Ramakrishna Mission
Vivekananda Centenary College, Rahara

DEPARTMENT OF CHEMISTRY

SYLLEBUS FOR
B.Sc. HONOURS WITH CHEMISTRY

CHOICE BASED CREDIT SYSTEM
(CBCS)

2020

Head of the Department
(with Post-Graduate Section)
Ramakrishna Mission
Vivekananda Centenary College
Rahara, Kolkata – 700 118

PROGRAMME OUTCOMES (POs)

PO Numbers	PROGRAMME OUTCOMES	COGNITIVE LEVEL
PO 1:	Recognize the scientific tempers and attitudes, which in turn can prove to be beneficial for the society since the scientific developments can make a nation or society to grow at a rapid pace.	R
PO 2:	Understand scientific knowledge and exchange ideas with other stakeholders; make people aware about sustainable utilization of resources with ethical approach.	U
PO 3:	Understand and apply the issues of environmental contexts and sustainable development as a basic interdisciplinary concern.	U, Ap
PO 4:	Create the ability to perform experiments and to analyse & interpret the obtained accurate results and thus gain the ability to solve problems, to involve in critical, independent, and creative thinking.	C
PO 5:	Possess expertise to apply and formulate ideas which will provide them competitive advantage in pursuing higher studies from India or abroad; and seek jobs in academia, research or industries.	Ap, C
PO 6:	Assemble the acquired in-depth knowledge of applied subjects towards the inculcation of professional and employment skills so that students can make a career and become an entrepreneur in diverse fields.	C

PROGRAMME SPECIFIC OUTCOMES (PSOs)

PO Numbers	PROGRAMME SPECIFIC OUTCOMES	COGNITIVE LEVEL
PSO 1:	Remember and understand the fundamental concepts of organic, inorganic, physical and analytical chemistry.	R, U
PSO 2:	Analyse and apply the principles of analysis **and** hands on training of different advanced and commonly used analytical equipment for qualitative, quantitative and synthetic laboratory exercises	An, Ap
PSO 3:	Apply the principles of chemistry in the fields of industry, agriculture, medicine and environment	Ap
PSO 4:	Be able to apply the knowledge of the scientific concepts learnt to develop novel research ideas in chemistry	C
PSO 5:	Be able to combine the theoretical and practical knowledge for entrepreneurship, research and development and societal benefits	C

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COURSE STRUCTURE

(BSC HONOURS WITH CHEMISTRY)

COURSE TYPE	TOTAL PAPERS	CREDIT		TOTAL CREDIT
		THEORY	PRACTICAL	
CC	14	14 × 4 = 56	14 × 2 = 28	56 + 28 = 84
DSE#	4	4 × 4 = 16	4 × 2 = 08	16 + 8 = 24
GE	4	4 × 4 = 16	4 × 2 = 08	16 + 8 = 24
SEC*	2	2 × 2 = 04		04
AECC	2	2 × 2 = 04		04
TOTAL CREDIT FOR BSC HONOURS WITH CHEMISTRY				**140**

#Optional Dissertation or project work in place of one DSE paper (6 credits) in 6th Semester

**Optional MOOCs courses in place of one SEC paper (2 credits)*

Abbreviations used:

CC: CORE COURSES

DSE: DISCIPLINE SPECIFIC ELECTIVES

GE: GENERIC ELECTIVES

SEC: SKILL ENHANCEMENT COURSES

AECC: ABILITY ENHANCEMENT COMPULSORY COURSES

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SEMESTERWISE DISTRIBUTION OF COURSES

SEMESTER	COURSE	COURSE NAME	CREDITS
SEMESTER-1	UGCHEMAECC01	English Communications/ Environmental Science	2
	UGCHEMCC01	Organic Chemistry-I + Organic Chemistry-I Lab	4+2
	UGCHEMCC02	Physical Chemistry-I + Physical Chemistry-I Lab	4+2
	GE-1	Generic Elective Theory + Practical	4+2
SEMESTER-2	UGCHEMAECC02	English Communications/ Environmental Science	2
	UGCHEMCC03	Inorganic Chemistry-I + Inorganic Chemistry-I Lab	4+2
	UGCHEMCC04	Organic Chemistry-II + Organic Chemistry-II Lab	4+2
	GE-2	Generic Elective Theory + Practical	4+2
SEMESTER-3	UGCHEMCC05	Physical Chemistry-II + Physical Chemistry-II Lab	4+2
	UGCHEMCC06	Inorganic Chemistry-II + Inorganic Chemistry-II Lab	4+2
	UGCHEMCC07	Organic Chemistry-III + Organic Chemistry-III Lab	4+2
	SEC-1	Skill Enhancement Course-1	2
	GE-3	Generic Elective Theory + Practical	4+2
SEMESTER-4	UGCHEMCC08	Physical Chemistry-III + Physical Chemistry-III Lab	4+2
	UGCHEMCC09	Inorganic Chemistry-III + Inorganic Chemistry-III Lab	4+2
	UGCHEMCC10	Organic Chemistry-IV + Organic Chemistry-IV Lab	4+2
	SEC-2	Skill Enhancement Course-2	2
	GE-4	Generic Elective Theory + Practical	4+2
SEMESTER-5	UGCHEMCC11	Inorganic Chemistry-IV+ Inorganic Chemistry-IV Lab	4+2
	UGCHEMCC12	Organic Chemistry-V + Organic Chemistry-V Lab	4+2
	UGCHEMDSE01	DSE-1 Theory + Practical	4+2
	DSE-2	DSE-2 Theory + Practical	4+2
SEMESTER-6	UGCHEMCC13	Inorganic Chemistry-V + Inorganic Chemistry-V Lab	4+2
	UGCHEMCC14	Physical Chemistry-IV + Physical Chemistry-IV Lab	4+2
	DSE-3	DSE-3 Theory + Practical	4+2
	DSE-4	Theory + Practical	4+2
TOTAL CREDITS			140

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SEMESTER – 1		
Course name	CHEMISTRY -CC01: ORGANIC CHEMISTRY-01	
Course code	UGCHEMCC01	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding different types of interactions present in molecules
2. Understanding and applying VB and MO theories
3. Understanding and analysing Reactivity of different organic molecules
4. Evaluating actual shape of a molecule
5. Remembering and applying different terminologies and their application in the higher field of chemistry
6. Understanding and applying asymmetric synthesis

THEORETICAL (60 LECTURES)

CC01: ORGANIC CHEMISTRY-01

UNIT-1: Bonding and Physical Properties **(30 Lectures)**

Valence Bond Theory: concept of hybridisation, shapes of molecules, resonance (including hyperconjugation); calculation of formal charges and double bond equivalent (DBE) index of hydrogen deficiency (IHD); schematic presentation of orbital pictures of bonding (sp^3, sp^2, sp: C-C, C-N & C-O systems and *s-cis* and *s-trans* geometry for suitable cases)

Electronic displacements: Illustration of the different phenomena with suitable examples: inductive effect, field effect, mesomeric effect, resonance, resonance energy; bond polarization and bond polarizability; time-variable effect inductomeric and electromeric effect; steric effect, steric inhibition of resonance.

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 with probable explanations.

MO theory: qualitative idea about molecular orbitals, pictorial presentation of bonding and antibonding interactions, idea about σ, σ^*, π, π^*, n – MOs; basic idea about Frontier MOs (FMO); concept of HOMO, LUMO and SOMO; interpretation of chemical reactivity in terms of FMO interactions; sketch and energy levels of π MOs of i) acyclic p orbital system (C=C, conjugated diene, triene, allyl and pentadienyl systems) ii) cyclic p orbital system (neutral systems: [4], [6]-

annulenes; charged systems: 3-,4-,5-membered ring systems); Hückel's rules for aromaticity up to [10]-annulene (including mononuclear heterocyclic compounds up to 6-membered ring); concept of antiaromaticity, quasiaromaticity and homoaromaticity – illustrations with examples; non-aromatic molecules; Frost diagram.
Reaction thermodynamics: interpretation from free energy and equilibrium data, analysis of enthalpy and entropy factor, calculation of enthalpy change via BDE, intermolecular & intramolecular reactions.

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

Physical properties: influence of hybridization on bond properties: bond dissociation energy (BDE) and bond energy; bond distances, bond angles; concept of bond angle strain (Baeyer's strain theory); melting point/boiling point and solubility of common organic compounds in terms of covalent & non-covalent intermolecular forces; polarity of molecules and dipole moments; relative stabilities of isomeric hydrocarbons in terms of heat of hydrogenation, heat of combustion and heat of formation.
Concept of organic acids and bases: effect of structure, substituent and solvent on acidity and basicity; proton sponge; hydride sponge; kinetic and thermodynamic acidity, gas-phase acidity and basicity – explanation and comparison; comparison between nucleophlicity and basicity; HSAB principle; application of thermodynamic principles in acid-base equilibria.

UNIT-2: Chemistry of alkenes and alkynes **(15 Lectures)**

Addition to C=C: reactivity, regioselectivity and stereoselectivity of Markownikoff and anti-Markownikoff additions with mechanism and evidences; details mechanism and regioselectivity and stereospecificity of hydrogenation, halogenations, iodolactonisation, hydrohalogenation, hydration, oxymercuration-demercuration, hydroboration-oxidation, epoxidation, *syn* and *anti*-hydroxylation, ozonolysis, addition of singlet and triplet carbenes reactions electrophile and nucleophile carbene, 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 with mechanisms: hydrogenation with Lindlar catalyst and Na/liquid NH_3, 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.

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UNIT-3: Stereochemistry I **(15 Lectures)**

Bonding geometries of carbon compounds and representation of molecules: tetrahedral nature of carbon and concept of asymmetry; Fischer, sawhorse, flying-wedge and Newman projection formulae and their inter translations.

Concept of chirality and symmetry: symmetry elements and point groups (C_{nv}, C_{nh}, C_{nv}, C_n, D_{nh}, D_{nh}, D_{nd}, D_n, S_n (C_s, C_i); molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of epimers; concept of stereogenicity, chirotopicity(topic attribute and topic relationship) and pseudoasymmetry; chiral centres and number of stereoisomerism: systems involving 1/2/3-chiral centre(s) (AA, AB, ABA and ABC types).

Relative and absolute configuration: D/L and *R/S* descriptors; *erythro/threo* and *meso* nomenclature of compounds; *syn/anti* nomenclatures for aldols; *E/Z* descriptors for C=C, conjugated diene, triene, C=N and N=N systems; combination of *R/S*- and *E/ Z*- isomerisms.

PRACTICAL (60 LECTURES)

CC01 LAB: ORGANIC CHEMISTRY-01 LAB

1. Checking the calibration of the thermometer
2. Purification of organic compounds by crystallization using the following solvents:
   a. Water
   b. Alcohol
   c. Alcohol-Water

3. Determination of the melting points of above compounds and unknown organic compounds (Kjeldahl method and electrically heated melting point apparatus)

(a) Effect of impurities on the melting point – mixed melting point of two unknown organic compounds

(b) Determination of boiling point of liquid compounds. (Boiling point lower than and more than 100 °C by distillation and capillary method)

4. Detection of special elements in an organic compound.

New addition: 4%	Modifications: 10%	Total change = 14%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs Addressed	PSOs addressed	Cognitive Level
CO 1	Analyse different types of chemical forces and interactions to predict the structure-activity relationships of different organic molecules	PO 2	PSO 4	An
CO 2	Apply the knowledge of VBT and MOT to discuss structure of molecules	PO 2	PSO 4	Ap, C
CO 3	Apply the knowledge addition reactions in alkenes and alkynes in organic synthesis	PO 2	PSO 3	Ap
CO 4	Analyse and apply the concept of crystallisation and purification of organic compounds	PO 1	PSO 2	An, Ap
CO 5	Evaluate boiling and melting points of unknown organic compounds	PO 2	PSO 2	E
CO 6	Apply the concept of asymmetric synthesis to design novel organic molecules	PO 4	PSO 5	Ap, C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 18 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

REFERENCE BOOKS FOR CC01

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

2. Keeler, J., Wothers, P. Chemical Structure and Reactivity – An Integrated approach, Oxford University Press.

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

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

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

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), Dorling Kindersley (India) Pvt. Ltd.

(Pearson Education)

10. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.

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.

REFERENCE BOOKS FOR CC01 LAB

1. Bhattacharyya, R. C, A Manual of Practical Chemistry.

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

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. Practical Organic Chemistry,5th Ed., Pearson (2012).

5. Dutta, S, B. Sc. Honours Practical Chemistry, Bharati Book Stall.

SEMESTER – 1		
Course name	CHEMISTRY -CC02: PHYSICAL CHEMISTRY-01	
Course code	UGCHEMCC02	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Kinetic model of an ideal gas
2. Theoretical basis of Equipartition principle and its limitation
3. Understanding thermodynamic principles for a system performing mechanical work and applying the laws of thermodynamics
4. Analysing how fast a chemical reaction can occur under certain physical conditions
5. Understanding and analysing role of catalysts and biocatalyst (e.g., enzymes, etc.) in a catalyzed reaction
6. Evaluating numerical problems and experimentally determine the order, rate and activation energy of a chemical reaction

THEORETICAL (60 LECTURES)

CC02: PHYSICAL CHEMISTRY-01

Unit-1: Kinetic Theory and Gaseous state (20 Lectures)

Kinetic Theory of gases: Concept of pressure and temperature; Collision of gas molecules; Collision diameter; Collision number and mean free path – mathematical formulations and explanations; Frequency of binary collisions (similar and different molecules); Wall collision and rate of effusion

Maxwell's distribution of speed and energy: Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; Calculation of number of molecules having energy ≥ ε, Principle of equipartition of energy, its derivation using kinetic energy distribution formula, and its application to calculate the classical limit of molar heat capacity of gases

Real gas and virial equation: Deviation of gases from ideal behaviour; compressibility factor; Boyle temperature; Andrew's and Amagat's plots and their interpretation; van der Waals equation and its features; its derivation and application in explaining real gas behaviour, other equations of state (Berthelot, Dietrici); Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; virial equation of state; van der Waals equation expressed in virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard-Jones potential - elementary idea)

Unit-2: Chemical Thermodynamics (25 Lectures)

Zeroth and 1st law of Thermodynamics: 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 (ideal and van der Waals) under isothermal and adiabatic conditions; Joule's experiment and its consequence

Thermochemistry: 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

Second Law: Need for a Second law; statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical concept of Entropy; Carnot engine and refrigerator; Kelvin – Planck and Clausius statements and equivalence of the two statements with entropic formulation; Carnot's theorem; Values of §dQ/T and Clausius inequality; Entropy change of systems and surroundings for various processes and transformations; Entropy and unavailable work; Auxiliary state functions (G and A) and their variation with T, P and V. Criteria for spontaneity and equilibrium.

Thermodynamic relations: Maxwell's relations; Gibbs- Helmholtz equation, Joule-Thomson experiment and its consequences; inversion temperature; Derivation of Joule-Thomson coefficient for a van der Waals gas; General heat capacity relations

Unit 3: Chemical kinetics **(15 Lectures)**

Rate law, order and molecularity: Introduction of rate law, Extent of reaction; rate constants, order; Forms of rates of zero-, first, second and n^{th} order reactions; Pseudo first order reactions (example using acid catalyzed hydrolysis of methyl acetate); Determination of order of a reaction by method of integration, half-life and differential method, isolation method; Illustration of opposing reactions, consecutive reactions and parallel reactions with explanation of kinetic and thermodynamic control of products (all steps first order); steady state approximation for multistep chemical reactions.

Role of T 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 uni-molecular 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, pH dependence and temperature dependence of enzyme activity, Autocatalysis; periodic reactions.

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PRACTICAL (60 LECTURES)

CC02 LAB: PHYSICAL CHEMISTRY-01 LAB

Experiment 1: Determination of pH of unknown solution (buffer), by color matching method

Experiment 2: Determination of heat of neutralization of a strong acid by a strong base

Experiment 3: Study of kinetics of acid-catalyzed hydrolysis of methyl acetate

Experiment 4: Study of kinetics of decomposition of H_2O_2

Experiment 5: Determination of heat of solution of oxalic acid from solubility measurement

New addition: 3%	Modifications: 3%	Total change = 6%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs Addressed	PSOs addressed	Cognitive Level
CO 1	Explain the theories of kinetic model of an ideal gas	PO 2	PSO 1	U
CO 2	Analyse and explain theoretical basis of Equipartition principle and its limitation	PO 2	PSO 3	An, E
CO 3	Apply the concepts of thermodynamics in different chemical reactions	PO 2	PSO 3	Ap
CO 4	Analyse how fast a chemical reaction can occur under certain physical conditions and what are the specific roles of different parameters affecting the speed or rate of any chemical reaction.	PO 2	PSO 4	R, An
CO 5	Analyse role of catalysts and biocatalyst (e.g., enzymes, etc.) in a catalyzed reaction and design new catalysts	PO 2	PSO 3	An, C
CO 6	Analyse and apply the theoretical knowledge to do the different thermodynamic and kinetic based experiments	PO 1	PSO 4	An, Ap

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

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Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 18 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC02

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press
2. Castellan, G. W. Physical Chemistry, Narosa
3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press
4. Engel, T. & Reid, P. Physical Chemistry, Pearson
5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill
6. Maron, S. & Prutton Physical Chemistry
7. Ball, D. W. Physical Chemistry, Thomson Press
8. Mortimer, R. G. Physical Chemistry, Elsevier
9. Laidler, K. J. Chemical Kinetics, Pearson
10. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry
11. Rakshit, P.C., Physical Chemistry Sarat Book House
12. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill
13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas

Clauze & Rosenberg, Chemical Thermodynamics

Reference Books for CC02 LAB

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
3. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
4. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
5. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta
6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

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SEMESTER – 2		
Course name	CHEMISTRY -CC03: INORGANIC CHEMISTRY-01	
Course code	UGCHEMCC03	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding the structure of atom
2. Periodic table and understand the periodic variation of different atomic and ionic properties
3. Understanding the acid-base behaviour of different organic and inorganic compounds
4. pH of acids and bases, buffer solution and their applications in respective areas
5. Understanding the redox behaviour of different substances
6. Applications of redox chemistry in different promising areas, like, solar cell, fuel cell, supercapacitors, batteries etc.

THEORETICAL (60 LECTURES)

CC03: INORGANIC CHEMISTRY-01

Unit-1: Extra nuclear Structure of atom **(18 Lectures)**

Bohr's theory, its limitations and atomic spectrum of hydrogen atom; Sommerfeld's Theory. Wave mechanics: de Broglie equation – mathematical expression with physical interpretation, Heisenberg's Uncertainty Principle and its significance, Schrödinger's wave equation, significance of ψ and ψ^2. Quantum numbers and their significance. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals. Qualitative and quantitative explanation of shapes of *s*, *p*, *d* and *f* orbitals. Pauli's Exclusion Principle, Hund's rules and multiplicity, Exchange energy and its significance in predicting stability of metal ions, Aufbau principle and its limitations, Ground state Term symbols of atoms and ions for atomic number upto 30. Understanding the electronic configurations of atoms and ions.

Unit-2: Chemical Periodicity **(8 Lectures)**

Historical development of Periodic table, Modern IUPAC Periodic table, Effective nuclear charge, screening effects and penetration, Slater's rules: calculation of effective nuclear charge, atomic radii, ionic radii (Pauling's univalent), covalent radii, lanthanide contraction. Ionization potential, electron affinity and electronegativity (Pauling's, Mulliken's and Allred-Rochow's scales) and factors influencing these properties, group electronegativities. Group trends and periodic trends in these properties in respect of s-, p-, d- and f- block elements. Secondary periodicity, Relativistic Effect, Mathematical idea of relativistic effect (qualitative idea); Explanation of group trends like inert pair effect, existence of Hg_2^{2+}, Au(I)-Au(I) bonds in the light of relativistic effect. Periodic properties of different elements and group trends.

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Unit-3: Acid-Base reactions **(16 Lectures)**

Acid-Base concept: Arrhenius concept, theory of solvent system (in H_2O, NH_3, SO_2 and HF), Bronsted-Lowry's concept, Levelling and differentiating effect, concept of pH, calculation of pH and derivations of related mathematical expressions for strong acid and strong base, weak acid and weak base systems. pH calculation for weak di-basic acids. Buffer solutions-idea, calculation of pH in buffer solution – same system and different system buffer, buffer capacity, calculation of zwitterionic pH for different amino acids, acid-base neutralisation and related graphical presentation for strong acid-strong base, weak acid-strong base, strong acid-weak base and weak acid-weak base systems. Titration of amino acid; Choice of acid-base indicators, theory of selection of indicators. Hammett equation and super acid systems, Lewis theory of acid-base, examples and illustrations of Lewis theory, Lux-Flood concepts of acid-base, examples and illustrations of Lux-Flood theory, relative strength of hydracids, oxyacids - Pauling's empirical rules, Ricci modification. Thermodynamic acidity parameters, Drago-Wayland equation. Gas phase acidity and proton affinity; Acidity and basicity of metal ions and anions in aqueous solution – relation of pK_a and (Z^2/r), Application of the different theory in predicting acid-base strength of different organic and inorganic acids, proton sponge and hydride sponge, solid acid catalyst, HSAB principle; theoretical explanation of HSAB theory and applications of SHAB theory.

Unit-4: Redox Reactions and precipitation reactions **(18 Lectures)**

Ion-electron method of balancing equation of redox reaction. Elementary idea on standard redox potentials with sign conventions, Nernst equation (without derivation). Influence of complex formation, precipitation and change of pH on redox potentials; formal potential. Feasibility of a redox titration, redox potential at the equivalence point, redox indicators. Redox potential diagram (Latimer and Frost diagrams) of common elements and their applications. Disproportionation and comproportionation reactions (typical examples)

Solubility product principle, common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides-applications in group analysis in semimicro qualitative analysis.

PRACTICAL (60 LECTURES)
CC03 LAB: INORGANIC CHEMISTRY 01 LAB

1. Acid and Base Titrations:

a) Estimation of alkali with acid
b) Estimation of carbonate and bicarbonate present together in a mixture.

2. Oxidation-Reduction Titrimetric

a) Estimation of Fe (II) using standardized $KMnO_4$ solution
b) Estimation of Cu (II) using $K_2Cr_2O_7$
c) Estimation of Fe (III) using $K_2Cr_2O_7$

New addition: 15%	Modifications: 15%	Total change = 30%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Apply the classical and quantum mechanical ideas to analyze different numerical problems	PO 2	PSO 2	Ap, An
CO 2	Recall the periodic table and explain the periodic variation of different periodic properties	PO 2	PSO 1	R, U
CO 3	Explain and analyse acid-base behaviour of different organic and inorganic compounds	PO 2	PSO 3	U, An
CO 4	Evaluate and apply the mathematical ideas based on pH in acid base reaction system	PO 2	PSO 4	E, Ap
CO 5	Apply the redox chemistry to design advanced materials like, solar cell, fuel cell, supercapacitors, batteries etc.	PO 5	PSO 4	Ap, C
CO 6	Analyse and apply the concept of pH and redox potential in respective quantitative analysis	PO 3	PSO 2	An, Ap

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of Two Questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of Two Questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of Two Questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-4: A set of Two Questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

REFERENCE BOOKS FOR CC03

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

2. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.

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

4. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).

5. Cotton, F. A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.

6. Sharpe, A. G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

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

8. Atkins, P. W. & Paula, J. Physical Chemistry, Oxford Press, 2006.

9. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).

10. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.

11. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

REFERENCE BOOKS FOR CC03 LAB

1. Mendham, J., A. I. Vogel's Quantitative Ch

2. Chemical Analysis 6th Ed., Pearson, 2009.

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SEMESTER – 2		
Course name	CHEMISTRY – CC04: ORGANIC CHEMISTRY-02	
Course code	UGCHEMCC04	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding chirality and applying the knowledge in enzymatic reactions
2. Understanding the fundamental principles of different spectroscopy and applying the knowledge in characterizing different aspects of molecules
3. Reactivity of different organic molecules, as well as, mechanism of different organic reactions
4. Applying the above concepts in the synthesis of different important organic compounds.

THEORETICAL (60 LECTURES)

CC04: ORGANIC CHEMISTRY–02

Unit-1: Stereochemistry II **(15 Lectures)**

Optical activity of chiral compounds: Optical rotation, specific rotation and molar rotation; racemic compounds, racemic modifications, racemisation (through cationic, anionic, radical intermediates and through reversible formation of stable achiral intermediates); resolution of acids, bases, amino acids and alcohols via diastereomeric salt formation; optical purity and enantiomeric excess, diastereomeric excess, invertomerism of chiral trialkylamines.

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

Concept of prostereoisomerism: Prostereogenic centre; 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 propseudoasymmetric centre.

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*), Gauche effect (mechanistic idea about stabilization). Difference in population of conformations in liquid and gas phase.

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Unit-2: Organic Spectroscopy **(15 Lectures)**

UV Spectroscopy: Introduction; types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; Bathochromic and Hypsochromic shifts; intensity of absorptions (Hyper-/Hypochromic effects); application of Woodward's Rules for calculation of λ_{max} for the following systems: conjugated diene, α,β-unsaturated aldehydes and ketones (alicyclic, homoannular and heteroannular); extended conjugated systems (dienes, aldehydes and ketones); relative positions of λ_{max} considering conjugative effect, steric effect, solvent effect, effect of pH; effective chromophore concentration: keto-enol systems; benzenoid transitions.

IR Spectroscopy: Introduction; modes of molecular vibrations (fundamental and non-fundamental); IR active molecules; application of Hooke's law, force constant; *fingerprint region* and its significance; effect of deuteration; overtone bands; vibrational coupling in IR, Fermi-resonance; characteristic and diagnostic stretching frequencies of C-H, N-H, O-H, C-O, C-N, C-X, C=C (including skeletal vibrations of aromatic compounds), C=O, C=N, N=O, C≡C, C≡N; characteristic/diagnostic bending vibrations are included; factors affecting stretching frequencies: effect of conjugation, electronic effects, mass effect, bond multiplicity, ring-size, solvent effect, H-bonding on IR absorptions; application in functional group analysis.

Unit-3: Substitution and Elimination Reactions **(15 Lectures)**

Free-radical substitution reaction: Radical formation and stability, electrophilic and nucleophilic radicals and their selectivity, 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^3 centre: mechanisms (with evidence), relative rates & stereochemical features: S_N1, S_N2, S_Ni, S_N2', S_N1', S_Ni' (allylic rearrangement); effects of solvent, substrate structure, leaving group and nucleophiles, HOMO-gen and LUMO-gen (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) – Cope reaction, Chugev reaction & ester pyrolysis; 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-4: Aromatic Substitution **(15 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; S_N1 mechanism; cine substitution (benzyne mechanism), structure of benzyne. Von Richter reaction, $ArS_{RN}1$, Vicarious nucleophilic substitution, Tele substitution.

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PRACTICAL (60 LECTURES)

CC04 LAB: ORGANIC CHEMISTRY-02 LAB

Experiment -1: Qualitative Analysis of Single Solid Organic Compounds

Detection of special elements. Detection of functional groups phenols, carbonyl (aldehyde and ketone), carboxylic acid, carboxylic ester, unsaturation, amino, nitro, amido and anilido groups.

1. Qualitative analysis of unknown organic compounds containing above functional groups.

New addition: 5%	Modifications: 0%	Total change = 5%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Apply the knowledge of stereochemistry in different enzymatic reactions	PO 2	PSO 3	Ap
CO 2	Apply the fundamental principles of different spectroscopy to solve spectroscopic aspects of molecules	PO 3	PSO 2	Ap, C
CO 3	Interpret reactivity of different organic molecules, and justify the mechanism of different organic reactions	PO 2	PSO 1	E
CO 4	Apply the fundamental concepts learnt to design different important organic compounds.	PO 2	PSO 4	Ap, C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of Two Questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of Two Questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of Two Questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-4: A set of Two Questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

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REFERENCE BOOKS FOR CC04

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.

REFERENCE BOOKS FOR CC04 LAB

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. Practical Organic Chemistry, 5th Ed. Pearson (2012).
5. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis, University Press (2000).

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SEMESTER – 3		
Course name	CHEMISTRY -CC05: PHYSICAL CHEMISTRY-02	
Course code	UGCHEMCC05	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding basic laws governing the adsorption, different adsorption isotherms and applying the knowledge in analysing the function of heterogeneous catalysts
2. Understanding the concepts of chemical equilibrium and applying the thermodynamic laws to explain chemical equilibrium
3. Understanding and applying Le Chatelier principle
4. Understanding the basic and fundamental concepts classical and quantum mechanics
5. Applying the concepts of quantum mechanics in different quantum mechanical system, such as particle in a box, simple harmonic oscillator, rigid rotor and one-electron system like hydrogen atom.

THEORETICAL (60 LECTURES)

CC05: PHYSICAL CHEMISTRY-02

Unit 1: Transport processes (15 Lectures)

Fick's law: Flux, force, phenomenological coefficients & their inter-relationship (general form), different examples of transport properties

Viscosity: General features of fluid flow (streamline flow and turbulent flow), Reynold's number; Newton's equation, viscosity coefficient; Poiseuille's equation; principle of determination of viscosity coefficient of liquids by falling sphere method, terminal velocity; determination of viscosity coefficient of a liquid relative to another by Ostwald viscometer; Temperature variation of viscosity of liquids and comparison with that of gases

Conductance and transport number: Ion conductance; Conductance and measurement of conductance, cell constant, specific conductance and molar conductance; Variation of specific and equivalent conductance with dilution for strong and weak electrolytes; Kohlrausch's law of independent migration of ions; Equivalent and molar conductance at infinite dilution and their determination for strong and weak electrolytes; Debye –Huckel theory of Ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect; Ostwald's dilution law; Ionic mobility; Application of conductance measurement (determination of solubility product and ionic product of water); Conductometric titrations

Transport number, Principles of Hittorf's and Moving-boundary method; Wien effect, Debye-Falkenhagen effect, Walden's rule

Unit 2: Applications of Thermodynamics – I **(25 Lectures)**

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 KP, KC and KX; 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 and its derivation
Nernst's distribution law; Application- (finding out Keq using Nernst dist law for $KI+I_2 = KI_3$ and dimerization of benzene

Chemical potential and other properties of ideal substances- pure and mixtures: a) 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

Unit 3: Foundation of Quantum Mechanics **(20 Lectures)**

Beginning of Quantum Mechanics: Wave-particle duality, light as particles: photoelectric and Compton effects; electrons as waves and the de Broglie hypothesis; Uncertainty relations (without proof)

Wave function: Schrodinger time-independent equation; nature of the equation, acceptability conditions imposed on the wave functions and probability interpretations of wave function

Concept of Operators: Elementary concepts of operators, eigenfunctions and eigenvalues; Linear operators; Commutation of operators, commutator and uncertainty relation; Expectation value; Hermitian operator; Postulates of Quantum Mechanics

Particle in a box: Setting up of Schrodinger equation for one-dimensional box and its solution; Comparison with free particle eigenfunctions and eigenvalues. Properties of PB wave functions (normalisation, orthogonality, probability distribution); Expectation values of x, x^2, p_x and p_x^2 and their significance in relation to the uncertainty principle; Application of particle in a one-dimensional box model to conjugated polyene system (such as butadiene and hexatriene); Extension of the problem to two and three dimensions and the concept of degenerate energy levels

Simple Harmonic Oscillator: setting up of the Schrodinger stationary equation, energy expression (without derivation), expression of wave function for n = 0, n = 1, n = 2 and n = 3 (without derivation) and their characteristic features; average displacement and average momentum of a SHO.

PRACTICAL (60 LECTURES)

CC05 LAB: PHYSICAL CHEMISTRY-02 LAB

Experiment 1: Study of viscosity of unknown liquid (glycerol, sugar) with respect to water

Experiment 2: Determination of partition coefficient for the distribution of I_2 between water and CCl_4

Experiment 3: Determination of K_{eq} for $KI + I_2 = KI_3$, using partition coefficient between water and CCl_4

Experiment 4: Conductometric titration of an acid (strong, weak/ monobasic, dibasic) against base strong

Experiment 5: Study of saponification reaction conductometrically

Experiment 6: Verification of Ostwald's dilution law and determination of K_a of weak acid

New addition: 3%	Modifications: Cyan 0%	Total change = 3%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Explain the basic laws governing the adsorption, different adsorption isotherms and apply the knowledge to analyze the role of heterogeneous catalysts	PO 2	PSO 3	U, An, Ap
CO 2	Apply the concepts and principles of chemical equilibrium in analyzing chemical reactions	PO 3	PSO 3	An, Ap
CO 3	Summerize the basic and fundamental concepts classical and quantum mechanics and evaluate different quantum mechanical problems	PO 4	PSO 2	U, E
CO 4	Apply the knowledge of physical chemistry to estimate different parameters in practical experiments	PO 5	PSO 2	Ap, C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC05

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press

2. Castellan, G. W. Physical Chemistry, Narosa

3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press

5. Levine, I. N. Physical Chemistry, Tata McGraw-Hill

6. Maron, S. & Prutton Physical Chemistry

8. Mortimer, R. G. Physical Chemistry, Elsevier

9. Laidler, K. J. Chemical Kinetics, Pearson

10. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry

11. Rakshit, P.C., Physical Chemistry Sarat Book House

13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas

Clauze & Rosenberg, Chemical Thermodynamics

14. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics:Basic Concepts and Methods Wiley

15. Glasstone, S. An Introduction to Electrochemistry, East-West Press

Reference Books for CC05 LAB

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson

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

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

6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.

7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

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SEMESTER – 3		
Course name	CHEMISTRY -CC06: INORGANIC CHEMISTRY-02	
Course code	UGCHEMCC06	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding concepts, theories and parameters related to bonding
2. Applying the knowledge of bonding in explaining the structure and properties of molecules and ions
3. Understanding the factors determining nuclear stability and applying the knowledge in different nuclear reactions
4. Understanding and applying nuclear models
5. Applying the concepts of radioactivity in power generation, age determination etc.

THEORETICAL (60 LECTURES)

CC06: INORGANIC CHEMISTRY-02

UNIT-1: Chemical Bonding-I **(24 Lectures)**

(i) *Ionic bond:* General characteristics of ionic compounds, 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. Different ionic lattice and their structure, Madelung constant, Born-Haber cycle and its application, Solvation energy. Defects in solids (elementary idea) and applications. Solubility energetics of dissolution process – examples and illustrations.

(ii) *Covalent bond:* Polarizing power and polarizability, ionic potential, Fazan's rules. Lewis structures, Applications of the different factors in explaining properties of molecules and ions; formal charge: concept and calculations, 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 – calculations of percentage of co-valency in molecules; ionic-covalent resonance, 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); Explanation of properties of molecules based on VSEPR theory and Bent's rule. Fluxional molecules: Examples with structural elucidation; Stereoactive and non-stereoactive lone pair.

UNIT-2: Chemical Bonding-II **(24 Lectures)**

(i) Molecular orbital concept of bonding (The approximations of the theory, Linear combination of atomic orbitals (LCAO)) (elementary pictorial approach): sigma and pi-bonds and delta 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. Explanation of molecular properties from MOT; Bond properties: bond orders, bond lengths.

(ii) *Metallic Bond:* Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

(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), receptor-guest interactions, Halogen bonds. Effects of chemical force, melting and boiling points.

UNIT-3: Radioactivity **(12 Lectures)**

Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models: shell model; liquid-drop model; Concept of nuclear quantum number, magic numbers. Radioactive disintegration series – 4n, (4n+1), (4n+2) series; Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Elementary idea on design of nuclear power plants; Separation and uses of isotopes. Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures.

PRACTICAL (60 LECTURES)

CC06 LAB: INORGANIC CHEMISTRY-02 LAB

1. Iodo-/ Iodimetric Titrations

a) Estimation of Cu (II)

b) Estimation of Vitamin C

c) Estimation of available chlorine in bleaching powder.

2. Gravimetry

a) Estimation of Ni (II) using Dimethylglyoxime (DMG).

b) Estimation of copper as CuSCN.

New addition: 8%	Modifications: 2%	Total change = 10%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Demonstrate the concepts, theories and parameters related to ionic, covalent, metallic and H-bonding	PO 1	PSO 1	U
CO 2	Apply the knowledge of bonding in explaining the structures, interactions and reactions of molecules and ions	PO 2	PSO 3	Ap

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CO 3	Elaborate the concept of radioactivity in promising fields like, nuclear power generation, radiation therapy etc.	PO 2	PSO 3	C
CO 4	Apply the knowledge of volumetric and gravimetric analysis in different chemical reactions	PO 2	PSO 2	Ap

U = Understanding; An = Analysing, Ap = Applying, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 08 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC06

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

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. Kaplan, I., Nuclear Physics, Addison-Wesley Publishing Company Inc. London, 1964.

12. Friedlander, G., Kennedy, J. W., Macias, E. S. And Miller, J. M., Nuclear and Radiochemistry, Wiley, 1981.

Reference Books for CC06 LAB

1. Mendham, J., *A. I. Vogel's Quantitative Chemical Analysis* 6th Ed., Pearson, 2009.

SEMESTER – 3		
Course name	CHEMISTRY -CC07: ORGANIC CHEMISTRY-03	
Course code	UGCHEMCC07	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding the reactivity of carbonyl and related organic compounds
2. Understanding and applying the concepts of reaction mechanism in organic synthesis
3. Understanding the fundamental principles of different spectroscopies
4. Applying the concepts of spectroscopy in evaluating different aspects of molecules
5. Understanding the reactivity of organometallic compounds in organic synthesis

THEORETICAL (60 LECTURES)

CC07: ORGANIC CHEMISTRY-03

UNIT-1: Carbonyl and Related Compounds (20 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, cyano hydrins 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; Meyer-Schuster and Rupe rearrangement, oxidations and reductions: Clemmensen, Wolff-Kishner, $LiAlH_4$, $NaBH_4$, 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, E- and Z-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, Tollens', 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.

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

Substitution at sp^2 carbon (C=O system): mechanism (with evidence): $B_{AC}2$, $A_{AC}2$, $A_{AC}1$, $A_{AL}1$ (in connection to acid and ester); acid derivatives: amides, anhydrides & acyl halides (formation and hydrolysis including comparison).

UNIT-2: Organic Spectroscopy **(25 Lectures)**

NMR Spectroscopy: introduction; nuclear spin; NMR active molecules; basic principles of Proton Magnetic Resonance; equivalent and non-equivalent protons; chemical shift and factors influencing it; ring current effect; significance of the terms: up-/downfield, shielded and deshielded protons; spin coupling and coupling constant (1st order spectra); relative intensities of *first-order* multiplets: Pascal's triangle; chemical and magnetic equivalence in NMR ; elementary idea about *non-first-order* splitting; anisotropic effects in alkene, alkyne, aldehydes and aromatics; NMR peak area, integration; relative peak positions with coupling patterns of common organic compounds (both aliphatic and benzenoid-aromatic); rapid proton exchange; interpretation of NMR spectra of simple compounds, Vander waals deshielding effect (isopropyl methyl ether).

Applications of IR, UV and NMR spectroscopy for identification of simple organic molecules.

Mass Spectroscopy: Basic principle of mass spectroscopy, McLafferty rearrangement, metastable peak, General fragmentation mode, Retro Diels Alder reaction, determination of the presence of halogen.

Alcohol, ethers and epoxides: synthesis and reactivity including pinacol-pinacolone rearrangement, Thiol, Thioether, Oxidation of 1,2-diols by periodic acid and lead tetraacetate

Phenols: ambident nucleophile: C- substitution versus O-substitution, reaction of phenols: Reimer-Tiemann reaction, Kolbe's reaction, Manasse reaction, alkylation, acetylation, Fries rearrangement, Claisen rearrangement, nitration, sulphonation, halogenation, oxidation (aerial), oxidative coupling by Fe^{3+}, Dakin reaction, Cumene-phenol rearrangement.

UNIT-3: Organometallics **(15 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; Use of silicon reagents (TMSCl, TMSI), concept of *umpolung* and base-nucleophile dichotomy in case of organometallic reagents.

PRACTICAL (60 LECTURES)

CC07 LAB: ORGANIC CHEMISTRY-03 LAB

1. Organic preparations:

(i) Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*-toluidines and *o*-, *m*-, *p*-anisidine) and phenols (β-naphthol, vanillin, salicylic acid) by any one method:

a. Using conventional method.

b. Using green approach

(ii) Benzolyation of one of the following amines (aniline, o-, m-, p- toluidines and o-, m-, p-anisidine) and one of the following phenols (β-naphthol, resorcinol, p-cresol) by Schotten-Baumann reaction.

(iii) Oxidation of ethanol/ isopropanol (Iodoform reaction).

(iv) Bromination of any one of the following:

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a. Acetanilide by conventional methods

b. Acetanilide using green approach (Bromate-bromide method)

(v) Nitration of any one of the following:

a. Acetanilide/nitrobenzene by conventional method

b. Salicylic acid by green approach (using ceric ammonium nitrate).

(vi) Selective reduction of meta dinitrobenzene to m-nitroaniline.

(vii) Reduction of p-nitrobenzaldehyde by sodium borohydride.

(viii) Hydrolysis of amides and esters.

(ix) Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.

(x) S-Benzylisothiouronium salt of one each of water soluble and water insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).

(xi) Aldol condensation using either conventional or green method.

(xii) Benzil-Benzilic acid rearrangement.

The above derivatives should be prepared using 0.5-1g of the organic compound. The solid samples must be collected and may be used for recrystallization, melting point and TLC.

New addition: 1%	Modifications: 1%	Total change = 2%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Explain and illustrate the reactivity of carbonyl and related organic compounds	PO 2	PSO 3	U
CO 2	Interpret the concepts of reaction mechanism in organic synthesis	PO 1	PSO 4	U, E
CO 3	Apply the fundamental principles of different spectroscopies and solve different spectrochemical data	PO 2	PSO 2	Ap, C
CO 4	Explain and interpret the reactivity of organometallic compounds in organic synthesis	PO 2	PSO 3	U, E
CO 5	Apply the concepts of synthesis in organic preparation	PO 2	PSO 3	Ap

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

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Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 20 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 20 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 10 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC07

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. 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. Ward, R. S., Bifunctional Compounds, Oxford Chemistry Primer, Oxford University Press.

12. Ahluwalia, V. K. Strategies for Green Organic Synthesis, ANE Books Pvt. Ltd.

Reference Books for CC07 LAB

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 Organic Chemistry, Pearson Education (2009).

4. Furniss, B.S., Hannaford, A.J., Smith, P.W.G., Tatchell, A.R. Practical Organic Chemistry, 5th Ed., 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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SEMESTER – 3		
Course name	CHEMISTRY -CC08: PHYSICAL CHEMISTRY-03	
Course code	UGCHEMCC08	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding the activity and activity coefficient of various ionic species present in the solution
2. Understanding various electrode processes; different types of electrodes
3. Derivation of Nernst equation using laws of Thermodynamics
4. Historical chronology leading to the development of Quantum Mechanics and understanding different fundamental theories of Quantum Mechanics
5. Understanding and applying Schrodinger's wave equation (time-independent), and several other mathematical techniques to determine the physical property of different models.

THEORETICAL (60 LECTURES)

CC08: PHYSICAL CHEMISTRY-03

UNIT-1: Application of Thermodynamics – II **(20 lectures)**

Colligative properties: Vapour pressure of solution; Ideal solutions, ideally diluted 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; Immiscible liquid pairs and steam distillation; Solid-liquid phase diagram; Type – I: Eutectic mixture, freezing mixture (KCl – H_2O system) and Type – II: solid compound of the components with congruent melting point separates from the solution (Sn – Mg system).

UNIT-2: Electrical Properties of molecules **(20 Lectures)**

Ionic equilibria: Chemical potential of an ion in solution; Activity and activity coefficients of ions in solution; Debye-Huckel limiting law-brief qualitative description of the postulates involved

qualitative idea of the model, the equation (without derivation) for ion-ion atmosphere interaction potential. Estimation of activity coefficient for electrolytes using Debye-Huckel limiting law; Derivation of mean ionic activity coefficient from the expression of ion-atmosphere interaction potential; Applications of the equation and its limitations

Electromotive Force: Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry; Chemical cells, reversible and irreversible cells with examples; Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb_2O_3 electrodes

Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers; Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation)

Dipole moment and polarizability: Polarizability of atoms and molecules, dielectric constant and polarisation, molar polarisation for polar and non-polar molecules; Clausius-Mosotti equation and Debye equation (both without derivation) and their application; Variation of molar polarisation with temperature and variation of molar polarisation with frequency of the applied electric field; Determination of dipole moments

UNIT-3: Quantum Chemistry **(20 Lectures)**

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component; Rigid rotator model of rotation of diatomic molecule; Schrödinger equation, transformation to spherical polar coordinates; Separation of variables. Spherical harmonics; Discussion of solution

Qualitative treatment of hydrogen atom and hydrogen-like ions: Setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression); Average and most probable distances of electron from nucleus; Setting up of Schrödinger equation for many-electron atoms (He, Li)

LCAO and HF-SCF: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+; Bonding and antibonding orbitals; Qualitative extension to H_2; Comparison of LCAO-MO and VB treatments of H_2 and their limitations; Hartree-Fock method development, SCF and configuration interaction (only basics)

PRACTICAL (60 LECTURES)

CC08 LAB: PHYSICAL CHEMISTRY-03 LAB

Experiment 1: Determination of solubility of sparingly soluble salt in water, in electrolyte with common ions and in neutral electrolyte (using common indicator)

Experiment 2: Potentiometric titration of Mohr's salt solution against standard $K_2Cr_2O_7$ solution

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Experiment 3: Determination of K_{sp} for AgCl by potentiometric titration of $AgNO_3$ solution against standard KCl solution

Experiment 4: Effect of ionic strength on the rate of Persulphate – Iodide reaction

Experiment 5: Study of phenol-water phase diagram

Experiment 6: pH-metric titration of acid (mono- and di-basic) against strong base

New addition: 0%	Modifications: Cyan 5%	Total change = 5%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Compare and explain the activity and activity coefficient of various ionic species present in the solution	PO 2	PSO 1	U, E
CO 2	Classify different types of electrodes and electrode processes	PO 1	PSO 3	U, An
CO 3	Demonstrate Nernst equation using laws of Thermodynamics and solve numerical problems	PO 1	PSO 4	U, C
CO 4	Recall historical chronology leading to the development of Quantum Mechanics and explain different fundamental theories of Quantum Mechanics	PO 1	PSO 1	R, E
CO 5	Interpret and illustrate Schrodinger's wave equation (time-independent), and several other mathematical techniques to determine the physical property of different models	PO 2	PSO 4	U, E

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

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Reference Books for CC08

1. Atkins, P. W. & Paula, J. de Atkin's, Physical Chemistry, Oxford University Press.
2. Castellan, G. W. Physical Chemistry, Narosa
3. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press
4. Levine, I. N. Physical Chemistry, Tata McGraw-Hill
5. Moore, W. J. Physical Chemistry, Orient Longman
6. Mortimer, R. G. Physical Chemistry, Elsevier
7. Engel, T. & Reid, P. Physical Chemistry, Pearson
8. Levine, I. N. Quantum Chemistry, PHI
9. Atkins, P. W. Molecular Quantum Mechanics, Oxford
10. Engel, T. & Reid, P. Physical Chemistry, Pearson
11. Maron, S.H., Prutton, C. F., Principles of Physical Chemistry, McMillan
12. Klotz, I.M., Rosenberg, R. M. Chemical Thermodynamics:Basic Concepts and Methods Wiley
13. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas
14. Glasstone, S. An Introduction to Electrochemistry, East-West Press

Reference Books for CC08 LAB

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)
2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson
3. Harris, D. C. Quantitative Chemical Analysis. 6th Ed., Freeman (2007)
4. Palit, S.R., De, S. K. Practical Physical Chemistry Science Book Agency
5. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N., University of Calcutta
6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.
7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

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SEMESTER – 4		
Course name	CHEMISTRY CC09: INORGANIC CHEMISTRY-03	
Course code	UGCHEMCC09	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Extraction and purification of metals based on redox potential
2. Understanding the chemistry of various compounds of the s-block and p-block elements
3. Understanding and applying several industrially important compounds
4. Understanding the basic theories of coordination bonding and coordination chemistry
5. Demonstrating isomerism in coordination compounds in different geometrical shapes

THEORETICAL (60 LECTURES)

CC09: INORGANIC CHEMISTRY-03

UNIT-1: General Principles of Metallurgy **(6 Lectures)**

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond's process, Zone refining - basic ideas on different process used in industry.

UNIT-2: Chemistry of *s* and *p* Block Elements **(30 Lectures)**

Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Beryllium hydrides and halides. Boric acid and borates, boron nitrides, borohydrides (diborane) and graphitic compounds, chemistry of boranes and its structural aspects based on PSEPT theory, coordination behaviour of borohydrides, carboranes and metallocarboranes – an outline. silanes, Periodic properties of elements in terms of atomic radius, ionization potential, bond strength, catenation etc. Hydrides, halides, oxides and oxoacids of nitrogen, phosphorus, sulphur and chlorine – structural aspects, acid-base behaviours, redox properties, hydrolysis behaviours. Peroxo acids of sulphur – structure and properties, sulphur-nitrogen compounds – preparation, structure and bonding and properties, interhalogen compounds, polyhalide ions, pseudohalogens, fluorocarbons and basic properties of halogens.

Noble Gases:

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2 and XeF_4). Xenon-oxygen compounds. Molecular shapes of noble gas compounds (VSEPR theory).

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Inorganic Polymers:

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes. Ring opening reactions of phosphazenes. Basic idea about inorganic coordination polymers with examples.

UNIT-3: Coordination Chemistry-I **(24 Lectures)**

Coordinate bonding: Development of modern coordination chemistry: a historical perspectives. Jorgensen's chain theory. Werner's theory of coordination complexes, double and complex salts. Labile and inert complex; Classification of ligands based on denticity. Flexidentate ligands (examples with illustrations), Ambidentate ligands (examples with illustrations), bridging ligands (examples with illustrations). Inorganic coordination polymers and metal-organic framework – a brief outline with suitable examples. Applications of MOFs; Chelating ligands (examples with illustrations), chelate complexes and their stability – kinetic and thermodynamic aspects, inner-metallic complex (examples with illustrations), types of inner-metallic complexes. Different coordination numbers (examples with illustrations), IUPAC nomenclature of coordination complexes (up to two metal centers), Isomerism in coordination compounds, their classifications, constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes. Identification of cis-trans isomers in square planar and octahedral complexes.

PRACTICAL (60 LECTURES)

CC09 LAB: INORGANIC CHEMISTRY-03 LAB

1. Complexometric titration

(a) Zn(II)
(b) Ca(II) and Mg(II) in a mixture.
(c) Hardness of water.

2. Inorganic preparations and spectroscopic characterizations

(a) *Cis* and *trans* $K[Cr(C_2O_4)_2(H_2O)_2]$
(b) Potassium diaquadioxalatochromate(III)
(c) Potassium tris(oxalato)ferrate(III)
(d) Tris-(ethylenediamine) nickel(II) chloride.

New addition: 35%	Modifications: 20%	Total change = 55%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Outline the principles of extraction and purification of metals based on redox potential	PO 2	PSO 1	U
CO 2	Explain and illustrate the chemistry of various compounds of the s-block and p-block elements	PO 2	PSO 3	U, E
CO 3	Discuss the basic theories of coordination bonding and coordination chemistry	PO 1	PSO 4	C
CO 4	Solve new research problems based on the knowledge on isomerism	PO 4	PSO 1	C
CO 5	Plan and design novel research ideas based on inorganic synthesis	PO 5	PSO 4	Ap, C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 10 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 15 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC09

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

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

3. Cotton, F. A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.

4. Miessler, G. L. & Donald, A. Tarr. Inorganic Chemistry 4th Ed., Pearson, 2010.

5. Purecell, K. F. and Kotz, J. C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.

6. Mingos, D. M. P., Essential trends in inorganic chemistry. Oxford University Press (1998).

Reference Books for CC09 LAB

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. Inorganic Synthesis, Vol. 1-10.

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SEMESTER – 4		
Course name	CHEMISTRY -CC10: ORGANIC CHEMISTRY-04	
Course code	UGCHEMCC10	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Preparation and reactivity of nitrogen based organic compounds
2. Understanding and applying the concept of retro synthesis and asymmetric synthesis
3. The mechanism of different organic rearrangement reactions
4. Understanding the mechanism, stereochemistry, regioselectivity in case of electrocyclic reactions, cycloaddition reactions and sigmatropic reactions.

THEORETICAL (60 LECTURES)

CC10: ORGANIC CHEMISTRY-04

UNIT-1: Nitrogen compounds **(15 Lectures)**

Amines: Aliphatic & Aromatic: preparation, separation (Hinsberg's method) and identification of primary, secondary and tertiary amines; reaction (with mechanism): Eschweiler–Clarke methylation, diazo coupling reaction, Mannich reaction; formation and reactions of phenylenediamines, diazomethane and diazoacetic ester.

Nitro compounds (aliphatic and aromatic): preparation and reaction (with mechanism): reduction under different conditions; Nef carbonyl synthesis, Henry reaction and conjugate addition of nitroalkane anion, distinction between alkyl nitrite and nitroalkanes. Victor Mayer test, cine substitution, IPSo substitution, various nucleophilic substitution.

Alkylnitrile and isonitrile: preparation and reaction (with mechanism): Thorpe nitrile condensation, von Richter reaction.

Diazonium salts and their related compounds: Diazo-coupling reactions (with mechanism) involving replacement of diazo group; reactions: Gomberg, Meerwein, Japp-Klingermann.

Rearrangements **(15 Lectures)**

Mechanism with evidence and stereochemical features for the following

Rearrangement to electron-deficient carbon: Wagner-Meerwein rearrangement, pinacol rearrangement, dienone-phenol; Wolff rearrangement in Arndt-Eistert synthesis, benzil-benzilic acid rearrangement, Demjanov rearrangement, Tiffeneau–Demjanov rearrangement (semipinacol rearrangement).

Rearrangement to electron-deficient nitrogen: rearrangements: Hofmann, Curtius, Lossen, Schmidt and Beckmann.

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Rearrangement to electron-deficient oxygen: Baeyer-Villiger oxidation, cumene hydroperoxide-phenol rearrangement and Dakin reaction.

Aromatic rearrangements: Migration from oxygen to ring carbon: Fries rearrangement and Claisen rearrangement.
Migration from nitrogen to ring carbon: Hofmann-Martius rearrangement, Fischer-Hepp rearrangement, *N*-azo to *C*-azo rearrangement, Bamberger rearrangement, Orton rearrangement and benzidine rearrangement.

UNIT-2: The Logic of Organic Synthesis **(15 Lectures)**

Retrosynthetic analysis: disconnections; synthons, donor and acceptor synthons; natural reactivity and *umpolung*; latent polarity in bifunctional compounds: consonant and dissonant polarity; illogical electrophiles and nucleophiles; synthetic equivalents; functional group interconversion and addition (FGI and FGA); C-C disconnections and synthesis: one-group and two-group (1,2- to 1,5-dioxygenated compounds), reconnection (1,6-dicarbonyl); protection-deprotection strategy (alcohol, amine, carbonyl, acid). Carbocyclic ring formation.

Strategy of ring synthesis: thermodynamic and kinetic factors; synthesis of large rings, application of high dilution technique.

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 stereogenic centre: Felkin-Anh and Zimmermann-Traxler models. Aldol reaction using Z- and E-enolates, syn/anti-aldol, kinetic and thermodynamic control over aldol reaction.

UNIT-3: Pericyclic reactions **(15 Lectures)**

Mechanism, stereochemistry, regioselectivity in case of
Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions.
Cycloaddition reactions: FMO approach, Diels-Alder reaction, photochemical [2+2] cycloadditions.
Sigmatropic reactions: FMO approach, sigmatropic shifts and their order; [1,3]- and [1,5]-H shifts and [3,3]-shifts with reference to Claisen and Cope rearrangements.

PRACTICAL (60 LECTURES)

CC10 LAB: ORGANIC CHEMISTRY-04 LAB

Quantitative Estimations: Each student is required to perform all the experiments.

1. Estimation of glycine by Sorenson's formalin method.
2. Study of the titration curve of glycine.
3. Saponification value of an oil or a fat.
4. Determination of Iodine number of an oil/ fat.
5. Estimation of aniline and phenol
6. Estimation of Glucose, sucrose.

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New addition: 1%	Modifications: 0%	Total change = 1%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Outline the preparation and explain the reactivity of nitrogen based organic compounds	PO 2	PSO 2	U, E
CO 2	Apply the concept of retro synthesis and asymmetric synthesis to design new target	PO 3	PSO 4	Ap, C
CO 3	Solve and interpret the mechanism of different new organic rearrangement reactions	PO 5	PSO 4	E, C
CO 4	Apply the knowledge of pericyclic reactions to solve new related problems	PO 1	PSO 4	Ap, C
CO 5	Quantitatively estimate composition of different organic compounds	PO 2	PSO 2	C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 15 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 10 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC10

1. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.

(Pearson Education).

2. Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

3. Norman, R.O. C., Coxon, J. M. Principles of Organic Synthesis, Third Edition, Nelson Thornes, 2003.

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

5. Silverstein, R. M., Bassler, G. C., Morrill, T. C. Spectrometric Identification of Organic Compounds, John Wiley and Sons, INC, Fifth edition.

6. Kemp, W. Organic Spectroscopy, Palgrave.

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7. Pavia, D. L. et al. Introduction to Spectroscopy, 5th Ed. Cengage Learning India Ed. (2015).

8. Dyer, J. Application of Absorption Spectroscopy of Organic Compounds, PHI Private Limited

9. March, J. Advanced Organic Chemistry, Fourth edition, Wiley.

10. Harwood, L. M., Polar Rearrangements, Oxford Chemistry Primer, Oxford University Press.

11. Bailey, Morgan, Organonitrogen Chemistry, Oxford Chemistry Primer, Oxford University Press.

12. Ahluwalia, V. K. Strategies for Green Organic Synthesis, ANE Books Pvt. Ltd.

13. Warren, S. Organic Synthesis the Disconnection Approach, John Wiley and Sons.

14. Warren, S., Designing Organic Synthesis, Wiley India, 2009.

15. Carruthers, W. Modern methods of Organic Synthesis, Cambridge University Press.

16. Willis, C. A., Wills, M., Organic Synthesis, Oxford Chemistry Primer, Oxford University Press.

Reference Books for CC10 LAB

1. Arthur, I. V. Quantitative Organic Analysis, Pearson

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

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SEMESTER – 5		
Course name	CHEMISTRY -CC11: INORGANIC CHEMISTRY-04	
Course code	UGCHEMCCXI	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. The elementary idea on crystal field theory
2. The colour, magnetic properties and chemical potentials of coordination compounds of transition metals
3. The colour, magnetic properties and chemical potentials of coordination compounds of lanthanoids and actinoids
4. Understanding the chemistry of semimicro qualitative analysis

THEORETICAL (60 LECTURES)

CC11: INORGANIC CHEMISTRY-04

UNIT-1: Coordination Chemistry-II **(36 Lectures)**

VB description and its limitations. Elementary Crystal Field Theory: splitting of d^n 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). Concept of MO formation based on LGO (Ligand Group Orbital) approach, d-orbital splitting pattern and CFSE for other geometry: square pyramidal, trigonal bipyramidal, square planar and tetrahedral. Metal-ligand bonding (MO concept, elementary idea) in square planar and tetrahedral complex. Magnetism and Colour: Orbital and spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ ions. Racah parameter. Selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea).

UNIT-2: Chemistry of d- and f- block elements **(24 Lectures)**

Transition Elements:

General comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, coordination chemistry. Applications of the elements in catalysis, magnetic fields and medicinal fields.

Lanthanoids and Actinoids:

General Comparison on Electronic configuration, oxidation states, colour, spectral and magnetic properties; lanthanide contraction, separation of lanthanides (ion-exchange method only). Applications of lanthanoids in optoelectronic devices, catalysis and MRI contrast agents.

PRACTICAL (60 LECTURES)

CC11LAB: INORGANIC CHEMISTRY-04 LAB

Qualitative semimicro analysis the following acid and basic radicals including insoluble materials

Cation Radicals: Na^+, K^+, Ca^{2+}, Sr^{2+}, Ba^{2+}, Al^{3+}, Cr^{3+}, Mn^{2+}/Mn^{4+}, Fe^{3+}, Co^{2+}/Co^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Pb^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}/Sn^{4+}, As^{3+}/As^{5+}, $Sb^{3+/5+}$, NH_4^+, Mg^{2+}.

Anion Radicals: F^-, Cl^-, Br^-, BrO_3^-, I^-, IO_3^-, SCN^-, S^{2-}, SO_4^{2-}, NO_3^-, NO_2^-, PO_4^{3-}, AsO_4^{3--}, BO_3^{3-}, CrO_4^{2-} / $Cr_2O_7^{2-}$, $Fe(CN)_6^{4-}$, $Fe(CN)_6^{3-}$.

Insoluble Materials: Al_2O_3(ig), Fe_2O_3(ig), Cr_2O_3(ig), $PbCrO_4$, SnO_2, $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$.

New addition: 4%	Modifications: 10%	Total change = 14%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Apply the knowledge of crystal field theory and its related aspects to discuss the chemistry of coordination compounds	PO 2	PSO 1	Ap, C
CO 2	Explain the colour, magnetic properties and chemical potentials of novel coordination compounds	PO 2	PSO 4	E
CO 3	Explain the colour, magnetic properties and chemical potentials of coordination compounds of lanthanoids and actinoids	PO 2	PSO 4	E
CO 4	Elaborate the principles of semimicro qualitative analysis to determine the presence of different elements in test samples	PO 3	PSO 3	E, C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

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Reference Books for CC11

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

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

3. Cotton, F. A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.

4. Atkin, P. Shriver & Atkins' Inorganic Chemistry 5th Ed. Oxford University Press (2010).

5. Purecell, K. F. and Kotz, J. C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.

6. Sinha, S. P., Ed., Lanthanide and Actinide Research (Journal, Vol. 1, 1986).

7. Wulfsberg, G., Principles of Descriptive Inorganic Chemistry, Brooks/Cole: Monterey, CA, 1987.

Reference Books for CC11 LAB

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

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SEMESTER – 5		
Course name	CHEMISTRY -CC12: ORGANIC CHEMISTRY-05	
Course code	UGCHEMCC12	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Different heterocyclic compounds of different sizes especially 5 and 6-membered heterocycles.
2. The synthesis and reactions of different heterocycles.
3. Understanding the key biological roles of heterocycles
4. Understanding the chemistry of carbohydrate, amino acids, peptides, proteins and nucleic acids including the functions of DNAs and RNAs
5. Chemical methods for sequencing biopolymers

THEORETICAL (60 LECTURES)

CC XII: ORGANIC CHEMISTRY V

UNIT-1: Carbocycles and Heterocycles **(16 Lectures)**

Polynuclear hydrocarbons and their derivatives: synthetic methods include Haworth, Pschorr, Bardhan-Sengupta, Bogert-Cook and other useful syntheses (with mechanistic details); fixation of double bonds and Fries rule; naphthalene with two fused benzene rings; reactions (with mechanism) of naphthalene, anthracene, phenanthrene and their derivatives.

Heterocyclic compounds: 5- and 6-membered rings with one heteroatom; reactivity, orientation and important reactions (with mechanism) of furan, pyrrole, thiophene and pyridine; synthesis (including retrosynthetic approach and mechanistic details): pyrrole: Knorr synthesis, Paal-Knorr synthesis, Hantzsch; furan: Paal-Knorr synthesis, Feist-Benary synthesis and its variation; thiophenes: Paal-Knorr synthesis, Hinsberg synthesis; pyridine: Hantzsch synthesis; benzo-fused 5- and 6-membered rings with one heteroatom: reactivity, orientation and important reactions (with mechanistic details) of indole, quinoline and isoquinoline; synthesis (including retrosynthetic approach and mechanistic details): indole: Fischer, Madelung and Reissert; quinoline: Skraup, Doebner- Miller, Friedlander; isoquinoline: Bischler-Napieralski synthesis.

UNIT-2: Cyclic Stereochemistry **(14 Lectures)**

Alicyclic compounds: concept of I-strain; conformational analysis: cyclohexane, mono and disubstituted cyclohexane; different strains in ring compounds, relative stabilities, symmetry properties and optical activity; topomerisation; ring-size and ease of cyclisation; conformation & reactivity in cyclohexane system: consideration of steric and stereoelectronic requirements; elimination (E2, E1, E1CB), nucleophilic substitution (S_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification,

lactonisation, pyrolytic *syn* elimination and fragmentation reactions, stereochemistry of cyclohexene, epoxidation. Cyclohexanone, 2-, 3- and 4-Alkyl ketone effects.

UNIT-3: Carbohydrates **(15 Lectures)**

Monosaccharides: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms): Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions (mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine-water oxidation, HNO_3 oxidation, selective oxidation of terminal $-CH_2OH$ of aldoses, reduction to alditols, Lobry de Bruyn-van Ekenstein rearrangement; stepping–up by 1- and 2- carbon (Kiliani-Fischer method) and stepping–down (Ruff's & Wohl's methods) of aldoses; end-group-interchange of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose.

Disaccharides: Glycosidic linkages, concept of glycosidic bond formation by glycosyl donor-acceptor; structure of sucrose, inversion of cane sugar.

UNIT-4: Biomolecules **(10 Lectures)**

Amino acids: synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction, Dakin-West reaction.

Peptides: peptide linkage and its geometry; syntheses (with mechanistic details) of peptides using *N*-protection & C-protection, solid-phase (Merrifield) synthesis; peptide sequence: *C*-terminal and *N*-terminal unit determination (Akabori, Edman, Sanger & 'dansyl' methods); partial hydrolysis; specific cleavage of peptides: Chemical methods: methionine (CNBr), Cysteine (2-nitro-5-thiocyanobenzoic acid), Tryptophan (o-iodosobenzoic acid) etc.

Nucleic acids: pyrimidine and purine bases (only structure & nomenclature); nucleosides and nucleotides corresponding to DNA and RNA; mechanism for acid catalysed hydrolysis of nucleosides (both pyrimidine and purine types); comparison of alkaline hydrolysis of DNA and RNA; elementary idea of double helical structure of DNA (Watson-Crick model); complimentary base–pairing in DNA. Preliminary ideas on bio-synthesis of nucleic acids.

UNIT-5: Natural Products: **(5 Lectures)**

Alkaloids: Structure and synthesis of ephedrine and nicotine.

Terpenoids: Classification, isoprene rule, structure and synthesis of citral, geraniol and nerol. Introduction to terpenoid biogenesis.

PRACTICAL (60 LECTURES)

CC12 LAB: ORGANIC CHEMISTRY-05 LAB

1. Extraction of caffeine from tea leaves.
2. Estimation of glucose and sucrose in a mixture
3. Identification of simple organic compounds by IR spectroscopy and NMR spectroscopy (Spectra to be provided).
4. Prepation of methyl orange, urea-formaldehyde.

5. Chromatography:
6. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography
7. Separation of a mixture of two sugars by ascending paper chromatography
8. Separation of a mixture of o-and p-nitrophenol or o-and p-aminophenol by thin layer chromatography (TLC)

New addition: 6%	Modifications: 6%	Total change = 12%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Classify and summarize heterocyclic compounds of different sizes especially 5 and 6-membered heterocycles	PO 1	PSO 1	Ap, An
CO 2	Apply the concepts of synthesis and reactions of heterocycles in designing novel drug molecules	PO 3	PSO 4	Ap, C
CO 3	Demonstrate the key biological functions of heterocycles	PO 1	PSO 3	U
CO 4	Illustrate and interpret the chemistry of carbohydrate, amino acids, peptides, proteins and nucleic acids	PO 2	PSO 4	E, C
CO 5	Apply the chromatographic techniques in separation of organic mixtures	PO 3	PSO 2	Ap

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 08 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 12 marks for each question to be set.

UNIT-4: A set of two questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-5: A set of two questions carrying a total of 04 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC12

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

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

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

4. Fleming, I. Molecular Orbitals and Organic Chemical reactions, Reference/Student Edition, Wiley, 2009.

5. Fleming, I. Pericyclic Reactions, Oxford Chemistry Primer, Oxford University Press.

6. Gilchrist, T. L. & Storr, R. C. Organic Reactions and Orbital symmetry, Cambridge University Press.

7. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd.(Pearson Education).

8. Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

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

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

11. James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.

12. Davis, B. G., Fairbanks, A. J., Carbohydrate Chemistry, Oxford Chemistry Primer, Oxford University Press.

13. Acheson, R.M. Introduction to the Chemistry of Heterocyclic compounds, John Wiely & Sons (1976).

14. Gilchrist, T. L. Heterocyclic Chemistry, 3rd edition, Pearson.

15. Davies, D. T., Heterocyclic Chemistry, Oxford Chemistry Primer, Oxford University Press.

Reference Books for CC12 LAB

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

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

3. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. Practical Organic Chemistry, 5th Ed., Pearson (2012).

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

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SEMESTER – 6		
Course name	CHEMISTRY -CC13: INORGANIC CHEMISTRY-05	
Course code	UGCHEMCC13	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. The role of metal ions in biological systems
2. The structures, functions of metalloproteins and metalloenzymes
3. Understanding the mechanism of redox reactions in biological systems, photosynthesis and chelation therapy
4. Understanding the structure, bonding and reactivity of organometallic complexes
5. Applications of organometallic complexes in catalysis
6. Understanding the thermodynamic and kinetic aspects of inorganic reaction mechanism

THEORETICAL (60 LECTURES)

CC13: INORGANIC CHEMISTRY-05

Unit-1: Bioinorganic Chemistry **(24 Lectures)**

Elements of life: essential and beneficial elements, major, trace and ultratrace elements. Basic chemical reactions in the biological systems and the role of metal ions (specially Na^+, K^+, Mg^{2+}, Ca^{2+}, $Fe^{3+/2+}$, $Cu^{2+/+}$, and Zn^{2+}). Metal ion transport across biological membrane Na^+/ K^+-ion pump. Dioxygen molecule in life. Dioxygen management proteins: structure and activity of Haemoglobin, Myoglobin, Hemocyanine and Hemerythrin. Electron transfer proteins: structure and activity of Cytochromes and Fe-S proteins (Ferredoxins). Carbonate bicarbonate buffering system, Hydrolytic enzymes: structure and activity of carbonic anhydrase and carboxypeptidase A. Structure and activity of catalase and peroxidase; Artificial metalloenzymes; Biological nitrogen fixation, structure and activity of nitrogenase enzyme; Photosynthesis: detail mechanistic aspects of Photosystem-I and Photosystem-II. Structure and activity of chlorophyll during photosynthesis; Toxic metal ions and their hazardous effects, chelation therapy (examples only), Pt and Au complexes as drugs (examples only), metal dependent diseases (examples only)

Unit-2: Organometallic Chemistry **(24 Lectures)**

Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. 18-electron and 16-electron rules (pictorial MO approach). Applications of 18-electron rule to metal carbonyls, nitrosyls, cyanides. General methods of preparation of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls. Structural elucidation of metal carbonyls using polyhedral skeletal electron pair repulsion theory (PSEPT) – Wade's rule; pi-acceptor behaviour of CO, synergic effect and use of IR data to explain extent of back bonding. Zeise's salt: Preparation, structure, evidences of synergic effect. Ferrocene: Preparation, reactions and preparation of derivatives (acetylation, alkylation, metallation, Mannich Condensation). Bonding in ferrocene; Reactions of organometallic complexes:

substitution, oxidative addition, reductive elimination and insertion reactions; fluxionality in organometallic compounds.

Catalysis by Organometallic Compounds

Study of the following industrial processes

1. Alkene hydrogenation (Wilkinson's Catalyst)

2. Hydroformylation

3. Ziegler-Natta catalysis for olefin polymerization.

Unit-3: Reaction Kinetics and Mechanism **(12 Lectures)**

Introduction to inorganic reaction mechanisms. Langford-Gray notation of reaction mechanism; Kinetic versus thermodynamic stability; labile and inertness of metal ions; Substitution reactions in square planar complexes, Trans- effect and its application in complex synthesis, theories of trans effect and trans influence, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes. Application of VBT and CFSE in understanding the labile and inertness of metal ions in solution; Concept and application of crystal field activation energy (CFAE); Substitution reactions in Co(III) and Cr(III) complexes; Electron transfer mechanism in coordination complex: Outer-sphere and Inner-sphere electron transfer (OSET and ISET) mechanism; Elementary idea of Marcus theory.

PRACTICAL (60 LECTURES)

CC13 LAB: INORGANIC CHEMISTRY-05 LAB

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.

New addition: 40%	Modifications: 40%	Total change = 80%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Evaluate the role of metal ions in biological systems	PO 1	PSO 1	E
CO 2	Apply the knowledge of redox reactions in biological systems in designing model biological systems	PO 3	PSO 4	Ap, C
CO 3	Illustrate the structure, bonding and reactivity of new organometallic complexes and apply the concept in designing novel organometallic catalyst	PO 2	PSO 3	U, C

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CO 4	Make use of the knowledge of inorganic reaction mechanism to explain new reactions	PO 3	PSO 4	Ap, E
CO 5	Elaborate the principles of semimicro qualitative analysis to determine the presence of different elements in test samples	PO 4	PSO 3	E, C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 18 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 18 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 14 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC13

1.Lippard, S. J. & Berg, J. M. Principles of Bioinorganic Chemistry Panima Publishing Company 1994.

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

4. Cotton, F. A., Wilkinson, G., Murrillo, C. A., Bochmann, M., Advanced Inorganic Chemistry 6th Ed. 1999., Wiley.

5. Bertini, I., Gray, H. B., Lippard, S. J., Valentine, J. S., Viva, 2007.

6.Basolo, F, and Pearson, R. C. Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.

7. Purecell, K. F. and Kotz, J. C., An Introduction to Inorganic Chemistry, Saunders: Philadelphia, 1980.

8. Powell, P. Principles of Organometallic Chemistry, Chapman and Hall, 1988.

9.Collman, J. P. et al. Principles and Applications of Organotransition Metal Chemistry. Mill Valley, CA: University Science Books, 1987.

10. Crabtree, R. H. The Organometallic Chemistry of the Transition Metals. New York, NY: John Wiley, 2000.

Reference Books for CC13 LAB

1. Svehla, G., Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.

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SEMESTER – 6		
Course name	CHEMISTRY -CC14: PHYSICAL CHEMISTRY-04	
Course code	UGCHEMCC13	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding the fundamental principles of rotational, vibrational, NMR and ESR spectroscopy
2. Applications of spectroscopic techniques in chemistry
3. Illustrating the concepts of photochemistry
4. Understanding the basics of different surface phenomena like, surface tension, adsorption etc.
5. Understanding different physicochemical phenomena of colloid chemistry

THEORETICAL (60 LECTURES)

CC14: PHYSICAL CHEMISTRY-04

Unit-1: Molecular Spectroscopy **(20 Lectures)**

Interaction of electromagnetic radiation with molecules and various types of spectra; Born-Oppenheimer approximation

Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies; Diatomic vibrating rotator, P, Q, R branches

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion

Nuclear Magnetic Resonance (NMR) spectroscopy: Principles of NMR spectroscopy, Larmor precession, chemical shift and low resolution spectra, different scales, spin-spin coupling and high resolution spectra, interpretation of PMR spectra of organic molecules

Electron Spin Resonance (ESR) spectroscopy: Its principle, hyperfine structure, ESR of simple radicals

Unit-2: Photochemistry **(20 Lectures)**

Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, Stark-Einstein

law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields and explanation

Photochemical Processes: Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; First order photophysical processes: Non-radiative (vibrational relaxation, internal conversion, inter system crossing) and radiative prcesses (Fluorescence and phosphorescence), Jablonskii diagram; Brief features of fluorescence and phosphorescence spectra.

Rate of Photochemical processes: Photochemical equilibrium and the differential rate of photochemical reactions, Photostationary state; HI decomposition, H_2-Br_2 reaction, dimerisation of anthracene; photosensitised reactions, quenching; Kinetics of collisional quenching: STERN – VOLMER equation.

Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence

Unit-3: Surface phenomenon **(20 Lectures)**

Surface tension and energy: Surface tension, surface energy, excess pressure, capillary rise and surface tension, contact angle; determination of relative surface tension using Stalagmometer, Work of cohesion and adhesion, spreading of liquid over other surface; Vapour pressure over curved surface; Temperature dependence of surface tension

Adsorption: Physical and chemical adsorption; Freundlich and Langmuir adsorption isotherms (with derivation); multilayer adsorption and BET isotherm (no derivation required); Gibbs adsorption isotherm and surface excess; Heterogenous catalysis (single reactant); Zero order and fractional order reactions;

Colloids: Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, Coagulation and Schultz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electrokinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrin's method; Stability of colloids and zeta potential; Micelle formation

PRACTICAL (60 LECTURES)

CC14 LAB: PHYSICAL CHEMISTRY-05 LAB

Experiment 1: Determination of surface tension of a liquid using Stalagmometer

Experiment 2: Determination of CMC from surface tension measurements

Experiment 3: Verification of Beer and Lambert's Law for KMnO4 and K2Cr2O7 solution

Experiment 4: Study of kinetics of K2S2O8 + KI reaction, spectrophotometrically

Experiment 5: Determination of pH of unknown buffer, spectrophotometrically

Experiment 6: Spectrophotometric determination of CMC

New addition: 0%	Modifications: 8%	Total change = 8%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Apply the knowledge of spectroscopy in solving related problems in chemistry	PO 3	PSO 2	Ap, C
CO 2	Apply the concepts of photochemistry to interpret different photochemical reactions	PO 3	PSO 2	Ap, E
CO 3	Apply the concepts of surface tension, adsorption etc. to analyse different surface phenomena	PO 3	PSO 3	Ap, An
CO 4	Designing new formulations for cosmetics, surfactants, medicines utilizing the concepts of colloid chemistry	PO 4	PSO 4	Ap, E
CO 5	Apply the knowledge of surface properties to determine the related parameters	PO 2	PSO 2	Ap, E

R= Remembering, U = Understanding; An = Analysing, Ap = Applying, E = Evaluating, C = Create

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 18 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CC14

1. Castellan, G. W. Physical Chemistry, Narosa
2. Levine, I. N. Physical Chemistry, Tata McGraw-Hill
3. Atkins, P. W. & Paula, J. de Atkin's, Physical Chemistry, Oxford University Press
4. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press
5. Mortimer, R. G. Physical Chemistry, Elsevier
6. Laidler, K. J. Chemical Kinetics, Pearson
7. Banwell, C. N. Fundamentals of Molecular Spectroscopy, Tata-McGraw-Hill
8. Barrow, G. M. Molecular Spectroscopy, McGraw-Hill
9. Hollas, J.M. Modern Spectroscopy, Wiley India
10. McHale, J. L. Molecular Spectroscopy, Pearson Education
11. Wayne, C. E. & Wayne, R. P. Photochemistry, OUP
12. Brown, J. M. Molecular Spectroscopy, OUP

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13. Levine, I. N. Quantum Chemistry, PHI

14. Atkins, P. W. Molecular Quantum Mechanics, Oxford

Reference Books for CC14 LAB

1. Viswanathan, B., Raghavan, P.S. Practical Physical Chemistry Viva Books (2009)

2. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson

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

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

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

6. Levitt, B. P. edited Findlay's Practical Physical Chemistry Longman Group Ltd.

7. Gurtu, J. N., Kapoor, R., Advanced Experimental Chemistry S. Chand & Co. Ltd.

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DISCIPLINE SPECIFIC ELECTVES (DSE)

Course name	DSE01: Advanced Physical Chemistry	
Course code	UGCHEMDSE01	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding structural parameters of ionic solids
2. Classifications of different lattice systems and lattice parameters
3. Understanding statistical thermodynamics
4. Third law of thermodynamics and its related topics
5. Understanding basic polymer chemistry

THEORETICAL (60 LECTURES)

DSE01: Advanced Physical Chemistry

Crystal Structure **(20 Lectures)**

Bravais Lattice and Laws of Crystallography: Types of solid, Bragg's law of diffraction; Laws of crystallography (Haüy's law and Steno's law); Permissible symmetry axes in crystals (absence of five-fold symmetry axis in nature); Lattice, space lattice, unit cell, symmetry elements, crystal planes, Bravais lattice. Packing of uniform hard sphere, close packed arrangements (fcc and hcp); Tetrahedral and octahedral voids, location and ratio of their numbers in close packed structure. Void space in p-type, F-type and I-type cubic systems

Crystal planes: Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]; Indexing of planes, Miller indices; calculation of dhkl; Relation between molar mass and unit cell dimension for cubic system; Bragg's law (derivation)

Determination of crystal structure: Powder method; Structure of NaCl and KCl crystals

Statistical Thermodynamics **(20 Lectures)**

Configuration: Macrostates, microstates and configuration; calculation with harmonic oscillator; variation of W with E; equilibrium configuration

Boltzmann distribution: Thermodynamic probability, entropy and probability, Boltzmann distribution formula (with derivation); Applications to barometric distribution; Partition function, concept of ensemble - canonical ensemble and grand canonical ensembles

Partition function: molecular partition function and thermodynamic properties, Maxwell's speed distribution; Gibbs' paradox

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Special selected topics **(20 Lectures)**

Specific heat of solid: Coefficient of thermal expansion, thermal compressibility of solids; Dulong – Petit's law; Perfect Crystal model, Einstein's theory – derivation from partition function, limitations; Debye's T^3 law – analysis at the two extremes

3rd law: Absolute entropy, Plank's law, Calculation of entropy, Nernst heat theorem

Adiabatic demagnetization: Approach to zero Kelvin, adiabatic cooling, demagnetization, adiabatic demagnetization – involved curves

Polymers: Classification of polymers, different types of molecular weight and their determination (viscosity average and weight average molecular weight only), nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers; Criteria for synthetic polymer formation; Relationships between functionality, extent of reaction and degree of polymerization; Mechanism and kinetics of step growth and copolymerization; Conducting polymers

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PRACTICAL (60 LECTURES)

DSE01 LAB: Advanced Physical Chemistry

Computer programs based on numerical methods for

Programming 1: Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid)

Programming 2: Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations)

Programming 3: Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values

Programming 4: Matrix operations (Application of Gauss-Siedel method in colourimetry)

Programming 5: Simple exercises using molecular visualization software

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New addition: 0%	Modifications: 35%	Total change = 35%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Explain and illustrate the structural features of different ionic solids based on crystallography	PO 2	PSO 1	U, E
CO 2	Classify and discuss the lattice systems and lattice parameters newly synthesized crystalline materials	PO 2	PSO 4	U, C
CO 3	Apply statistical thermodynamics to solve new related problems	PO 3	PSO 4	Ap, C
CO 4	Apply third law of thermodynamics to interpret related systems	PO 4	PSO 1	Ap, E
CO 5	Design new polymer for advanced applications	PO 4	PSO 4	C
CO 6	Develop computer programs based on numerical methods for applications in chemistry	PO 6	PSO 4	C

R= Remembering, U = Understanding; An = Analysing, Ap = Applying, E = Evaluating, C = Create

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 16 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for DSE01

1. Castellan, G. W. Physical Chemistry, Narosa
2. Levine, I. N. Physical Chemistry, Tata McGraw-Hill
3. Moore, W. J. Physical Chemistry, Orient Longman
4. Atkins, P. W. & Paula, J. de Atkins', Physical Chemistry, Oxford University Press
5. McQuarrie, D. A. & Simons, J. D. Physical Chemistry: A Molecular Approach, Viva Press
6. Engel, T. & Reid, P. Physical Chemistry, Pearson
7. Nash, L. K. Elements of Statistical Thermodynamics, Dover
8. Rastogi, R. P. & Misra, R.R. An Introduction to Chemical Thermodynamics, Vikas
9. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata-McGraw-Hill

10. Billmeyer, F. W. Textbook of Polymer Science, John Wiley & Sons, Inc.

11. Seymour, R. B. & Carraher, C. E. Polymer Chemistry: An Introduction, Marcel Dekker, Inc.

12. Odian, G. Principles of Polymerization, Wiley

13. Billmeyer, F. W. Textbook of Polymer Science, Wiley Interscience, 1971.

Reference Books for DSE01 LAB

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

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

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

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

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

ANY THREE FROM THE FOLLOWING RECOMMENDED FOUR DSE

(DSE02 to DSE05) COURSES ARE TO CHOOSE

Course name	DSE02: Analytical Methods in Chemistry	
Course code	UGCHEMDSE2	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding analysis of analytical data based on statistical treatment
2. Basic principles on instrumentation techniques for optical method of analysis
3. Fundamental concepts of analytical chemistry involving qualitative and quantitative analysis
4. Applying the techniques for quantitative analysis of elements in different samples
5. Understanding the basic concepts on chromatography

THEORETICAL (60 LECTURES)

DSE02: ANALYTICAL METHODS IN CHEMISTRY

Qualitative and quantitative aspects of analysis: **(05 Lectures)**

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals.

Optical methods of analysis: **(25 Lectures)**

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, validity of Beer-Lambert's law.

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method.

Infrared Spectrometry: Basic principles of instrumentation (choice of source, monochromator & detector) for single and double beam instrument; sampling techniques. Applications in analytical chemistry.

Structural illustration through interpretation of data, Effect and importance of isotope substitution.

Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, detector, choice of flame and Burner designs. Techniques of atomization and sample introduction; Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples. Applications in analytical and environmental chemistry.

Gravimetric and tritimetric methods of analysis **(25 Lectures)**

Requirements of gravimetry: properties of precipitates and precipitating regents, particle size and filterability of precipitates, colloidal and crystalline precipitates coprecipitation and post-precipitation drying and ignition of precipitates, organic and inorganic reagent used in precipitation of metal ions in gravimetry; principles of gravimetric estimation of chloride, phosphate, zinc, iron, aluminium, magnesium, nickel and copper singly;

Primary and secondary standard substances in acid-base, redox, complexometric (EDTA) and argentometric titrations. Principle and application of redox tritimetric estimation based on the use of the following reagents: $KMnO_4$, $K_2Cr_2O_7$, I_2, $Na_2S_2O_3.5H_2O$, $KH(IO_3)_2$ and $KBrO_3$. Theory of Mohr's titration and Volhard's titration; Principle of argentimetric estimation of chloride using adsorption indicators; Applications in analysis and estimation of metal ions in industrial and environmental samples.

Principle of complexometric EDTA titration, metal ion indicators (examples), masking and demasking reactions, estimation of Cu-Zn, Fe-Al and Ca-Mg mixture by EDTA titration methods.

Dissolution, scheme of analysis and principles of estimation of the constituents of the following materials: dolomite, pyrolusite, chalchopyrites, Portland cement, basic slag, brass, steel and type metal.

Separation techniques: **(5 Lectures)**

Chromatography: Classification, principle and efficiency of the technique.

Basic idea about adsorption, partition & ion exchange chromatography

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PRACTICAL (60 LECTURES)

DSE02 LAB: ANALYTICAL METHODS IN CHEMISTRY

Optical methods of analysis:

1. Determination of λ_{max} of Cu(II) complexes
2. Determination of λ_{max} of Ni(II) complexes
3. Determination of λ_{max} of Ni(II) complexes

Gravimetric and tritimetric methods of analysis

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

New addition: 7%	Modifications: 8%	Total change = 15%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Analyse analytical data based on statistical treatment	PO 2	PSO 1	An
CO 2	Apply the knowledge on instrumentation techniques for optical method of analysis to solve related analytical problems	PO 3	PSO 4	Ap, C
CO 3	Apply the different analytical techniques to estimate industrial samples quantitatively	PO 2	PSO 4	Ap, C
CO 4	Adapt the chromatographic separation techniques in research and development areas of both industry and academia	PO 4	PSO 1	C
CO 5	Analyse samples spectrophotometrically and interpret the data	PO 2	PSO 4	An, E
CO 6	Apply the titrimetric methods of analysis in analysing geochemical samples	PO 2	PSO 4	Ap, An

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for DSE02

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

2. Willard, H.H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.

3. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.

4. Harris, D.C.: Exploring Chemical Analysis, 9th Ed. New York, W.H. Freeman, 2016.

5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age International Publisher, 2009.

6. Skoog, D.A. Holler F.J. & Nieman, T.A. Principles of Instrumental Analysis, Cengage Learning India Ed.

7. Mikes, O. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.

8. Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.

Reference Books for DSE02 LAB

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

2. Willard, H.H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.

3. Christian, G.D. Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.

4. Harris, D.C. Exploring Chemical Analysis, 9th Ed. New York, W.H. Freeman, 2016.

5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age International Publisher, 2009.

6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Cengage Learning India Edition.

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Course name	DSE03: Green Chemistry	
Course code	UGCHEMDSE03	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding green chemistry and its scope and limitations
2. Twelve fundamental principles of green chemistry
3. Designing a Green Synthesis using these principles
4. Applications of green chemistry in real world cases
5. Combinatorial chemistry and sustainable development of green chemistry

THEORETICAL (60 LECTURES)

DSE03: GREEN CHEMISTRY

Introduction to Green Chemistry: (04 Lectures)

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:(30 Lectures)

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

- 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.
- Prevention/ minimization of hazardous/ toxic products reducing toxicity. risk = (function) hazard × exposure; waste or pollution prevention hierarchy.
- Green solvents– supercritical fluids, Gas expanded liquid (GXLs), CO_2 expanded liquid (CXLs), water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents and how to compare greenness of solvents.
- Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy.
- Selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups.
- 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.
- 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.

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

Examples of Green Synthesis/ Reactions and some real world cases: (16 Lectures)

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 CO2 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. An 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 Inter esterification for production of no Trans-Fats and Oils

9. Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting brass, steel and type metal.

Future Trends in Green Chemistry: **(10 Lectures)**

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions; co crystal controlled solid state synthesis (C2S3); Green chemistry in sustainable development.

PRACTICAL (60 LECTURES)

DSE03 LAB: GREEN CHEMISTRY

1. Safer starting materials

- Preparation and spectroscopic characterization of nanoparticles of gold using tea leaves.
- Preparation and spectroscopic characterization of nanoparticles of silver using tea leaves.

2. Using renewable resources

- Preparation of biodiesel from vegetable/ waste cooking oil.

3. Avoiding waste

Principle of atom economy

- Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.

- Preparation of propene by two methods can be studied

Triethylamine ion + OH^- → propene + trimethylpropene + water

$$\text{1-propanol} \xrightarrow{H_2SO_4/\Delta} \text{propene} + \text{water}$$

- Other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy.

4. Use of enzymes as catalysts

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

5. Alternative Green solvents

- Extraction of D-limonene from orange peel using liquid CO2 prepared form dry ice.

Mechanochemical solvent free synthesis of azomethines

6. Alternative sources of energy

- Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).
- Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

New addition: 10%	Modifications: 0%	Total change = 10%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Select green chemistry-based methods for synthesis	PO 2	PSO 1	An
CO 2	Apply the fundamental principles of green chemistry design new experiments	PO 3	PSO 4	Ap, C
CO 3	Apply the green chemistry techniques to maximize environmental benefits	PO 4	PSO 4	Ap, C
CO 4	Plan new green methodologies for applications in real world systems	PO 4	PSO 1	Ap, C
CO 5	Apply the concept of combinatorial chemistry in formulations of new drug molecules	PO 2	PSO 4	Ap, C

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Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-4: A set of two questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for DSE03

1. Anastas, P.T. & Warner, J.K.: Green Chemistry - Theory and Practical, Oxford University Press (1998).

2. Matlack, A.S. Introduction to Green Chemistry, Marcel Dekker (2001).

3. Cann, M.C. & Connely, M.E. Real-World cases in Green Chemistry, American Chemical Society, Washington (2000).

4. Ryan, M.A. & Tinnesand, M. Introduction to Green Chemistry, American Chemical Society, Washington (2002).

5. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2nd Edition, 2010.

Reference Books for DSE03 LAB

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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Course name	DSE04: Inorganic Materials of Industrial Importance	
Course code	UGCHEMDSE04	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding chemistry of glass, ceramics and cements
2. Classification, preparation and composition of glass, ceramics and cements
3. Understanding preparation, chemical composition and applications of fertilizers
4. Understanding basics theories, synthesis and applications of nanomaterials
5. Composition, properties and applications of different composite materials and conducting polymers

THEORETICAL (60 LECTURES)

DSE04: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

Silicate Industries **(18 Lectures)**

Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

Ceramics: Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fibre.

Cements: Classification of cement, ingredients and their role, Manufacture of cement and the setting process, quick setting cements.

Fertilizers: **(8 Lectures)**

Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

Nanomaterials: **(12 Lectures)**

Overview of nanostructures and nanomaterials: classification.

Wet chemical synthesis of (i) Plasmonic nanoparticles like gold nanoparticles, silver nanoparticles (ii) Magnetic nanoparticles like nickel nanoparticles, cobalt nanoparticles, Fe_3O_4 nanoparticles (iii) Semiconductor nanoparticles like TiO_2 nanoparticles, ZnO nanoparticles, CdS nanoparticles. Galvanic Replacement Reaction (GRR) protocol for synthesis of hollow or porous nanostructures. Synthesis of Bi-metallic and Tri-metallic nanostructures involving GRR strategy. Wet chemical method for synthesis of anisotropic nanostructures including gold nanorods, silver nanocubes, nickel nanowires. Green synthesis of plasmonic nanoparticles using natural source. self-assembled

nanostructures-biological nanostructure; control of nanoarchitecture-one dimensional control. Carbon nanotubes and inorganic nanowires. Bio-inorganic nanomaterials, DNA and nanomaterials, natural and antisical nanomaterials, bionano composites. Designing of Environmentally safe marine antifoulant.

Instruments used for characterizations of nanomaterials: a brief idea about Field Emission Scanning Electron Microscope (FESEM), Transmission Electron Microscope (TEM), High-Resolution Transmission Electron Microscope (HRTEM), Atomic Force Microscope (AFM), Powder X-Ray Diffraction (PXRD), UV-vis spectrophotometer.

Applications of nanomaterials in bio-medicinal field, sensing, surface enhanced Raman spectroscopy (SERS), catalysis, environmental pollution abatement like degradation of organic dye molecules, pesticides and other hazardous materials employing photocatalysis, electrocatalysis for energy related research.

Composite materials: **(12 Lectures)**

Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix composites, fibre-reinforced composites, nano-polymer composites, semiconductor nanoparticles-plasmonic nanoparticles composite, plasmonic nanoparticles-bio (DNA) composite; environmental effects on composites, applications of composites.

Speciality polymers: **(10 Lectures)**

Conducting polymers - Introduction, conduction mechanism, polyacetylene, polyparaphenylene, polyaniline and polypyrrole, applications of conducting polymers, Ion-exchange resins and their applications. Ceramic & Refractory: Introduction, classification, properties, raw materials, manufacturing and applications.

PRACTICAL (60 LECTURES)

DSE04 LAB: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE

1. Determination of free acidity in ammonium sulphate fertilizer.
2. Estimation of Calcium in Calcium ammonium nitrate fertilizer.
3. Estimation of phosphoric acid in superphosphate fertilizer.
4. Analysis of Cement.
5. Preparation of pigment (zinc oxide).
6. Synthesis of silver and gold nanoparticles and their spectroscopic analysis.
7. Synthesis of nickel nanoparticles and nickel nanowires.

New addition: 30%	Modifications: 18%	Total change = 48%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Demonstrate and compare the chemistry of glass, ceramics and cements	PO 2	PSO 1	U, E
CO 2	Design novel glass and ceramic materials for advanced applications	PO 5	PSO 4	C
CO 3	Design new methods for synthesis and applications of novel nanomaterials	PO 4	PSO 2	Ap, C
CO 4	Design novel composite materials and conducting polymers in advanced versatile fields	PO 5	PSO 3	C
CO 5	Analyse commercial fertilizer samples and formulate new fertilizers	PO 2	PSO 3	An, C
CO 6	Develop new nano scale materials for advanced applications	PO 6	PSO 4	C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 08 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 10 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-4: A set of two questions carrying a total of 20 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for DSE04

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.

2. R. M. Felder, R. W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.

3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.

4. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.

5. P. C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.

6. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas Publications, New Delhi.

7. Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

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Reference Books for DSE04 LAB

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.

2. R. M. Felder, R. W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.

3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: Introduction to Ceramics, Wiley Publishers, New Delhi.

4. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.

5. P. C. Jain, M. Jain: Engineering Chemistry, Dhanpat Rai & Sons, Delhi.

6. R. Gopalan, D. Venkappayya, S. Nagarajan: Engineering Chemistry, Vikas

7. Publications, New Delhi.

8. Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

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Course name	DSE05: Industrial Chemicals and Environment	
Course code	UGCHEMDSE05	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding large scale production, storage and hazards in handling of the gases
2. Manufacture, application, analysis and hazards in handling industrial chemicals
3. Understanding causes and effects of environmental pollution
4. Procedures of industrial waste management
5. Available natural sources of energy and nuclear pollution

THEORETICAL (60 LECTURES)

DSE05: INDUSTRIAL CHEMICALS AND ENVIRONMENT

Industrial Gases and Inorganic Chemicals (10 Lectures)

Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene.

Inorganic Chemicals: Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.

Industrial Metallurgy (4 Lectures)

Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology.

Environment and its segments (30 Lectures)

Ecosystems. Biogeochemical cycles of carbon, nitrogen and sulphur.

Air Pollution: Major regions of atmosphere. Chemical and photochemical reactions in atmosphere. Air pollutants: types, sources, particle size and chemical nature; Photochemical smog: its constituents and photochemistry. Environmental effects of ozone, Major sources of air pollution.

Pollution by SO_2, CO_2, CO, NO_x, H_2S and other foul-smelling gases. Methods of estimation of CO, NO_x, SO_x and control procedures.

Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.

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Water Pollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems.

Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc. Sludge disposal.

Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

Energy & Environment **(10 Lectures)**

Sources of energy: Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.

Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

Biocatalysis **(6 Lectures)**

Introduction to biocatalysis: Importance in "Green Chemistry" and Chemical Industry.

PRACTICAL (60 LECTURES)

DSE05 LAB: INDUSTRIAL CHEMICALS AND ENVIRONMENT

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD)
3. Determination of Biological Oxygen Demand (BOD)
4. Percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by simple titration method (AgNO3 and potassium chromate).
6. Estimation of total alkalinity of water samples (CO32-, HCO3-) using double titration method.
7. Measurement of dissolved CO2.
8. Study of some of the common bio-indicators of pollution.
9. Estimation of SPM in air samples.
10. Preparation of borax/ boric acid.

New addition: 0%	Modifications: 0%	Total change = 0%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Take part in large scale production, storage and hazards in handling of industrial gases	PO 2	PSO 3	An
CO 2	Develop new methodologies for manufacturing and safe handling of industrial chemicals	PO 3	PSO 4	C
CO 3	Develop strategies to minimize environmental pollution	PO 4	PSO 3	C
CO 4	Plan to manage industrial waste to maximize environmental and economical benefits	PO 4	PSO 4	C
CO 5	Propose conserving natural sources of energy and design alternate energy resources	PO 5	PSO 4	C
CO 6	Determine parameters related to environmental pollution	PO 2	PSO 2	E

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 13 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-4: A set of two questions carrying a total of 12 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for DSE05

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.

2. R.M. Felder, R.W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.

3. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.

4. S. S. Dara: A Textbook of Engineering Chemistry, S. Chand & Company Ltd. New Delhi.

5. K. De, Environmental Chemistry: New Age International Pvt., Ltd, New Delhi.

6. S. M. Khopkar, Environmental Pollution Analysis: Wiley Eastern Ltd, New Delhi.

7. S.E. Manahan, Environmental Chemistry, CRC Press (2005).

8. G.T. Miller, Environmental Science 11th edition. Brooks/ Cole (2006).

9. A. Mishra, Environmental Studies. Selective and Scientific Books, New Delhi (2005).

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Reference Books for DSE05 LAB

1. E. Stocchi: Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.

2. R.M. Felder, R.W. Rousseau: Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.

3. J. A. Kent: Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.

4. S. S. Dara: A Textbook of Engineering Chemistry, S. Chand & Company Ltd. New Delhi.

5. K. De, Environmental Chemistry: New Age International Pvt., Ltd, New Delhi.

6. S. M. Khopkar, Environmental Pollution Analysis: Wiley Eastern Ltd, New Delhi.

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SKILL ENHANCEMENT COURSES (SEC)

Course name	CHEMISTRY SEC-1: Pharmaceutical Chemistry	
Course code	UGCHEMSEC1	Credits: 2, Full Marks: 50
Number of lectures required: 60		

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding the procedure to design and develop new drug molecules
2. Basic retrosynthetic approach for target drug molecule
3. Synthetic methodologies for different classes of drugs
4. Different aerobic and non-aerobic fermentation procedure for synthesis
5. Large scale production of different drugs

THEORETICAL (60 LECTURES)

SEC-1: PHARMACEUTICAL CHEMISTRY

Drugs & Pharmaceuticals

Drug discovery, design and development; Basic Retrosynthetic approach. Synthesis of the representative drugs of the following classes: analgesics agents, antipyretic agents, anti-inflammatory agents (Aspirin, paracetamol, Ibuprofen); antibiotics (Chloramphenicol); antibacterial and antifungal agents (Sulphonamides; Sulphanethoxazol, Sulphacetamide, Trimethoprim); antiviral agents (Acyclovir), Central Nervous System agents (Phenobarbital, Diazepam), Cardiovascular (Glyceryl trinitrate), antilaprosy (Dapsone), HIV-AIDS related drugs (AZT- Zidovudine).

Fermentation

Aerobic and anaerobic fermentation. Production of (i) Ethyl alcohol and citric acid, (ii) Antibiotics; Penicillin, Cephalosporin, Chloromycetin and Streptomycin, (iii) Lysine, Glutamic acid, Vitamin B2, Vitamin B12 and Vitamin C.

Practical

1. Preparation of Aspirin and its analysis.

2. Preparation of magnesium bisilicate (Antacid).

New addition: 0%	Modifications: 0%	Total change = 0%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Outline the procedure to design and develop new drug molecules	PO 2	PSO 4	U, C
CO 2	Plan retrosynthetic approach to target new drug molecule	PO 4	PSO 3	Ap, C
CO 3	Develop and analyse different classes of drug molecules	PO 5	PSO 4	E, C
CO 4	Apply aerobic and non-aerobic fermentation procedure for developing new drugs	PO 6	PSO 3	Ap, C
CO 5	Take part in large scale production of different drugs	PO 5	PSO 4	An

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Reference Books for SEC-1

- Patrick, G. L. Introduction to Medicinal Chemistry, Oxford University Press, UK, 2013.

- Singh, H. & Kapoor, V.K. Medicinal and Pharmaceutical Chemistry, Vallabh Prakashan, Pitampura, New Delhi, 2012.

- Foye, W.O., Lemke, T.L. & William, D.A.: Principles of Medicinal Chemistry, 4th ed., B.I. Waverly Pvt. Ltd. New Delhi.

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Course name	CHEMISTRY SEC-2: FUEL CHEMISTRY	
Course code	UGCHEMSEC2	Credits: 4, Full Marks: 50
Number of lectures required: 60		

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Understanding renewable and non-renewable sources of energy
2. Composition, carbonization and uses of coal
3. Refining of crude petroleum and applications of different petroleum products
4. Understanding different industrial procedure, like, fractional distillation, thermal cracking, reforming etc.
5. Different types of lubricant

THEORETICAL (60 LECTURES)

SEC-2: FUEL CHEMISTRY

Review of energy sources (renewable and non-renewable). Classification of fuels and their calorific value.

Coal: Uses of coal (fuel and nonfuel) in various industries, its composition, carbonization of coal. Coal gas, producer gas and water gas—composition and uses. Fractionation of coal tar, uses of coal tar bases chemicals, requisites of a good metallurgical coke, Coal gasification (Hydro gasification and Catalytic gasification), Coal liquefaction and Solvent Refining.

Petroleum and Petrochemical Industry: Composition of crude petroleum, Refining and different types of petroleum products and their applications.

Fractional Distillation (Principle and process), Cracking (Thermal and catalytic cracking), Reforming Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels. Petrochemicals: Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and its derivatives Xylene.

Lubricants: Classification of lubricants, lubricating oils (conducting and non-conducting) Solid and semisolid lubricants, synthetic lubricants.

Properties of lubricants (viscosity index, cloud point, pore point) and their determination.

New addition: 0%	Modifications: 0%	Total change = 0%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Select renewable and non-renewable sources of energy	PO 3	PSO 1	E
CO 2	Apply carbonization of coal to maximize its calorific value	PO 4	PSO 3	Ap, C
CO 3	Refine crude petroleum and formulate different petroleum products	PO 6	PSO 3	C
CO 4	Take part in different industrial procedures like, fractional distillation, thermal cracking, reforming etc.	PO 4	PSO 3	An
CO 5	Develop different types of lubricant as per user requirement	PO 5	PSO 4	C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Reference Books for SEC-2

- Stocchi, E. Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK (1990).
- Jain, P.C. & Jain, M. Engineering Chemistry Dhanpat Rai & Sons, Delhi.
- Sharma, B.K. & Gaur, H. Industrial Chemistry, Goel Publishing House, Meerut (1996).

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GENERIC ELECTIVES (CHEMISTRY)

Course name	CHEMISTRY GE-1	
Course code	UGCHEMGE1	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Physical properties of liquid, like, surface tension, viscosity etc.
2. Definition of thermodynamic terms and first law of thermodynamics
3. Composition of atomic nucleus, laws of radioactivity and decay kinetics
4. Understanding factors responsible for stability of organic compounds and organic reactions
5. Understanding basic stereochemistry of organic molecules
6. Understanding different types of interactions and bonding between atoms and ions

THEORETICAL (60 LECTURES)

CHEMISTRY GE-1

Basic physical chemistry I **(15 Lectures)**

Liquid state:

Physical properties of liquids and their measurements: surface tension and viscosity.

Thermodynamics I:

(a) Definition of thermodynamic terms: Intensive and extensive variables, isolated, closed and open systems. Cyclic, reversible and irreversible processes. Thermodynamic functions and their differentials. Zeroth law of thermodynamics, concept of heat (q) and work (w); IUPAC nomenclature of work and heat.

(b) First law of thermodynamics, internal energy (U) and enthalpy (H); relation between Cp and Cv, calculation of w, q, ΔU and ΔH for expansion of ideal gas under isothermal and adiabatic conditions for reversible and irreversible processes including free expansion, P, V, T relationship for adiabatic reversible process, Joule's Law Joule-Thomson Coefficient and inversion temperature.

(c) Application of First law of thermodynamics: standard state, standard enthalpy changes of physical and chemical transformations: fusion, sublimation, vaporization, solution, dilution, neutralization, ionization. Hess's law of constant heat summation. Bond- dissociation energy, Kirchhoff's equation, relation between ΔH and ΔU of a reaction.

Thermochemistry: 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.

General Chemistry **(10 Lectures)**

Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models: shell model; liquid-drop model; Concept of nuclear quantum number, magic numbers. Radioactive disintegration series – 4n, (4n+1), (4n+2) series; Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. Elementary idea on design of nuclear power plants; Separation and uses of isotopes. Radio chemical methods: principles of determination of age of rocks and minerals, radio carbon dating, hazards of radiation and safety measures.

Basic organic chemistry I **(20 Lectures)**

(a) Inductive effect, resonance and resonance energy. Homolytic and heterolytic bond breaking, electrophiles and nucleophiles; carbocations, carbanions and radicals (stability and reactivity)

(b) Aromatic Hydrocarbons: Structure of benzene, general mechanism of electrophilic substitution, reactions of benzene, Mechanisms and evidences in favour of it; orientation and reactivity; reactions: nitration, nitrosation, sulfonation, halogenation, Friedel-Crafts reaction

(c) Stereochemistry of carbon compounds:
Bonding geometries of carbon compounds and representation of molecules: tetrahedral nature of carbon and concept of asymmetry; Fischer, sawhorse, flying-wedge and Newman projection formulae and their inter translations.
Concept of chirality and symmetry: symmetry elements and point groups ($C_{\infty v}$, C_{nh}, C_{nv}, C_n, $D_{\infty h}$, D_{nh}, D_{nd}, D_n, S_n (C_s, C_i)); molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of epimers; concept of stereogenicity, chirotopicity(topic attribute and topic relationship) and pseudoasymmetry; chiral centres and number of stereoisomerism: systems involving 1/2/3-chiral centre(s) (AA, AB, ABA and ABC types).
Relative and absolute configuration: D/L and *R/S* descriptors; *erythro/threo* and *meso* nomenclature of compounds; *syn/anti* nomenclatures for aldols; *E/Z* descriptors for C=C, conjugated diene, triene, C=N and N=N systems; combination of *R/S*- and *E/Z*- isomerisms.

Basic inorganic chemistry I **(15 Lectures)**

(i) *Ionic bond:* General characteristics of ionic compounds, 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. Different ionic lattice and their structure; Madelung constant, Born-Haber cycle and its application, Solvation energy. Defects in solids (elementary idea) and applications. Solubility energetics of dissolution process – examples and illustrations.

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(ii) *Covalent bond:* Polarizing power and polarizability, ionic potential, Fazan's rules. Lewis structures, Applications of the different factors in explaining properties of molecules and ions; formal charge: concept and calculations. 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 – calculations of percentage of co-valency in molecules; ionic-covalent resonance, 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); Explanation of properties of molecules based on VSEPR theory and Bent's rule. Fluxional molecules: Examples with structural elucidation; Stereoactive and non-stereoactive lone pair.

Hydrogen bonding (theories of hydrogen bonding, valence bond treatment), receptor-guest interactions, Halogen bonds. Effects of chemical force, melting and boiling points.

PRACTICAL (60 LECTURES)

CHEMISTRY GE-1 LAB

Section A: Inorganic Chemistry - Volumetric Analysis

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of oxalic acid by titrating it with $KMnO_4$.
3. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
4. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.
5. Estimation of Cu (II) ions iodometrically using $Na_2S_2O_3$.

Section B: Organic Chemistry

1. Detection of extra elements (N, S, Cl, Br, I) in organic compounds
2. Test for the following functional groups.

Aromatic $-NO_2$, Aromatic $-NH_2$, -OH (phenolic), Carbonyl (aldehyde and ketone), --COOH and olefinic unsaturation.

3. Determination of the melting point of the compound

New addition: 70%	Modifications: 25%	Total change = 95%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Explain different physical properties of liquid, like, surface tension, viscosity etc.	PO 2	PSO 2	U
CO 2	Define different thermodynamic terms and apply first law of thermodynamics in chemical reactions	PO 3	PSO 2	R, Ap
CO 3	Choose correct reaction pathway or stable product utilizing the related concepts and theories	PO 2	PSO 2	Ap, C
CO 4	Interpret basic stereochemistry of organic molecules	PO 1	PSO 1	E
CO 5	Estimate the metal ions quantitatively in an unknown sample	PO 4	PSO 4	C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 06 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 17 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-4: A set of two questions carrying a total of 10 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CHEMISTRY GE-1

- Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
- Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
- Lee, J.D. Concise Inorganic Chemistry ELBS, 1991.
- Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley.
- Eliel, E.L. Stereochemistry of Carbon Compounds, Tata McGraw Hill education, 2000.
- Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S.
- Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010.

Reference Books for CHEMISTRY GE-1 LAB

Svehla, G. Vogel's Qualitative Inorganic Analysis, Pearson Education

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Course name	CHEMISTRY GE-2	
Course code	UGCHEMGE2	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Phase equilibrium for one component systems
2. Kinetics and related factors of chemical reactions
3. Laws of photochemistry and different theories of acid-base
4. Classification, preparation and properties of colloids
5. Reactions of carboxylic acids, carbohydrates and amino-acids
6. Theories, stereochemistry and IUPAC nomenclature of coordination compounds

THEORETICAL (60 LECTURES)

CHEMISTRY GE-1

Basic physical chemistry II **(35 Lectures)**

(a) Phase equilibrium:

Definitions of phase, component and degrees of freedom. Phase rule. Definition of phase diagram. Phase equilibria for one component system – water, CO_2.

Heterogeneous systems: Nernst Distribution Law, miscibility and distillation of binary liquid mixtures, azeotropic mixture, Critical Solution temperature, steam distillation.

(b) Chemical kinetics and catalysis:

Rate law, order and molecularity: Introduction of rate law, Extent of reaction; rate constants, order; Forms of rates of zero-, first, second and n^{th} order reactions; Pseudo first order reactions (example using acid catalyzed hydrolysis of methyl acetate); Determination of order of a reaction by method of integration, half-life and differential method, isolation method; Illustration of opposing reactions, consecutive reactions and parallel reactions with explanation of kinetic and thermodynamic control of products (all steps first order); steady state approximation for multistep chemical reactions.

Role of T 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 uni-molecular 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, pH dependence and temperature dependence of enzyme activity. Autocatalysis; periodic reactions.

(c) Photochemistry:

Lambert-Beer's law: Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, physical significance of absorption coefficients; Laws of photochemistry, Stark-Einstein law of photochemical equivalence quantum yield, actinometry, examples of low and high quantum yields and explanation

Photochemical Processes: Potential energy curves (diatomic molecules), Frank-Condon principle and vibrational structure of electronic spectra; Bond dissociation and principle of determination of dissociation energy (ground state); Decay of excited states by radiative and non-radiative paths; Pre-dissociation; First order photophysical processes: Non-radiative (vibrational relaxation, internal conversion, inter system crossing) and radiative prcesses (Fluorescence and phosphorescence), Jablonskii diagram; Brief features of fluorescence and phosphorescence spectra.

Role of photochemical reactions in biochemical processes, photostationary states, chemiluminescence

(d) Acids-bases and solvents:

Acid-Base concept: Arrhenius concept, theory of solvent system (in H_2O, NH_3, SO_2 and HF), Bronsted-Lowry's concept, Levelling and differentiating effect, concept of pH, calculation of pH and derivations of related mathematical expressions for strong acid and strong base, weak acid and weak base systems. pH calculation for weak di-basic acids. Buffer solutions-idea, calculation of pH in buffer solution – same system and different system buffer, buffer capacity, calculation of zwitterionic pH for different amino acids, acid-base neutralisation and related graphical presentation for strong acid-strong base, weak acid-strong base, strong acid-weak base and weak acid-weak base systems. Titration of amino acid; Choice of acid-base indicators, theory of selection of indicators. Hammett equation and super acid systems, Lewis theory of acid-base, examples and illustrations of Lewis theory, Lux-Flood concepts of acid-base, examples and illustrations of Lux-Flood theory, relative strength of hydracids, oxyacids - Pauling's empirical rules, Ricci modification. Thermodynamic acidity parameters, Drago-Wayland equation. Gas phase acidity and proton affinity; Acidity and basicity of metal ions and anions in aqueous solution – relation of pK_a and (Z^2/r), Application of the different theory in predicting acid-base strength of different organic and inorganic acids, proton sponge and hydride sponge, solid acid catalyst, HSAB principle; theoretical explanation of HSAB theory and applications of SHAB theory.

(e) Solutions of non-electrolytes:

Vapour pressure of solution; Ideal solutions, ideally diluted 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.

(f) Colloids:

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Colloids: Lyophobic and lyophilic sols, Origin of charge and stability of lyophobic colloids, Coagulation and Schultz-Hardy rule, Zeta potential and Stern double layer (qualitative idea), Tyndall effect; Electrokinetic phenomena (qualitative idea only); Determination of Avogadro number by Perrin's method; Stability of colloids and zeta potential; Micelle formation

Properties of colloids: Brownian motion, peptization, dialysis, Tyndal effect and its applications. Protecting colloids, gold number, isoelectric points, coagulation of colloids by electrolytes, Schulze-Hardy rule.

Basic organic chemistry II **(15 Lectures)**

(a) Carboxylic acids and their derivatives: acidity of carboxylic acids and effects of substituents on acidity, chemical reactivity, mechanism of esterification of carboxylic acids and hydrolysis of esters (BAC^2 and AAC^2 only)

(b) Carbohydrate: Aldoses up to 6 carbons; structure of D-glucose & D-fructose (configuration & conformation); ring structure of monosaccharides (furanose and pyranose forms); Haworth representations and non-planar conformations; anomeric effect (including stereoelectronic explanation); mutarotation; epimerization; reactions (mechanisms in relevant cases): Fischer glycosidation, osazone formation, bromine-water oxidation, HNO_3 oxidation, selective oxidation of terminal $-CH_2OH$ of aldoses, stepping–up by 1- and 2- carbon (Kiliani-Fischer method) and stepping–down (Ruff's & Wohl's methods) of aldoses; end-group-interchange of aldoses; acetonide (isopropylidene) and benzylidene protections; ring-size determination; Fischer's proof of configuration of (+)-glucose.

(c) *Amino acids:* synthesis with mechanistic details: Strecker, Gabriel, acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperazine; isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction, Dakin-West reaction.

Basic inorganic chemistry II **(10 Lectures)**

Coordinate bonding: Development of modern coordination chemistry: a historical perspectives, Jorgensen's chain theory. Werner's theory of coordination complexes, double and complex salts. Labile and inert complex; Classification of ligands based on denticity. Flexidentate ligands (examples with illustrations), Ambidentate ligands (examples with illustrations), bridging ligands (examples with illustrations). Chelating ligands (examples with illustrations), chelate complexes and their stability – kinetic and thermodynamic aspects, inner-metallic complex (examples with illustrations), types of inner-metallic complexes. Different coordination numbers (examples with illustrations), IUPAC nomenclature of coordination complexes (up to two metal centers), Isomerism in coordination compounds, their classifications, constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes. Identification of cis-trans isomers in square planar and octahedral complexes.

<u>Preparation and uses of the following compounds:</u>

Sodium borohydride, lithium aluminium hydride, calcium carbide, hydrazine, hydroxylamine, sodium bismuthate, sodium thiosulphate, potassium peroxydisulphate, Perchloric acid, potassium bromate, potassium ferrocyanide, Mohr's salt, potassium chromate, potassium dichromate and potassium permanganate.

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PRACTICAL (60 LECTURES)

CHEMISTRY GE-2 LAB

Inorganic Chemistry Semi-micro qualitative analysis (using H_2S or other methods) of mixtures - not more than four ionic species (two anions and two cations, excluding insoluble salts) out of the following:

Cations: NH_4^+, Pb^{2+}, Bi^{3+}, Cu^{2+}, Cd^{2+}, Fe^{3+}, Al^{3+}, Co^{2+}, Ni^{2+}, Mn^{2+}, Zn^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, K^+

Anions: CO_3^{2-}, S^{2-}, SO_2^-, $S_2O_3^{2-}$, NO_3^-, CH_3COO^-, Cl^-, Br^-, I^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, BO_3^{3-}, F^-

New addition: 45%	Modifications: 40%	Total change = 85%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Analyse how fast a chemical reaction can occur under certain physical conditions and what are the specific roles of different parameters affecting the speed or rate of any chemical reaction.	PO 2	PSO 4	R, An
CO 2	Apply laws of photochemistry to explain different photochemical reactions	PO 3	PSO 1	U, Ap
CO 3	Design new drug molecule utilizing the concepts of carbohydrate and proteins	PO 5	PSO 4	Ap, C
CO 4	Interpret theories, stereochemistry and IUPAC nomenclature of coordination compounds	PO 1	PSO 1	E
CO 5	Elaborate the principles of semimicro qualitative analysis to determine the presence of different elements in test samples	PO 4	PSO 2	E, C

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 20 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 06 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-3: A set of two questions carrying a total of 14 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-4: A set of two questions carrying a total of 10 marks for each question to be set. Students will be required to answer any one question out of the two questions.

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Reference Books for CHEMISTRY GE-2

- Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
- Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
- Lee, J.D. Concise Inorganic Chemistry ELBS, 1991.
- Cotton, F.A., Wilkinson, G. & Gaus, P.L. Basic Inorganic Chemistry, 3rd ed., Wiley.
- Eliel, E.L. Stereochemistry of Carbon Compounds, Tata McGraw Hill education, 2000.
- Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S.
- Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010.

Reference Books for CHEMISTRY GE 2 LAB

Svehla, G. Vogel's Qualitative Inorganic Analysis, Pearson Education

Course name	CHEMISTRY GE-3	
Course code	UGCHEMGE3	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Principles of thermochemistry
2. Different factors and equations related to salt hydrolysis
3. Application of solubility product principle in different chemical reactions
4. Preparation and reactions of different aromatic hydrocarbons
5. Preparation and reactions of alcohols, phenols, ethers, esters etc.
6. Preparation and reactions of aliphatic and aromatic carbonyl compounds

THEORETICAL (60 LECTURES)

CHEMISTRY GE-3

Section A: Physical Chemistry-1 **(30 Lectures)**

Chemical Energetics **(10 Lectures)**

Review of thermodynamics and the Laws of Thermodynamics.

Important principles and definitions of thermochemistry. 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

Statement of Third Law of thermodynamics and calculation of absolute entropies of substances.

Chemical Equilibrium: **(8 Lectures)**

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between G and G^o, Le Chatelier's principle. Relationships between Kp, Kc and Kx for reactions involving ideal gases.

Ionic Equilibria: **(12 Lectures)**

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect. concept of pH, calculation of pH and derivations of related mathematical expressions for strong acid and strong base, weak acid and weak base systems. pH calculation for weak di-basic acids. Buffer solutions-idea, calculation of pH in buffer solution – same system and different system buffer, buffer capacity, calculation of zwitterionic pH for different amino acids,

acid-base neutralisation and related graphical presentation for strong acid-strong base, weak acid-strong base, strong acid-weak base and weak acid-weak base systems.

Section B: Organic Chemistry-2 **(30 Lectures)**

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

Aromatic hydrocarbons **(8 Lectures)**

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).

Alkyl and Aryl Halides **(8 Lectures)**

Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (SN1, SN2 and SNi) reactions.

Preparation: from alkenes *and* alcohols.

Reactions: hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson's ether synthesis: Elimination vs substitution.

Aryl Halides *Preparation:* (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer & Gattermann reactions.

Reactions (Chlorobenzene): Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: 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.

Alcohols, Phenols and Ethers (Upto 5 Carbons) **(14 Lectures)**

Alcohols: *Preparation:* Synthesis and reactivity including pinacol-pinacolone rearrangement, Thiol, Thioether, Oxidation of 1,2-diols by periodic acid and lead tetraacetate

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, alk. $KMnO_4$, acidic dichromate, conc. HNO_3). Oppeneauer oxidation *Diols:* (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols: Reimer-Tiemann reaction, Kolbe's reaction, Manasse reaction, alkylation, acetylation, Fries rearrangement, Claisen rearrangement, nitration, sulphonation, halogenation, oxidation (aerial), oxidative coupling by Fe^{3+}, Dakin reaction, Cumene hydroperoxide method, from diazonium salts. 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.

Aldehydes and ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde, acetone and benzaldehyde)

Preparation: from acid chlorides and from nitriles.

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Reactions – Reaction with HCN, ROH, $NaHSO_3$, NH2 -G derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemensen reduction and Wolff Kishner reduction. Meerwein-Pondorff Verley reduction.

PRACTICAL (60 LECTURES)

CHEMISTRY GE-3 LAB

Section A: Physical Chemistry

Thermochemistry

1. Determination of heat capacity of calorimeter for different volumes.
2. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
3. Determination of enthalpy of ionization of acetic acid.
4. Determination of integral enthalpy of solution of salts (KNO3, NH4Cl).
5. Determination of enthalpy of hydration of copper sulphate.
6. Study of the solubility of benzoic acid in water and determination of *H*.

Ionic equilibria pH masurements

Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH-meter.

(a) Preparation of buffer solutions:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide

Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

Section B: Organic Chemistry

1. Purification of organic compounds by crystallization (from water and alcohol) and distillation.
2. Criteria of Purity: Determination of melting and boiling points.
3. Preparations: Mechanism of various reactions involved to be discussed. Recrystallisation, determination of melting point and calculation of quantitative yields to be done.

(a) Bromination of Phenol/Aniline

(b) Benzoylation of amines/phenols

(c) Oxime and 2,4-dinitrophenylhydrazone of aldehyde/ketone

New addition: 2%	Modifications: 10%	Total change = 12%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Apply the theories of thermochemistry in different chemical reactions	PO 2	PSO 1	Ap
CO 2	Solve various related problems utilizing the concepts and equations of salt hydrolysis	PO 3	PSO 1	Ap, C

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CO 3	Explain different chemical reactions considering solubility product principle	PO 2	PSO 2	E
CO 4	Design new chemical reactions of aromatic hydrocarbon applying the preparation and reactions of them	PO 5	PSO 4	Ap, C
CO 5	Explain different organic reactions of alcohols, phenols, ethers, esters	PO 2	PSO 2	E
CO 6	Determine physical parameters, like, pH, enthalpy, heat capacity of chemical compound or reaction	PO 2	PSO 3	E

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CHEMISTRY GE-3

- Graham Solomon, T.W., Fryhle, C.B. & Dnyder, S.A. Organic Chemistry, John Wiley & Sons (2014).
- McMurry, J.E. Fundamentals of Organic Chemistry, 7th Ed. Cengage Learning India Edition, 2013.
- Sykes, P. A Guidebook to Mechanism in Organic Chemistry, Orient Longman, New Delhi (1988).
- Finar, I.L. Organic Chemistry (Vol. I & II), E.L.B.S.
- Morrison, R.T. & Boyd, R.N. Organic Chemistry, Pearson, 2010.
- Bahl, A. & Bahl, B.S. Advanced Organic Chemistry, S. Chand, 2010.
- Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
- Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
- Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
- Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
- Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).

Reference Books for CHEMISTRY GE-3 LAB

- 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.
- Mann, F.G. & Saunders, B.C. Practical Organic Chemistry Orient-Longman, 1960.
- Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

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Course name	CHEMISTRY GE-4	
Course code	UGCHEMGE4	Credits: 6, Full Marks: 100
Number of lectures required: 120		
Marks Distribution (100)	Theory: Endsem (50) + Midsem (10) + Attendance (05) Practical: Experiment (30) + Attendance (05)	

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. The elementary idea on crystal field theory
2. The colour, magnetic properties and chemical potentials of coordination compounds of transition metals
3. Kinetic model of an ideal gas
4. Theoretical basis of Equipartition principle and its limitation
5. Evaluating numerical problems and experimentally determine the order, rate and activation energy of a chemical reaction
6. Classifications of different lattice systems and lattice parameters

THEORETICAL (60 LECTURES)

CHEMISTRY GE-4

Transition Elements (3*d* series) **(12 Lectures)**

General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu.

Lanthanoids and Actinoids:

General Comparison on Electronic configuration, oxidation states, colour, spectral and magnetic properties; lanthanide contraction, separation of lanthanides (ion-exchange method only). Applications of lanthanoids in optoelectronic devices, catalysis and MRI contrast agents.

Coordination Chemistry **(8 Lectures)**

Valence Bond Theory (VBT): Inner and outer orbital complexes of Cr, Fe, Co, Ni and Cu (coordination numbers 4 and 6). Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

Drawbacks of VBT. IUPAC system of nomenclature.

Crystal Field Theory **(10 Lectures)**

VB description and its limitations. Elementary Crystal Field Theory: splitting of d^n 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). Concept of MO formation based on LGO (Ligand Group Orbital) approach, d-orbital splitting pattern and CFSE for other geometry: square pyramidal, trigonal bipyramidal, square planar and tetrahedral. Metal-ligand bonding (MO concept, elementary idea) in square planar and tetrahedral complex. Magnetism and Colour: Orbital and

spin magnetic moments, spin only moments of d^n ions and their correlation with effective magnetic moments, including orbital contribution; quenching of magnetic moment: super exchange and antiferromagnetic interactions (elementary idea with examples only); d-d transitions; L-S coupling; qualitative Orgel diagrams for $3d^1$ to $3d^9$ ions. Racah parameter. Selection rules for electronic spectral transitions; spectrochemical series of ligands; charge transfer spectra (elementary idea).

Kinetic Theory of Gases **(8 Lectures)**

Kinetic Theory of gases: Concept of pressure and temperature; Collision of gas molecules; Collision diameter; Collision number and mean free path – mathematical formulations and explanations; Frequency of binary collisions (similar and different molecules); Wall collision and rate of effusion; Maxwell's distribution of speed and energy: Nature of distribution of velocities, Maxwell's distribution of speeds in one, two and three dimensions; Kinetic energy distribution in one, two and three dimensions, calculations of average, root mean square and most probable values in each case; Calculation of number of molecules having energy $\geq \varepsilon$, Principle of equipartition of energy, its derivation using kinetic energy distribution formula, and its application to calculate the classical limit of molar heat capacity of gasesReal gas and virial equation: Deviation of gases from ideal behaviour; compressibility factor; Boyle temperature; Andrew's and Amagat's plots and their interpretation; van der Waals equation and its features; its derivation and application in explaining real gas behaviour, other equations of state (Berthelot, Dietrici); Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states; virial equation of state; van der Waals equation expressed in virial form and significance of second virial coefficient; Intermolecular forces (Debye, Keesom and London interactions; Lennard-Jones potential - elementary idea)

Liquids **(6 Lectures)**

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).

Solids **(8 Lectures)**

Forms of solids. Symmetry elements, unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of Crystallography - Law of constancy of interfacial angles, Law of rational indices. Miller indices. X–Ray diffraction by crystals, Bragg's law. Structures of NaCl, KCl and CsCl (qualitative treatment only). Defects in crystals. Glasses and liquid crystals.

Chemical Kinetics **(8 Lectures)**

The concept of reaction rates. Effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction. Derivation of integrated rate equations for zero, first and second order reactions (both for equal and unequal concentrations of reactants). Half–life of a reaction. General methods for determination of order of a reaction. Concept of activation energy and its calculation from Arrhenius equation.

Theories of Reaction Rates: Collision theory and Activated Complex theory of bimolecular reactions. Comparison of the two theories (qualitative treatment only).

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PRACTICAL (60 LECTURES)

CHEMISTRY GE-4 LAB

Section A: Inorganic Chemistry

1. Estimate the amount of nickel present in a given solution as bis(dimethylglyoximato) nickel(II) or aluminium as oximate in a given solution gravimetrically.
2. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.
3. Estimation of total hardness of a given sample of water by complexometric titration.

Section B: Physical Chemistry

(I) Surface tension measurement (use of organic solvents excluded).

a) Determination of the surface tension of a liquid or a dilute solution using a stalagmometer.

b) Study of the variation of surface tension of a detergent solution with concentration.

(II) Viscosity measurement (use of organic solvents excluded).

a) Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald's viscometer.

b) Study of the variation of viscosity of an aqueous solution with concentration of solute.

(III) Chemical Kinetics

Study the kinetics of the following reactions.

3. Initial rate method: Iodide-persulphate reaction
4. Integrated rate method:
   c. Acid hydrolysis of methyl acetate with hydrochloric acid.
   d. Saponification of ethyl acetate.
   e. Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methyl acetate

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New addition: 35%	Modifications: 20%	Total change = 55%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Apply the knowledge of crystal field theory and its related aspects to discuss the chemistry of coordination compounds	PO 3	PSO 1	Ap, C
CO 2	Explain the colour, magnetic properties and chemical potentials of novel coordination compounds	PO 2	PSO 4	E
CO 3	Explain the theories of kinetic model of an ideal gas	PO 1	PSO 1	U
CO 4	Analyse and explain theoretical basis of Equipartition principle and its limitation	PO 2	PSO 3	An, E
CO 5	Explain and illustrate the structural features of different ionic solids based on crystallography	PO 2	PSO 1	U, E

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

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Question Pattern for End Semester Examination

UNIT-1: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

UNIT-2: A set of two questions carrying a total of 25 marks for each question to be set. Students will be required to answer any one question out of the two questions.

Reference Books for CHEMISTRY GE-4

- Barrow, G.M. *Physical Chemistry* Tata McGraw-Hill (2007).
- Castellan, G.W. *Physical Chemistry* 4th Ed. Narosa (2004).
- Kotz, J.C., Treichel, P.M. & Townsend, J.R. *General Chemistry* Cengage Learning India Pvt. Ltd., New Delhi (2009).
- Mahan, B.H. *University Chemistry* 3rd Ed. Narosa (1998).
- Petrucci, R.H. *General Chemistry* 5th Ed. Macmillan Publishing Co.: New York (1985).
- Cotton, F.A. & Wilkinson, G. *Basic Inorganic Chemistry,* Wiley.
- Shriver, D.F. & Atkins, P.W. *Inorganic Chemistry*, Oxford University Press.
- Wulfsberg, G. *Inorganic Chemistry,* Viva Books Pvt. Ltd.
- Rodgers, G.E. *Inorganic & Solid State Chemistry,* Cengage Learning India Ltd., 2008.

Reference Books for CHEMISTRY GE-4 LAB

- Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.

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ABILITY ENHANCEMENT COMPULSORY COURSES (AECC)

Course name	English for Communication	
Course code	UGCHEMAECC01	Credits: 2, Full Marks: 50
Number of lectures required: 30		

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Demonstrate mastery of the discipline by detailing the development and current practices of Listening, Speaking, Reading and Writing as Language skills.
2. Conduct research that engages and responds to diverse audiences of scholars, students, and community members.
3. Demonstrate values and ethics in all activities

COURSE CONTENT

Unit I: Introduction to Communication **(10 Lectures)**

- ✓ Process of Communication
- ✓ Levels of Communication
- ✓ Flow of Communication
- ✓ Verbal and Non-Verbal Communication
- ✓ Barriers to Communication

Unit II: Listening and Speaking Skills **(10 Lectures)**

Listening and its types.

- ✓ Barriers to effective listening,
- ✓ Trials of a good listener.
- ✓ Introduction to English Phonetic Symbols: Consonants and Vowels with illustrations in use.
- ✓ Dialogue
- ✓ Group Discussion
- ✓ Presentation
- ✓ Interview Technique.

Unit III: Reading and Writing Skills **(10 Lectures)**

- ✓ Techniques of Reading
- ✓ Types of Reading
- ✓ Reading Comprehension (unseen passage)
- ✓ Paragraph Writing
- ✓ Letter Writing
- ✓ Email Writing
- ✓ Report Writing
- ✓ Proposal writing
- ✓ Book Review
- ✓ Poster Making

New addition: 0%	Modifications: 0%	Total change = 0%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes	POs addressed	PSOs addressed	Cognitive Level
CO 1	Enhance their English language proficiency in the aspects of reading, writing, listening and speaking	PO 3	PSO 1	Ap, C
CO 2	Develop academic literacy required for undergraduate learning, further studies and research	PO 2	PSO 2	E
CO 3	Apply the requisite communicative skills and strategiesto future careers	PO 1	PSO 2	U
CO 4	Gain an insight into cultural literacy and cross-cultural awareness and engage in self-directed English languagelearning	PO 2	PSO 5	An, E
CO 5	Be responsible and ethical English users	PO 2	PSO 1	U, E

R = Remembering, U = Understanding, Ap = Applying, An = Analysing, E = Evaluating, C = Creating

Question Pattern for End Semester Examination (Course Code: AECC)

COMPONENT	NATURE OF THE QUESTION	MAXIMUM MARKS
Part A	Short answers	5 X 1 = 5 Marks
Part B	Listening	1 X 5 = 5 Marks
Part C	Speaking (Presentation and Project submission)	1 X 15 = 15 Marks
Part C	Reading Comprehension	1 X 5 = 5 Marks
Part C	Writing	2 X 5 = 10 Marks 1 X 10 = 10 Marks

Prescribed Books:

1. Vibrant English (New Delhi: Orient Black Swan)
2. Speak Well (New Delhi: Orient Black Swan) a compulsory supplementary Work Book forexercises on Interactions, dialogue, presentation skills, Group discussions, debates and Interviews.

Recommended Readings for advanced learning:

1. Advanced Skills in English. eds E Suresh Kumar et. al.
2. Practising Writing Skills, Work Book
3. Enhancing English and Employability Skills
4. Business Communication,
5. English for Fluency
6. English Language Practice
7. Basics of Academic English- 1 and 2
8. Practising English- all these are Orient Black Swan publications

Course name	Environmental Sciences	
Course code	UGCHEMAECC02	Credits: 2, Full Marks: 50
Number of lectures required: 30		

Course Objectives:

At the end of studying this course a student will acquire knowledge on:

1. Remembers and understands the concept, components and function of natural resources andecosystems.
2. Understand and evaluate the Cause, effects and control measures of various environmentalpollutants.
3. Understand the basic idea about the disasters and its management.
4. Understand and apply the knowledge about the social, environmental issues and environmental legislation.

Course Content

1. **Definition**, scope and importance. Need for public awareness. **(1 Lecture)**
2. **Natural Resources: Renewable and non-renewable**: Forest, Water, Mineral, Food, Energy & Land resources – Use and associated problems. **(4 Lectures)**
3. **Ecosystems:** Concept, Structure and function, Energy flow, Ecological succession, Food chains, food webs and ecological pyramids. Types – Forest, Grassland, Desert & Aquatic (ponds, streams, lakes, rivers, oceans, estuaries) ecosystems. **(6 Lectures)**
4. **Environmental Pollution:** Definition, Cause, effects and control measures of - Air, Water, Soil, Noise pollution and Nuclear hazards. Solid waste Management. Role of an individual in preventionof pollution. **(5 Lectures)**
5. **Disasters and management**: Floods, Earthquake, Cyclone and Landslides. **(4 Lectures)**
6. **Social Issues and the Environment:** Water conservation, rain water harvesting, watershed management. Resettlement and rehabilitation of people; its problems and concerns. Environmental ethics: Issues and possible solutions. Climate change, global warming, acid rain, ozone layer depletion, nuclear accidents and holocaust. Wasteland reclamation. Consumerism and waste products. Urban problems related to energy. **(5 Lectures)**
7. **Environmental legislation:** Environment Protection Act. Air (Prevention and Control of Pollution) Act. Water (Prevention and control of Pollution) Act. Wildlife Protection Act. Forest Conservation Act. Issues involved in enforcement of environmental legislation. Public awareness. **(4 Lectures)**
8. **Human Population and the Environment:** Population growth, variation among nations; Population explosion – Family Welfare Programme; Environment and human health (including HIV/AIDS); Human Rights; Role of Information Technology in Environment and human health. **(3 Lectures)**

New addition: 0%	Modifications: 0%	Total change = 0%
Note: The marked portions have been revised vide BOS meeting dated 18/02/2020		

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Course Outcomes:

After completion of this course the student will be able to

CO No.	Course Outcomes:	PO Addressed	PSOs Addressed	Cognitive Level
CO 1:	Define and demonstrate the concept, components andfunction of natural resources and ecosystems.	PO1	PSO 3	R, U
CO 2:	Define, illustrate and analyse the cause, effects and control measures of various environmental pollutants.	PO 3	PSO 3	R, U, An
CO 3:	Demonstrate the basic idea about the disasters and itsmanagement.	PO 3	PSO 3	U
CO 4:	Illustrate and apply the knowledge about the social, environmental issues and environmental legislation.	PO 4	PSO 3	U, Ap
CO 5:	Define, demonstrate and evaluate the impact of human population on the Environment	PO 6	PSO 3	R, U, E

R= remembering, U = understanding, Ap = applying, An = analysing, E = evaluating, and C = creating

Books Recommended for AECC02

1. Agarwal KC, 2001. Environmental Biology, Nidi Publishers Ltd. Bikaner.
2. Bharucha Erach, 2003. The Biodiversity of India, Mapin Publishing Pvt. Ltd, Ahmedabad – 380013,India. Email: mapin@icenet.net
3. Brunner RC, 1989, Hazardous Waste Incineration, McGraw Hill Inc. 480pgs.
4. Clark RS, Marine Pollution, Clanderson Press, Oxofrd (TB).
5. Cunningham WP, Cooper TH, Gorhani E & Hepworth MT, 2001. Environmental Encyclopaedia, Jaico Publishing House, Mumbai, 1196pgs.
6. De AK, Environmental Chemistry, Wiley Eastern Ltd.
7. Down to Earth, Center for Science and Environment (R)
8. Hawkins RE, Encyclopaedia of Indian Natural History, Bombay Natural History Society, Bombay (R)
9. Heywood V H and Watson R T, 1995. Global Biodiversity Assessment. Cambridge University Press1140pgs.
10. Mckinney ML and Schoch RM, 1996. Environmental Science Systems and Solutions. Web enhancededition, 639pgs.
11. Mhaskar AK, Matter Hazardous, Techno-Science Publications (TB)
12. Miller TG, Jr. Environmental Science, Wadsworth Publishing CO. (TB)
13. Odum EP, 1971. Fundamentals of Ecology. WB Saunders Co. USA, 574pgs.
14. Rao MN and Datta AK, 1987. Waste Water Treatment. Oxford and IBH Publishing Co. Pvt. Ltd.345pgs.

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