. Temperature dependence of equilibrium constant. van't Hoff's equations (isobar and isochore) Shifting of equilibrium due to change in external parameters e.g. concentration, temperature, pressure and addition of inert gas; Le Chatelier's principle and its its applications.

(II) Ionic Equilibrium: Concept of mean ionic activity and mean ionic activity coefficient. Ionic strength, Debye-Huckel limiting law. Solubility, activity solubility product, concentration solubility product of sparingly soluble salt. Their interrelations. Effect of addition of inert electrolyte on the solubility and concentration solubility product. Common ion effect and its applications. pH, calculation

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of pH in various solutions, ionic product of water, Dissociation constants of weak acids and weak bases, Buffer and buffer capacity, Henderson equation, salt hydrolysis and expressions of pH, acid-base neutralisation reactions, Acid-base neutralization curves, Indicator and its choice for neutralization reactions.

Inorganic Chemistry-III

Chemistry of s and p block Elements: (15 Lectures)

Group trends in electronic configuration, common oxidation states, inert pair effect, diagonal relationship, Oxo/Peroxo acids of P, S and Cl. Study of the following compounds with emphasis on: preparation, structure & bonding, properties and uses: Li_2O, Na_2O_2 and KO_2, BeH_2, $BeCl_2$, boric acid, borates, borax, sodium perborate, boron nitrides, borazines, borohydrides (diborane), carbides (covalent and ionic type), diamond, graphite, silanes, silicones, phosphazenes, sulphur-nitrogen binary compounds, interhalogen compounds, polyhalide ions, pseudohalogens, Chlorofluorocarbons (CFCs). Noble Gases: Separation of Noble gases, Clathrates; Structure and properties of XeF_2, XeF_4, XeF_6, xenate and perxenate. Use of noble gases.

Reference Books:

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

Rodgers, G.E. *Inorganic & Solid State Chemistry*, Cengage Learning India Ltd., 2008.

MI-4P Practical **Credit: 01**

(30 Lectures)

Section A: Physical Chemistry Lab

- Determination of solubility and concentration solubility product of a sparingly soluble salt (say KHTa) using acid-base titration.
- Preparation of buffer solutions and find the pH of an unknown buffer solution by colour matching method

Section B: Inorganic Chemistry Laboratory

Identification of three radicals from the given mixtures. Emphasis should be given to the understanding of the chemistry of different reactions:

- **Acid Radicals**: NH_4^+, Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, $Mn^{2+/4+}$, $Fe^{2+/3+}$, $Co^{2+/3+}$, Ni^{2+} and Cu^{2+}.
- **Basic Radicals**: Cl^-, Br^-, I^-, SCN^-, S^{2-}, SO_4^{2-}, NO_3^-, NO_2^-, PO_4^{3-}, BO_3^{3-} and H_3BO_3.

Reference Books:

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

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