VIDYASAGAR UNIVERSITY

Midnapore, West Bengal

PROPOSED CURRICULUM & SYLLABUS (DRAFT) OF

BACHELOR OF SCIENCE WITH CHEMISTRY

(MULTIDISCIPLINARY STUDIES)

3-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 IN LIFE SCIENCES/ PHYSICSL SCIENCES with CHEMISTRY

(*Under CCFUP, 2023*)

Level	YR.	SEM	Course Type	Course Code	Course Title	Credit	L-T-P	Marks		
								CA	ESE	TOTAL
B.Sc. in Life Sc. / Physical Sc. with Chemistry	2nd	III	**SEMESTER-III**							
			Major-A2	CEMPMJ02	**T: General Chemistry-I; P: Practical** *(To be studied by students taken* **Chemistry** *as Discipline- A)*	4	3-0-1	15	60	75
			Major-A3	CEMPMJ03	**T: General Chemistry-II; P: Practical** *(To be studied by students taken* **Chemistry** *as Discipline- A)*	4	3-0-1	15	60	75
			SEC	SEC03	*To be taken from SEC-03 of Discipline C.*	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.-C3)	CEMMIN03	**T: Inorganic Chemistry –II & Organic Chemistry-II; P: Practical** *(To be studied by students taken Chemistry as Discipline- C)*	4	3-0-1	15	60	75
					Semester-III Total	20				375
		IV	**SEMESTER-IV**							
			Major-B2		*To be decided (Same as MajorA2 for Chemistry taken as Discipline-B)*	4	3-0-1	15	60	75
			Major-B3		*To be decided (Same as Major–A3 for* **Chemistry** *taken as Discipline-B)*	4	3-0-1	15	60	75
			Major (Elective) -1	CEMMJE-01	**To be chosen from the given options** *(To be studied by students taken Chemistry as Discipline- A)*	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.-C4)	CEMMIN04	**T: Physical Chemistry –III & Inorganic Chemistry-III; P: Practical** *(To be studied by students taken Chemistry as Discipline- C)*	4	3-0-1	15	60	75
			Summer Intern.	IA	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

MJP = Major Programme (Multidisciplinary), MI = Minor, A/B = Choice of Major Discipline; C= Choice of Minor Discipline; 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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MAJOR (MJ)

MJ A2/B2: General Chemistry-I **Credits 04 (FM: 75)**

MJ A2/B2T: General Chemistry-I **Credits 03 [45L]**

FIRST LAW OF THERMODYNAMICS AND THERMOCHEMISTRY, CHEMICAL KINETICS, CHEMICAL PERIODICITY, CHEMICAL BONDING AND MOLECULAR STRUCTURE, AROMATIC HYDROCARBONS, ALKYL AND ARYL HALIDES

Course contents:

A. THERMODYNAMICS-PART-I: First Law of Thermodynamics and Thermochemistry

(7 LECTURES)

(I) First Law of Thermodynamics, Thermochemistry: Some basic concepts, Zeroth law of Thermodynamics and its applications, First law of thermodynamics and its applications. Work in various processes, Internal Energy, Enthalpy, Heat capacity, Adiabatic changes of states.
Basic laws of thermochemistry, Standard states; Kirchhoff's equation. Enthalpy of reactions for various processes; bond dissociation enthalpy and the average bond enthalpy, adiabatic flame temperature.

B. CHEMICAL KINETICS **(8 LECTURES)**

Introduction, Differential rate law, rate constant and its unit, order and molecularity: Integrated rate laws for simple reactions involving only one reactant, Integrated rate laws involving more than one reactants. Pseudo first order reactions. Determination of order of a reaction: method of differential rate law, method of half-life time. Complex reactions: Opposing reactions, Equilibrium Constant; Consecutive reactions, slowest step is the rate determining step. Parallel reactions Temperature dependence of rate constant; Arrhenius equation, energy of activation. Homogeneous catalysis: with reference to acid-base catalysis.

Chemical Periodicity: **(6 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: **(12 LECTURES)**

Ionic Bonding: General characteristics of ionic bonding. lattice energy, solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation (no derivation need) for calculation of lattice energy, Born-Haber cycle and its applications. Fajan's rules and its applications.
Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics or *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. Comparison of VB and MO approaches.

Functional Organic Chemistry **(12 LECTURES)**

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Aromatic hydrocarbons

Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid.
Reactions: (Case benzene): Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation) (upto 4 carbons on benzene). Side chain oxidation of alkyl benzenes (upto 4 carbons on benzene).

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Alkyl and Aryl Halides

Alkyl Halides (Upto 5 Carbons)

Preparation: from alkenes *and* alcohols.

Reactions: Nucleophilic Substitution (S_N1, S_N2 and S_Ni) reactions, nitrite & nitro formation, nitrile & isonitrile formation. Williamson's ether synthesis.

Aryl Halides

Preparation: (Chloro, bromo and iodo-benzene case): Using Sandmeyer& Gattermann reactions.

Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne formation: KNH_2/NH_3 (or $NaNH_2/NH_3$). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

Suggested Readings:

1. Graham Solomon, T.W., Fryhle, C.B. & Dnyder, S.A. *Organic Chemistry*, John Wiley &Sons (2014).
2. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
3. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, NewDelhi (1988).
4. Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.
5. Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.
6. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.
7. Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
8. P.C. Rakshit, Physical Chemistry
9. S Pahari, Physical Chemistry
10. H. Chatterjee, Physical Chemistry
11. A. Nag, Physical Chemistry
12. Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt.Ltd., New Delhi (2009).
13. Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
14. Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
15. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
16. Cotton, F.A., Wilkinson, G. & Gaus, P.L. *Basic Inorganic Chemistry*, 3rd ed., Wiley.
17. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. *Concepts and Models in InorganicChemistry*, John Wiley & Sons.
18. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. *Inorganic Chemistry: Principles ofStructure and Reactivity*, Pearson Education India, 2006.

MJ A2/B2P: General Chemistry-I (Practical) **Credits 01**

Section A: Physical Chemistry:

1. Study of kinetics of acid-catalyzed hydrolysis of ester
2. Study of kinetics of decomposition of H2O2
3. Study the kinetics of inversion of cane sugar using polarimeter.

Section B: Organic Chemistry

1. Purification of organic compounds by crystallization (from water and alcohol)
2. Criteria of Purity: Determination of melting and boiling points.
3. **Identification of a pure organic compound**

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

Section C: Inorganic Chemistry - Qualitative semi micro analysis of mixtures containing three radicals**.**

1. **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+}.
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.

Suggested Readings:

1. 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.
2. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019
3. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.
4. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand &Co.: New Delhi (2011)

MJ A3/B3: General Chemistry-II **Credits 04 (FM: 75)**

MJ A3/B3T: General Chemistry-II **Credits 03 [45L]**

THERMODYNAMICS-II AND STATES OF MATTER, FUNCTIONAL ORGANIC CHEMISTRY & COORDINATION CHEMISTRY

Course contents:

A. THERMODYNAMICS-II: Second Law of Thermodynamics and Auxilliary State Functions: (8 LECTURES)

Limitations of 1st law of thermodynamics, Statement of 2nd law of thermodynamics. Carnot engine: Carnot cycle, Efficiency of Carnot, Carnot's theorem; statements only. Concept of entropy (S). Properties of entropy. Conditions of spontaneity and equilibrium in terms of entropy. 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.

B. STATES OF MATTER-I: Gaseous State and Liquid State (14 LECTURES)

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

(II) Maxwell's velocity distribution in 3D. Nature of the distribution, graphical representation, calculation of average, RMS, most probable speed and average kinetic energy. Maxwell's kinetic energy distribution in 3D. Nature of the distribution and graphical representation of average kinetic energy. Principle of Equipartition of energy and its limitations, 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. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only).

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(III) 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.

(IV) van der Waals equation and its features; 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.

Brief discussions of viscosity and surface tension of liquids:

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

C. Functional Organic Chemistry: **(12 LECTURES)**

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Alcohols, Phenols and Ethers (Upto 5 Carbons)

Alcohols: *Preparation:* Preparation of 1^{o}, 2^{o} and 3^{o} alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters.
Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alkaline $KMnO_4$, acidic dichromate, conc. HNO_3). Oppeneauer oxidation
Diols*:* (Upto 6 Carbons) Pinacol-Pinacolone rearrangement.

Phenols: (Phenol case)

Preparation: Cumene hydroperoxide method, from diazonium salts.

Reactions: Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer-Tiemann Reaction, Gattermann-Koch Reaction, Houben-Hoesch Condensation, Schotten-Baumann Reaction.

Ethers (aliphatic and aromatic): Cleavage of ethers with HI.

D. Coordination Chemistry: **(11 LECTURES)**

Concept of double salt, complex salt, Werner's theory, Classification of ligands: chelating ligands and chelate complexes, Valence Bond Theory (VBT): Inner and outer orbital complexes of Fe, Co, Ni and Cu (coordination numbers 4 and 6). Stereoisomerism in complexes with coordination numbers 4 and 6. Limitation of VBT. IUPAC system of nomenclature (mononuclear complexes only).

Suggested Readings:

1. Graham Solomon, T.W., Fryhle, C.B. & Dnyder, S.A. *Organic Chemistry*, John Wiley & Sons (2014).
2. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
3. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
4. Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.
5. Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.

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6. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.
7. Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
8. Castellan, G.W. Physical Chemistry
9. P.C. Rakshit, Physical Chemistry
10. S Pahari, Physical Chemistry
11. H. Chatterjee, Physical Chemistry
12. A. Nag, Physical Chemistry
13. Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
14. Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
15. Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
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.
19. Rodgers, G.E. *Inorganic & Solid State Chemistry*, Cengage Learning India Ltd., 2008.
20. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.

MJ A3/B3P: General Chemistry-II (Practical) **Credits 01**

Course Outline:

Section A: Physical Chemistry

1. Determination of relative viscosity coefficient of an unknown solution using Ostwald viscometer
2. Determination of relative surface tension of an unknown solution using Stalagmometer.

Section B: Organic Chemistry

A. Identification of a pure organic compound

Liquid Compounds: methyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform and nitrobenzene.

B. Inorganic Chemistry: Complexometric titration:

1. Estimation of Zn(II)
2. Estimation of Ca(II)
3. Estimation of Mg(II)
4. Determination of hardness of water.

Suggested Readings:

1. 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.
2. Ghosh S. , Das Sharma M , Majumder D and Manna S, "Chemistry in Laboratory", Santra Publication Pvt Ltd, 2019
3. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.
4. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

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Major Elective (MJE)-01: Quantum Mechanics-II, Photochemistry, Chemistry of s & p Block Elements, Polynuclear Hydrocarbons and Application of Spectroscopy to Simple Organic Molecules. **Credits 04 (FM: 75)**

Major Elective (MJE)-01T: **Credits 03 [45L]**

Course contents:

A. QUANTUM MECHANICS-II: Postulates of Quantum Mechanics: (12 LECTURES)

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, 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. Postulate-3 of Quantum Mechanics: Eigen value equations, Commutation relations and their physical significance. Important theorems regarding commutations and simultaneous eigen functions. Postulate-4 of Quantum Mechanics: Average values of a classical observable in a quantum state, Representation of quantum mechanics, Hermitian operator; definition properties and examples, Theorems of Hermitian operators, Postulate-5 of Quantum Mechanics: Time dependent Schrodinger equation, Concept of stationary states, Ehrenfest equation of states.

B. PHOTOCHEMISTRY: (8 LECTURES)

Basic laws of photochemistry, Quantum yield, Lambert-Beer's law: Lambert-Beer's law and its limitations, Absorbance, transmittance and molar extinction coefficient, calibration curve. Photophysical Processes: Fluorescence, phosphorescence, internal conversion and intersystem crossing, Jablonskii diagram, photostationary state or photochemical equilibrium, photosensitized reaction.

C. Chemistry of *s* and *p* block elements: (Lecture 10)

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, boric acid, borax, sodium perborate, boron nitrides, borazines, borohydrides (diborane), carbides (covalent and ionic type), diamond, graphite, silicones, phosphazenes, sulphur-nitrogen binary compounds, interhalogen compounds, polyhalide ions, pseudohalogens, Chlorofluorocarbons (CFCs). Separation of Noble gases, Clathrates; Structure and properties of XeF_2, XeF_4, XeF_6.

D. Polynuclear Hydrocarbons and Application of Spectroscopy to Simple Organic Molecules: (15 LECTURES)

Polynuclear Hydrocarbons: Properties of the following compounds with reference to electrophilic and nucleophilic substitution: Naphthalene, Anthracene.

Application of Spectroscopy to Simple Organic Molecules:

Application of visible, ultraviolet and Infrared spectroscopy in organic molecules. Electromagnetic radiations, electronic transitions, λ_{max} & ε_{max}, chromophore, auxochrome, bathochromic and hypsochromic

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shifts. Application of electronic spectroscopy and Woodward rules for calculating l max of conjugated dienes and α,β-unsaturated Compounds.

Infrared radiation and types of molecular vibrations, functional group and fingerprint region. IR spectra of alkanes, alkenes and simple alcohols (inter and intramolecular hydrogen bonding), aldehydes, ketones, carboxylic acids and their derivatives (effect of substitution on >C=O stretching absorptions).

Suggested Readings:

1. James E. Huheey, Ellen Keiter & Richard Keiter: Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Publication.
2. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.
3. G.L. Miessler & Donald A. Tarr: Inorganic Chemistry, Pearson Publication.
4. J.D. Lee: A New Concise Inorganic Chemistry, E.L.B.S.
5. F.A. Cotton & G. Wilkinson: Basic Inorganic Chemistry, John Wiley & Sons.
6. I.L. Finar: Organic Chemistry (Vol. I & II), E.L.B.S.
7. John R. Dyer: Applications of Absorption Spectroscopy of Organic Compounds,
8. Prentice Hall.
9. R.M. Silverstein, G.C. Bassler & T.C. Morrill: Spectroscopic Identification of
10. Organic Compounds, John Wiley & Sons.
11. R.T. Morrison & R.N. Boyd: Organic Chemistry, Prentice Hall.
12. Peter Sykes: A Guide Book to Mechanism in Organic Chemistry, Orient Longman.
13. Arun Bahl and B. S. Bahl: Advanced Organic Chemistry, S. Chand.
14. Banwell, C. N. & McCash, E. M. Fundamentals of Molecular Spectroscopy 4th Ed. Tata McGraw-Hill: New Delhi (2006).
15. Chandra, A. K. Introductory Quantum Chemistry Tata McGraw-Hill (2001).
16. House, J. E. Fundamentals of Quantum Chemistry 2nd Ed. Elsevier: USA (2004).
17. Castellan, G.W. Physical Chemistry
18. P.C. Rakshit, Physical Chemistry
19. S Pahari, Physical Chemistry
20. H. Chatterjee, Physical Chemistry
21. A. Nag, Physical Chemistry
22. Lowe, J. P. & Peterson, K. Quantum Chemistry, Academic Press (2005).
23. Kakkar, R. Atomic & Molecular Spectroscopy: Concepts & Applications, Cambridge University Press (2015).

Major Elective (MJE)-01P: Practical — Credits 01

Course Outline:

Section A: Inorganic Chemistry

1. Verification of Beers law and determination of molar extinction coefficient and concentration of a color absorbing species ($K_2Cr_2O_7$ and $KMnO_4$ solutions) using a colorimeter or spectrophotometer.
2. Determination of pK_{In} of Bromocresol green indicator and the determination of pH of an unknown buffer spectrophotometrically
3. Study of of $K_2S_2O_8$ – KI kinetics and determination of rate constant spectrophotometrically.

Section B: Inorganic Chemistry

1. Estimation of Ni(II) using dimethylglyoxime (DMG)
2. Paper chromatographic separation of (a) Ni(II) and Co(II) (b) Fe(III) and Al(III) (b) Identify and separate the sugars present in the given mixture by paper chromatography.

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Suggested Readings:

1. A.I. Vogel: Qualitative Inorganic Analysis, Prentice Hall, 7th Edn.
2. A.I. Vogel: Quantitative Chemical Analysis, Prentice Hall, 6th Edn.
3. 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.
4. Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.
5. Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
6. Khosla, B. D.; Garg, V. C. & Gulati, A., Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).
7. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. Experiments in Physical Chemistry 8th Ed.; McGraw-Hill: New York (2003).
8. Halpern, A. M. & McBane, G. C. Experimental Physical Chemistry 3rd Ed.; W.H. Freeman & Co.: New York (2003).

OR

Major Elective (MJE)-01 Green Chemistry. **Credits 04 (FM: 75)**

Major Elective (MJE)-01T: Green Chemistry **Credits 03 [45L]**

Course Contents:

Introduction to Green Chemistry

What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry

Principles of Green Chemistry and Designing a Chemical synthesis

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following:

a. Designing a Green Synthesis using these principles; Prevention of Waste/ byproducts; maximum incorporation of the materials used in the process into the final products, Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.
b. Prevention/ minimization of hazardous/ toxic products reducing toxicity. Risk = (function) hazard × exposure; waste or pollution prevention hierarchy.
c. Green solvents – supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solvent less processes, immobilized solvents and how to compare greenness of solvents.
d. Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy.
e. Selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups.
f. Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis.
g. Prevention of chemical accidents designing greener processes, inherent safer design, principle of ISD "What you don't have cannot harm you", greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation.

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h. Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

Green Synthesis/ Reactions and some real world cases:

1. Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis)
2. Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave assisted reactions in organic solvents Diels-Alder reaction and Decarboxylation reaction
3. Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to iodine)
4 Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments.
5 Designing of Environmentally safe marine antifoulant.
6 Rightfit pigment: synthetic azopigments to replace toxic organic and inorganic pigments.
7 n efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.
8 Healthier fats and oil by Green Chemistry: Enzymatic interesterification for production of no Trans-Fats and Oils
9 Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting

Suggested Readings:

1. Ahluwalia, V.K. & Kidwai, M.R. *New Trends in Green Chemistry*, Anamalaya Publishers (2005).
2. Anastas, P.T. & Warner, J.K.: *Green Chemistry - Theory and Practical*, Oxford University Press (1998).
3. Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker (2001).
4. Cann, M.C. & Connely, M.E. *Real-World cases in Green Chemistry*, American Chemical Society, Washington (2000).
5. Ryan, M.A. & Tinnesand, M. *Introduction to Green Chemistry*, American Chemical Society, Washington (2002).
6. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition, 2010.

Major Elective (MJE)-01T: Green Chemistry Lab Credits 01

1. Using renewable resources

- Preparation of biodiesel from vegetable/ waste cooking oil.

2. Avoiding waste

- Principle of atom economy.
- Use of molecular model kit to stimulate the reaction to investigate how the atom economycan illustrate Green Chemistry.
- Preparation of propene by two methods can be studied
  (I) Triethylamine ion + OH^- → propene + trimethylpropene + water
  (II) 1-propanol $\xrightarrow{H_2SO_4/\Delta}$ propane + water
- Other types of reactions, like addition, elimination, substitution and rearrangement shouldalso be studied for the calculation of atom economy.

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3. Use of enzymes as catalysts

Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide.

Suggested Readings:

1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice*, Oxford University Press (1998).
2. Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate chemistry experiment*. American Chemical Society, Washington DC (2002).
3. Ryan, M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).
4. Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. I.K. *Green Chemistry Experiment: A monograph International Publishing House Pvt Ltd. New Delhi*. Bangalore CISBN 978-93-81141-55-7 (2013).
5. Cann, M.C. & Connelly, M. E. *Real world cases in Green Chemistry*, American Chemical Society (2008).
6. Cann, M. C. & Thomas, P. *Real world cases in Green Chemistry*, American Chemical Society (2008).
7. Lancaster, M. *Green Chemistry: An Introductory Text* RSC Publishing, 2nd Edition,2010.
8. Pavia, D.L., Lampman, G.M., Kriz, G.S. & Engel, R.G. *Introduction to Organic Laboratory Techniques: A Microscale and Macro Scale Approach*, W.B.Saunders,1995.

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MINOR (MI)

MI-3/C3: Same as Minor-3 (CEMMIN03) of Chemistry (Hons) programme — **Credits 04**, **Full Marks: 75**

MI-4/C4: Same as Minor-4 (CEMMIN04) of Chemistry (Hons) programme — **Credits 04**, **Full Marks: 75**

SKILL ENHANCEMENT COURSE (SEC)

(To be studied by students taken Chemistry as Discipline- C)

SEC-03 P: Same as SEC-03 (CEMSEC03) of Chemistry (Hons) programme — **Credits 03**, **Full Marks: 50**

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