Ramakrishna Mission Residential College

(Autonomous)

Narendrapur, Kolkata – 700103

Department of Chemistry

Syllabi for Courses offered by the Department at Under Graduate Level

Under **CBCS**

2018

Programme Name: BSc with Honors in Chemistry

Programme Code: BSHCHE

Chemistry (Honours)

Objective: Chemistry is the science which deals with composition, properties, transformation of matter, study of structure and their interactions with energy. B Sc. Honours in chemistry lays down the foundation stone of all the traditional branches and emerging fields of Chemical Sciences. Nevertheless it is also important for those people who intend to pursue career in Chemical Engineering and Technology, Chemical Biology, Molecular Biology and Biotechnology etc.

The course has been designed to have insight in almost all the aspects of chemistry and to build a solid foundation in the subject to choose a career in industry/academics or research. The syllabus very well covers the area of basic science as well as areas like consumer products; soaps, detergents, shampoos, drugs, food and nutrients, industrially important chemicals, fertilizers, pigments etc. The employment areas for the B. Sc. chemistry graduates include pharmaceutical industries, chemical manufacturers, forensic science department, plastic industries, agrochemical industries, etc. Apart from these, they are also recruited in other fields such as oil, gas and power sectors, geological departments and even in defense services.

The B.Sc. chemistry graduates have many options for their higher studies. Some of the higher study options after B.Sc. chemistry honors are: M.Sc. in Chemistry (with specialization in Analytical Chemistry, Organic Chemistry, Inorganic Chemistry, Physical Chemistry and Biochemistry), Polymer Science and Pharmaceutical Science etc.

So Chemistry is a very promising subject for the under graduate students to pursue their academic/professional carrier.

Chemistry (Generic Elective)

Objective: This course is designed for the students who take Chemistry as an elective subject along with their chosen honours subject. Some of these honours subjects like Physics/Mathematics/Statistics/Computer Science etc specifically require some knowledge in chemistry. Hence this course is designed to cater to this specific need by chalking out a common minimum requirement of the above-mentioned disciplines, as far as practicable.

Name of the Programme: B.Sc. Chemistry Honours **Programme Code: BSHCHE**

Sl No.	Name of the Course	Semester	Course Code	Credit	Marks
1	Physical chemistry-I, Physical chemistry Practical-I	1	HCHE1CC01L	6	100
2	Inorganic Chemistry-I, Organic Chemistry-I, Organic Chemistry Practical-I	1	HCHE1CC02L	6	100
3	Inorganic Chemistry-II, Inorganic Chemistry Practical-I	2	HCHE2CC03L	6	100
4	Organic Chemistry-II, Physical chemistry-II, Organic Chemistry Practical-II	2	HCHE2CC04L	6	100
5	Inorganic Chemistry-III, Inorganic Chemistry Practical-II	3	HCHE3CC05L	6	100
6	Organic Chemistry-III, Organic Chemistry Practical-III	3	HCHE3CC06L	6	100
7	Physical chemistry-III, Physical chemistry Practical-II	3	HCHE3CC07L	6	100
8	Inorganic Chemistry-IV, Inorganic Chemistry Practical-III	4	HCHE4CC08L	6	100
9	Organic Chemistry-IV, Organic Chemistry Practical-IV	4	HCHE4CC09L	6	100
10	Physical chemistry-IV, Physical chemistry Practical-III	4	HCHE4CC010L	6	100
11	Inorganic Chemistry-V, Physical chemistry-V, Physical chemistry Practical-IV	5	HCHE5CC011L	6	100
12	Organic Chemistry-V, Organic Chemistry Practical-V	5	HCHE5CC012L	6	100
13	Polymer and Supramolecular Chemistry, Polymer Chemistry Practical	5	HCHE5DS11L	6	100
14	Green Chemistry, Green Chemistry practical	5	HCHE5DS12L	6	100
15	Analytical Chemistry, Analytical Chemistry Practical	5	HCHE5DS21L	6	100
16	Inorganic Materials of Industrial Importance, Inorganic Materials of Industrial Importance Practical	5	HCHE5DS22L	6	100
17	Inorganic Chemistry-VI, Organic Chemistry-VI, Inorganic Chemistry Practical-IV	6	HCHE6CC013L	6	100
18	Physical Chemistry-VI, Catalysis, Physical Chemistry Practical-V	6	HCHE6CC014L	6	100
19	Computer Application, Computer Application Practical	6	HCHE6DS31L	6	100
20	Industrial Chemicals and Environment, Industrial Chemicals & Environment Practical	6	HCHE6DS32L	6	100
21	Natural Products and Drugs, Natural Products and Drugs Practical	6	HCHE6DS41L	6	100
22	Molecular Modelling and Drug Design, Computational Calculations Practical	6	HCHE6DS42L	6	100
			Total	108	1800

Name of the course: B.Sc. CHEMISTRY GENERAL ELECTIVE

1	Essentials of Chemistry-I, Essentials of Chemistry-I Practical	1	HCHE1GE01L	6	100
2	Essentials of Chemistry-I, Essentials of Chemistry-I Practical	2	HCHE2GE01L	6	100
3	Essentials of Chemistry-II, Essentials of Chemistry-II Practical	3	HCHE3GE02L	6	100
4	Essentials of Chemistry-II, Essentials of Chemistry-II Practical	4	HCHE4GE02L	6	100
			Total	12	200

CHEMISTRY HONOURS SYLLABUS

SEMESTER – 1		
Course name	**Physical chemistry-I and Physical chemistry Practical-I**	
Course code	**HCHE1CC01L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- gaseous state.
- basic mathematics like differential and integral calculus and statistics like probability.
- first law of thermodynamics and energy conservation principle.
- electrical conductivity of solutions.
- chemical rate processes.
- physicochemical experiments.

Theoretical (50 M)

Physical Chemistry-I

Module-1: The gaseous state **8M**

*The gaseous state***:** deviation from ideal behaviour. Real gas isotherm-results of amagat's and andrews' experiments. Significance of the van der waals' equation and the explanation of the real gas behaviour using it. Continuity of state. Boyle temperature and the critical constants in terms of van der Waals'constants. Law of corresponding state. Virial equation of state. van der Waals' form of the second virial coefficient and the significance of the second virial coefficient.

Intermolecular forces: Debye, Keesom and London interactions, Lennard-Jones potential - elementary idea.

Module-2: Essentials of mathematical and statistical methods for chemistry **14M**

Mathematical Methods: Functions of a single variables-Concepts of Derivatives and Differentials, Interpretation of first order and second order derivatives, maxima, minima and point of inflection. Taylor's series and Maclaurin series expansions of functions of a single variable. Functions of multiple variables- Partial derivatives (first order and second order), Total differential, Chain rule, Interpretation of the partial derivatives, Idea of saddle point. (Examples to be restricted to the functions of two variables only). Homogeneous functions and Euler's theorem.

Definite integral (for functions of a single variable only) and area, Gamma functions, Error functions. Pfaff differential expressions, Exact and inexact differentials, Path dependent and path independent integrals – use of integrating factors and elementary idea of line integration.

*Principles of Statistics***:** Elementary Probability: Classical definition and its limitations, simple problems using classical definition. Random variables (discrete and continuous), Probability distribution –

probability mass function (p.m.f.) and probability density function (p.d.f), important characteristic features of probability distributions. Idea of Binomial, Normal and Gamma distributions.

Module-3: Thermodynamics I: Preliminaries, zeroth law, first law and energy 8M

Introduction: Importance and scope, definition of system and surroundings, types of systems. Extensive and intensive properties and state of a system.Steady state and equilibrium state.

Preliminaries: Thermodynamic coordinates, equation of state, change of state, thermodynamic processes. State functions and path functions. Concept of heat and work (IUPAC convention).Reversible and irreversible processes. Calculation of work done and P-Vdiagrams for different processes.

*The zeroth law***:** Concept of thermal equilibrium, the zeroth law of thermodynamics and temperature.

First law of thermodynamics: Statement. Law of existence and conservation of the state function 'Energy(U)'. Joule's experiment and its consequence. Applications of the First Law to adiabatic and isothermal changes.

Module-4: Electrochemistry I - electrolytic conductance 8M

Electrolytic Conductance: Types of conductors, types of Electrolytes. Ionogens and ionophores.Ions in Solution, solvodynamic radius. Conductance of electrolyte solutions: specific conductance, equivalent conductance of electrolytes and its splitting into ionic conductance. Variation of Conductance for weak and strong electrolytes. Kohlrausch empirical equation, Kohlrausch's law of independent migration of ions. Conductance at infinite dilution. Debye –Huckel theory of Ion atmosphere (qualitative)-asymmetric effect, relaxation effect and electrophoretic effect. Migration of ions: ionic mobility, transference number. Principles of Hittorf's method and moving boundary method.Principle of conductance measurement.Determination of Λo. Principles of conductometric titration.

Module-5: Chemical kinetics 12M

Introduction of reaction rate in terms of extent of reaction: rate constants, order and molecularity of reactions. Principles of determination of order of a reaction by half-life and differential methods. Order with respect to concentration vs. order with respect to time. Principles of determination of rate constant by physical property measurement. Rate- determining step and steady-state approximations - explanation with suitable examples. Opposing reactions, consecutive reactions and parallel reactions (all steps first order).Kinetic and thermodynamic control of products. Chain reactions.

Temperature dependence of rate constant: Arrhenius equation, energy of activation.

Collision theory (detailed treatment), transition state theory (thermodynamic treatment), Lindeman theory of unimolecular reaction

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Practical (30 M)

Physical Chemistry Practical-I

(Exp -20 M, LNB-05 M and Viva-voce- 05 M)

At least 5-6 experiments are to be done in this semester. More experiments may be included to the following set of experiments. The following experiments may be replaced by equivalent/better experiments in a semester.

1. Determination of the specific rotation of an optically active substance and the concentration of a supplied solution of the substance.
2. Determination of the partition coefficient of a solute between water and an immiscible liquid.

3. Determination of the solubility and solubility product of Potasium hydrogen tartrate in water and in KCl solution.
4. Determination of solubility product of lead iodide by titrimetric method.
5. Determination of cell constant of a conductance cell.
6. Determination of pH of a unknown buffer solution by color matching method.

Question Pattern for End Semester Examination
(HCHE1CC01L)

Module-1: A set of questions carrying a total of 12 to 14 marks to be set. Students will be required to answer questions of 8 marks only.

Module-2: A set of questions carrying a total of 21 to 24 marks to be set. Students will be required to answer questions of 14 marks only.

Module-3: A set of questions carrying a total of 12 to 14 marks to be set. Students will be required to answer questions of 8 marks only.

Module-4: A set of questions carrying a total of 12 to 14 marks to be set. Students will be required to answer questions of 8 marks only.

Module-5: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Reference Books for HCHE1CC01L

Theory:

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. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
7. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, TataMcGraw-Hill
8. Koltz & Rosenberg, Chemical Thermodynamics: Basic Concepts and Methods 7th Edition. Wiley-Interscience.
9. The Principles of Chemical Equilibrium 3rd Edition, Kenneth Denbigh, Cambridge University Press; 3rd Edition (1971).
10. The Principles of Chemical Equilibrium 3rd Edition, Kenneth Denbigh, Cambridge University Press; 4rd Edition (1981).
11. An Introduction To Electrochemistry, Samuel Glasstone, East-West Press (Pvt.) Ltd. (2006).
12. Principles of Physical Chemistry; Samuel H. Maron, Carl F. Prutton; The Macmillan Company; 4th edition (1970).
13. Silbey, R. J., Alberty, R. J. and Bawendi, M. G. Physical Chemistry; Wiley-India; 4th edition
14. Bevan Ott, J. and Boerio-Goates, J. Chemical Thermodynamics: Principles and Applications, Elsevier

15. Graetzel, M. &Infelta, P., The Bases of Chemical Thermodynamics; Overseas Press
16. Moore, W. J. Physical Chemistry, Orient Longman
17. Laidler, K. J. Chemical Kinetics, Pearson
18. Saha, M. N. and Srivastava, A Treatise on Heat, The Indian Publisher.
19. Loeb, L. B. Kinetic Theory of Gases, McGraw-Hill book Company.
20. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).
21. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier(2005).

Practical:

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

SEMESTER – 1	
Course name	**Inorganic Chemistry-I, Organic Chemistry-I and Organic Chemistry**

	Practical-I	
Course code	**HCHE1CC02L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- different types of bonding such as ionic, covalent and coordinate bonding.
- extra nuclear structure of atoms.
- hybridization, geometry, steric hindrance, electronegativity, polarity, formal charges and stereochemistry.
- detection of special elements present in solid organic compounds, solubility of organic compounds functional group(s) present in the sample, melting point determination, preparation of derivative(s) of the sample, purification of the derivative.
- the survey of literature of the sample.

Theoretical (50 M)

Inorganic Chemistry-I and Organic Chemistry-I

Group-A

Module-1: Chemical bonding-I **15M**

(i) *Ionic bond:* General characteristics, types of ions, size effects, radius ratio rule and its application and limitations. Packing of ions in crystals . Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.Defects in solids (elementary idea). Solubility energetics of dissolution process

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

Module-2: Extra nuclear structure of atom **10M**

Quantum numbers and their significance, Schrödinger's wave equation, significance of ψ and ψ^2. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals. Pauli's Exclusion Principle, Hund's rules and multiplicity, Exchange energy, Aufbau principle and its limitations, Ground state Term symbols of atoms and ions for atomic number upto 30.

Group-B

Module-1: Bonding and physical properties **13M**

Valence Bond Theory: Concept of hybridisation, shapes of molecules, resonance (including hyperconjugation); calculation of formal charges and double bond equivalent (DBE); 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: Inductive effect, field effect, mesomeric effect, resonance energy; bond polarization and bond polarizability; electromeric effect; steric effect, steric inhibition of resonance.

MO theory: Qualitative idea about molecular orbitals, bonding and antibonding interactions, idea about σ, σ^*, π, π^*, n – MOs; concept of HOMO, LUMO and SOMO; 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 [8] annulene (including mononuclear heterocyclic compounds up to 6-membered ring); concept of antiaromaticity and homoaromaticity; non-aromatic molecules; Frost diagram (qualitative drawing).

Physical properties: Influence of hybridization on bond properties: bond dissociation energy (BDE) and bond energy; bond distances, bond angles; concept of bond angle strain; 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 and heat of combustion data.

Concept of organic acids and bases: Effect of structure, substituent and solvent on acidity and basicity; proton sponge; comparison between nucleophilicity and basicity;

Module-2: Stereochemistry I **12M**

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, molecular chirality and centre of chirality; asymmetric and dissymmetric molecules; enantiomers and diastereomers; concept of stereogenicity, chirotopicity 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.

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

Practical (30 M)

Organic Chemistry Practical-I

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

Experiment: Qualitative analysis of single solid organic compounds

1. Detection of special elements (N, S, Cl, Br) by Lassaigne's test
2. Solubility and classification (solvents: H_2O, 5% HCl, 5% NaOH and 5% $NaHCO_3$)
3. Detection of the following functional groups by systematic chemical tests: aromatic amino (-NH_2), aromatic nitro (-NO_2), amido (-$CONH_2$, including imide), phenolic –OH, acid groups, carbonyl (distinguish between -CHO and >C=O); only one test for each functional group is to be reported.
4. Melting point of the given compound.
5. Preparation, purification and melting point determination of a crystalline derivative of the given compound.
6. Identification of the compound through literature survey.

Question Pattern for End Semester Examination

(**HCHE1CC02L**)

Group-A

Module-1: A set of questions carrying a total of 23 to 26 marks to be set. Students will be required to answer questions of 15 marks only.

Module-2: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Group-B

Module-1: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-2: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Reference Books for HCHE1CC02L

Group-A

Theory:

1. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
2. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
3. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
4. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
5. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
6. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
7. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
8. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Group-B

Theory:

1. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
2. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
3. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
4. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
6. James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
7. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
8. Smith, B. M. March's Advanced organic Chemistry: Reaction, Mechanism and Structure, Seventh Edition.
9. Carey, F.A., Sundberg, R. J. Advanced Organic Chemistry: Structure and Mechanism (Part A), Springer India Private Limited.

Practical:

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).
6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
7. Vogel, A. I A Text Book of Practical Organic Chemistry Including Qualitative organic Analysis. Third edition. ELBS and Longman group Limited.

SEMESTER – 2		
Course name	**Inorganic Chemistry-II and Inorganic Chemistry Practical-I**	
Course code	**HCHE2CC03L**	Credits:6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- acid base reactions.
- chemical bonding in advanced level.
- chemical periodicity.
- quantitative inorganic analysis.

Theoretical (50 M)

Inorganic Chemistry-II

Module-1: Acid-base reactions **15M**

Acid-Base concept: Arrhenius concept, theory of solvent system (in H_2O, NH_3, SO_2 and HF), Bronsted-Lowry's concept, relative strength of acids, Pauling's rules. Lux-Flood concept, Lewis concept, group characteristics of Lewis acids, solvent levelling and differentiating effects. Thermodynamic acidity parameters, Drago-Wayland equation. Superacids, Gas phase acidity and proton affinity; HSAB principle. Acid-base equilibria in aqueous solution (Proton transfer equilibria in water), pH, buffer. Acid-base neutralisation curves; indicator, choice of indicators.

Module-2: Chemical bonding-II **20M**

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

Module-3: Chemical periodicity **15M**

Modern IUPAC Periodic table, Effective nuclear charge, screening effects and penetration, Slater's rules, 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- and d-block elements. Secondary periodicity, Relativistic Effect, Inert pair effect.

Practical (30 M)

Inorganic Chemistry Practical-I

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

1. Preparation of standard solution and acid base titration.
2. Standardization of NaOH solution using standard oxalic acid solution and determination of strength of unknown H_2SO_4 solution.
3. Estimation of carbonate and bicarbonate in a mixture.
4. Standardization of $KMnO_4$ solution using standard oxalic acid solution and estimation of Mohr's salt.
5. Estimation of Mohr's salt using standard $K_2Cr_2O_7$.
6. Standardization of sodium thiosulphate using standard $K_2Cr_2O_7$ solution and estimation of iodine content in iodized salts.
7. Determination of strength of H_2O_2 using standard $KMnO_4$ solution.
8. Complexometric determination of total hardness of H_2O.

Question Pattern for End Semester Examination

(**HCHE2CC03L**)

Module-1: A set of questions carrying a total of 23 to 26 marks to be set. Students will be required to answer questions of 15 marks only.

Module-2: A set of questions carrying a total of 30 to 35 marks to be set. Students will be required to answer questions of 20 marks only.

Module-3: A set of questions carrying a total of 23 to 26 marks to be set. Students will be required to answer questions of 15 marks only

Reference Books for HCHE2CC03L

Theory:

1. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
2. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
3. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
4. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
5. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
6. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
7. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
8. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Practical:

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

SEMESTER – 2		
Course name	**Organic Chemistry-II, Physical Chemistry-II and Organic Chemistry Practical-II**	
Course code	**HCHE2CC04L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

- **Objectives:** At the end of studying this course a student will acquire knowledge on
- reaction mechanism, reactive intermediates, reaction thermodynamics, tautomerism, reaction kinetics.
- stereochemistry in advanced level.
- separation and purification of organic compounds, determination of melting point and boiling points.
- the state parameters,
- ideal machines, Effiency of a machine, limits to the conversion of heat to work,
- Total energy available of a collection of matter (Enthalpy),
- The auxilary functions - Free energy that guide the direction of a process, feasibility of any process etc.
- liquid state and electrical properties of molecules
- kinetic theory of gases.

Theoretical (50 M)

Organic Chemistry-II and Physical Chemistry-II

Group-A

Module-1: General treatment of reaction mechanism 13M

Mechanistic classification: Ionic, radical and pericyclic (definition and example); reaction type: addition, elimination and substitution reactions (definition and example); nature of bond cleavage and bond formation: homolytic and heterolytic bond fission, homogenic and heterogenic bond formation; curly arrow rules in representation of mechanistic steps; reagent type: electrophiles and nucleophiles (elementary idea).

Reactive intermediates: Carbocations (carbenium and carbonium ions), non-classical cabocations, carbanions, carbon radicals, carbenes: generation and stability, structure using orbital picture and electrophilic/nucleophilic behavior of reactive intermediates (elementary idea).

Reaction thermodynamics: Free energy and equilibrium, enthalpy and entropy factor, calculation of enthalpy change *via* BDE, intermolecular & intramolecular reactions. Application of thermodynamic principles in acid-base equilibria.

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

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

Module-2: Stereochemistry II **12M**

Chirality arising out of stereoaxis: Stereoisomerism of substituted cumulenes with even and odd number of double bonds; chiral axis in allenes, spiro compounds, alkylidenecycloalkanes and biphenyls;related configurational descriptors (R_a/$S_{a);}$ atropisomerism; racemisation of chiral biphenyls.

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*).

Group-B

Module-1: Thermodynamics II: The second law and entropy, the auxiliary functions and applications to the systems of fixed composition **12M**

Second law of thermodynamics: The need of a second law. Kelvin – Planck (KP) and Clausius (CL) statements and their equivalence. Efficiency of heat engines; Carnot's theorems. Refrigerator and heat pump. Carnot's Cycle.

Entropy (S) –definition and concept. Clausius inequality. Criteria for spontaneity and equilibrium. Entropy and unavailable work.

Second law in terms of entropy. Validity of KP and CL statements and W_{rev} *vs* W_{irrev} from entropic point of view. Diagrammatic representation of various thermodynamic processes using T, P, V, U and S as coordinates. Non-crossing of two adiabats. Applications of the second law and entropy to different processes.

The combined form of the first and second laws-the fundamental equation for U and S.

Auxiliary state functions: Enthalpy (H), Helmholtz Energy (A) and Gibbs energy (G). The fundamental equations for H, A and G. The concept of available work. Criteria for spontaneity and equilibrium in terms of S, U, H, A and G.

Thermodynamic Relationships: Response of U, S, H, A and G towards the change of P, V, T and relations to measurable properties. Maxwell relations. Thermodynamic equations of state. Gibbs-Helmholtz equations. Changes of U, S, H, A and G in different processes.

Heat changes in constant pressure and in constant volume processes. C_P, C_V and $C_P - C_V$ relation. Joule-Thomson Experiment and its consequences. Joule-Thomson coefficient for real gases. Inversion temperature.

Module-2: **Liquid state and electrical properties of molecules** **6M**

Liquid State: Short range order and long range disorder in liquids. Vapour pressure. Surface tension, surface energy, excess pressure, capillary rise and measurement of surface tension. Work of cohesion and

adhesion, spreading of liquid over other surface. Vapour pressure over curved surface. Temperature dependence of surface tension. Transport phenomena in liquid state: diffusion and viscosity flux, force, phenomenological coefficients & their inter-relationship (general form), different examples of transport properties.

Diffusion: The concepts and Fick's First Law.

Viscosity: General features of fluid flow (streamline flow and turbulent flow). Newton's equation, Newtonian's fluid, viscosity coefficient. Poiseuille's equation. Stokes law of viscosity. Temperature dependence of viscosity.

Electrical properties of molecules: Polarizability of atoms and molecules, dielectric constant and polarization, molar polarization for polar and nonpolar molecules. Clausius-Mosotti equation and Debye equation (both without derivation) and their application in determination of dipole moment.

Module-3:- Kinetic theory of gases **7M**

Kinetic theoretical interpretation of pressure, temperature and energy.

Nature of distribution of molecular velocity and speed in one, two and three dimensions. The Maxwell-Boltzmann distribution of molecular speeds. Different measures of speed and velocity of gas molecules. Kinetic energy distribution in one, two and three dimensions. Calculation of the number of molecules having at least certain critical amount of energy.

Principle of equipartition of energy and computation of heat capacity of gases. Temperature variation of heat capacity.

Collision of gas molecules-collision diameter and collision frequency. Mean free path. Wall collision frequency. Effusion and Graham's law. Viscosity of gases and its temperature dependence

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Practical (30 M)

Organic Chemistry Practical-II
(Exp-20 M, LNB-05 M and Viva Voce 05 M)

Separation based upon solubility, by using common laboratory reagents like water (cold, hot), dil. HCl, dil. NaOH, dil. $NaHCO_3$, *etc*., of components of a binary solid mixture; purification of **any one** of the separated components by crystallization and determination of its melting point. The composition of the mixture should be of the following types **[ANY THREE]**: *p*-Nitrobenzoic acid/*p*-Aminobenzoic acid; *p*-Nitrotolune/*p*-Anisidine; benzoic acid/naphthalene; urea/phenyl benzoate; *p*-toluidine/benzophenone; *p*-chlorobenzoic acid/benzophenone, Benzoic acid/Anthracene; Glucose/Biphenyl; Benzoic acid/Benzophenone; Urea/Benzophenone. **Use of pH paper** is recommended.

Each student is required to perform all the experiments [Any **FIVE** will be set in the examination]

1. Estimation of glycine by Sörensen's formol method
2. Estimation of glucose by titration using Fehling's solution
3. Estimation of sucrose by titration using Fehling's solution
4. Estimation of aromatic amine (aniline) by bromination (Bromate-Bromide) method
5. Estimation of acetic acid in commercial vinegar
6. Estimation of urea (hypobromite method)
7. Estimation of saponification value of oil/fat/ester

8. Preparation of ferrous oxalate dihydrate, $FeC_2O_4.2H_2O$ and determination of composition of $FeC_2O_4.2H_2O$.

Determination of boiling point of common organic liquid compounds [**ANY FIVE**]*n*-butyl alcohol, cyclohexanol, ethyl methyl ketone, cyclohexanone, acetylacetone, isobutyl methyl ketone, isobutyl alcohol, acetonitrile, benzaldehyde and acetophenone. [Boiling points of the chosen organic compounds should preferably be within 180^0C (Demo)].

Question Pattern for End Semester Examination
(HCHE2CC04L)

Group-A

Module-1: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-2: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Group-B

Module-1: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-2: A set of questions carrying a total of 9 to 11 marks to be set. Students will be required to answer questions of 6 marks only.

Module-3: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Reference Books for HCHE2CC04L

Group-A

Theory:

1. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
2. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
3. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
4. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
5. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
6. James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
7. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
8. Smith, B. M. March's Advanced organic Chemistry: Reaction, Mechanism and Structure, Seventh Edition.
9. Carey, F.A., Sundberg, R. J. Advanced Organic Chemistry: Structure and Mechanism (Part A), Springer India Private Limited.

Practical:

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).
6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
7. Vogel, A. I A Text Book of Practical Organic Chemistry Including Qualitative organic Analysis. Third edition. ELBS and Longman group Limited.

Group-B

Theory:

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. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
7. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata McGraw-Hill
8. Koltz & Rosenberg, Chemical Thermodynamics: Basic Concepts and Methods 7th Edition. Wiley-Interscience.
9. The Principles of Chemical Equilibrium 3rd Edition, Kenneth Denbigh, Cambridge University Press; 3rd Edition (1971).
10. The Principles of Chemical Equilibrium 3rd Edition, Kenneth Denbigh, Cambridge University Press; 4rd Edition (1981).
11. An Introduction To Electrochemistry, Samuel Glasstone, East-West Press (Pvt.) Ltd. (2006).
12. Principles of Physical Chemistry; Samuel H. Maron, Carl F. Prutton; The Macmillan Company; 4th edition (1970).
13. Silbey, R. J., Alberty, R. J. and Bawendi, M. G. Physical Chemistry; Wiley-India; 4th edition
14. Moore, W. J. Physical Chemistry, Orient Longman
15. Saha, M. N. and Srivastava, A Treatise on Heat, The Indian Publisher
16. Loeb, L. B. Kinetic Theory of Gases, McGraw-Hill book Company.

SEMESTER – 3

Course name	Inorganic Chemistry-III and Inorganic Chemistry Practical-II	
Course code	HCHE3CC05L	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- basic coordination chemistry of inorganic compounds
- radioactivity
- redox reactions
- chemistry of s and p block elements
- noble gases
- inorganic polymers
- qualitative semimicro analysis of inorganic compounds

Theoretical (50 M)
Inorganic Chemistry-III

Module-1: Coordination chemistry-I **12M**

Coordinate bonding: double and complex salts. Werner's theory of coordination complexes, Classification of ligands, Ambidentate ligands, chelates, Coordination numbers, IUPAC nomenclature of coordination complexes (up to two metal centers), Isomerism in coordination compounds, constitutional and stereo isomerism, Geometrical and optical isomerism in square planar and octahedral complexes.

Module-2: Radioactivity **7M**

Nuclear stability and nuclear binding energy. Nuclear forces: meson exchange theory. Nuclear models (elementary idea): Concept of nuclear quantum number, magic numbers. Nuclear Reactions: Artificial radioactivity, transmutation of elements, fission, fusion and spallation. Nuclear energy and power generation. 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.

Module-3: Redox reactions **12M**

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). Electroanalytical methods: Basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of pKa values

Solubility and solubility product – common ion effect and their applications to the precipitation and separation of common metallic ions as hydroxides, sulfides, phosphates, carbonates, sulfates and halides.

Module-4: Chemistry of *s* and *p* block elements 14M

Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation.Hydrides and their classification ionic, covalent and interstitial.Basic beryllium acetate and nitrate.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, silanes, Oxides and oxoacids of nitrogen, phosphorus, sulphur and chlorine.Peroxo acids of sulphur, sulphur-nitrogen compounds, 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).

Module-5: Inorganic rings and cages: 5M

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes.

Practical (30 M)

Inorganic Chemistry Practical-II

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

Qualitative semi-micro analyses of mixtures containing not more than two radicals and only one insoluble salt. Emphasis should be given to the understanding of the chemistry of different reactions.

Cations: 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+} (Demo), Bi^{3+} (Demo), Sn^{2+}/Sn^{4+}, As^{3+}/As^{5+}(Demo), $Sb^{3+/5+}$ (Demo), NH_4^+, Mg^{2+} (Demo).

Anions: 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), SnO_2, $SrSO_4$, $BaSO_4$, CaF_2, $PbSO_4$.

Question Pattern for End Semester Examination

(**HCHE3CC05L**)

Module-1: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-2: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module-3: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-4: A set of questions carrying a total of 21 to 24 marks to be set. Students will be required to answer questions of 14 marks only.

Module-5: A set of questions carrying a total of 8 to 9 marks to be set. Students will be required to answer questions of 5 marks only.

Reference Books for HCHE3CC05L

Theory:

1. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
2. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
3. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
4. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
5. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
6. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
7. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
8. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Practical:

1. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.
2. Svehla, G., Vogel's Qualitative Inorganic Analysis, Seventh Edition, Pearson.

SEMESTER – 3

Course name	Organic Chemistry-III and Organic Chemistry Practical-III	
Course code	HCHE3CC06L	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- chemistry of alkene and alkynes
- chemistry of carbonyl compounds
- will acquire knowledge of elimination and substitution reactions

Theoretical (50 M)

Organic Chemistry-III

Module-1: Chemistry of alkenes and alkynes **13M**

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

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

Module-2: Carbonyl and related compounds **13M**

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

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

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

Module-3: Substitution reactions 12M

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

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

Module-4: Elimination reactions and aromatic substitution 12M

Elimination reactions: E1, E2, E1cB and Ei (pyrolytic *syn* eliminations); formation of alkenes and alkynes; mechanisms (with evidence), reactivity, regioselectivity (Saytzeff/Hofmann)and stereoselectivity; comparison between substitution and elimination.

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

Nucleophilic aromatic substitution: Addition-elimination mechanism and evidences in favour of it; S_N1 mechanism; cine substitution (benzyne mechanism), structure of benzyne.

Practical (30 M)
Organic Chemistry Practical-III

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

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

1. Nitration of aromatic compounds
2. Condensation reactions
3. Hydrolysis of amides/imides/esters
4. Acetylation of phenols/aromatic amines
5. Brine mediated benzoylation of amines/amino acids.
6. Side chain oxidation of aromatic compounds
7. Diazo coupling reactions of aromatic amines
8. Bromination of anilides using green approach (Bromate-Bromide method)
9. Redox reaction including solid-phase method
10. Green 'multi-component-coupling' reaction

11. Selective reduction of *m*-dinitrobenzene to *m*-nitroaniline
Students must also calculate percentage yield, based upon isolated yield (crude) and theoretical yield.

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

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

Question Pattern for End Semester Examination
(HCHE3CC06L)

Module-1: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-2: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-3: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-4: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Reference Books for HCHE3CC06L

Theory:

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. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Carey, F.A., Sundberg, R. J. Advanced Organic Chemistry: Structure and Mechanism (Part A), Springer India Private Limited.
8. Carey, F.A., Sundberg, R. J. Advanced Organic Chemistry: Reaction and Synthesis (Part B), Springer India Private Limited.

Practical:

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).
6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
7. Vogel, A. I A Text Book of Practical Organic Chemistry Including Qualitative organic Analysis. Third edition. ELBS and Longman group Limited.

SEMESTER – 3

Course name	Physical Chemistry-III and Physical Chemistry Practical-II	
Course code	HCHE3CC07L	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- Advanced level Thermodynamics. Conditions for Chemical and other types of equilibrium.
- conductometric method.
- study of kinetics of acid-catalyzed hydrolysis ester.
- the determination of pH of a supplied solution using E versus
- pH curves involving quinhydrone electrode.
- adsorption and surfactants

Theoretical (50 M)

Physical Chemistry-III

Module-1: Thermodynamics III: Systems of variable composition, chemical energetics and chemical reaction equilibrium 18M

Thermodynamics of Systems of variable composition:

Chemical Potential: Composition as a variable. Chemical potential (μ) and other partial molar properties. Chemical potential in terms of G, H, U and A. Chemical potential and material equilibrium. Other partial molar properties and interrelation among various partial molar properties, T, P dependence of μ. Maxwell relations involving chemical potential. Gibbs –Duhem equation.

Gaseous Phase: i) Pure ideal gas-its Chemical potential and other thermodynamic functions. ii) Ideal mixture of ideal gases- thermodynamic parameters of mixing. Chemical potential of an ideal gas in an ideal gas mixture.

Concept of standard states and choice of standard state of ideal gases.

Condensed Phase: i) Chemical potential of pure solid and pure liquids. ii) Ideal solutions: Raoult's law. Definition and mixing properties of ideal solutions. Chemical potential of a component in an ideal solution.

Real Gas: i) Pure real gas-its chemical potential, fugacity, fugacity coefficient. Estimation of fugacity. i) Mixture of real gases: Chemical potential and fugacity of a real gas in a mixture. Mixing of real gases-differences from mixing of ideal gases. Ideal mixtures of real gases, the Lewis-Randal rule. Choice of standard states of real gases.

Ideally Dilute Solution: Henry's law. Definition and choice of standard states of solvent and solutes.

Non-ideal, Non-electrolytic solutions: Chemical potentials of the components of a real solution. Activity and activity coefficients. Conventions regarding the standard states and activity coefficients. The molality and molarity scales and standard states.
Excess thermodynamic functions-definition and significance only.
Condensed Phase: Choice of standard states of solids and liquids. Activity of pure solids and pure liquids. Extension of the activity concept of gases.
Chemical Energetics: Thermodynamic functions (U,S,H,A,G) of chemical reactions and their standard values. Hess' law. Heats of reaction at constant pressure and constant volume. Effect of temperature on "reaction heats" – Kirchoff's equation. Bond enthalpy.
Chemical Reaction Equilibrium: Spontaneous reactions and equilibrium condition. Variation of reaction free energy as a function of advancement of reaction and its explanation. The law of mass action and the equilibrium constant. Equilibrium involving ideal gases: K_p and other forms of equilibrium constants.
Equilibrium involving real gases: K_f
Equilibrium involving gases together with immiscible liquids and/or solids.
Reaction equilibrium in solution: K_a and equilibrium constants expressed in molality and molarity scales.
Coupled reactions.
Effects, if any, of the following on the equilibrium constant and equilibrium composition-temperature, pressure, volume, an inert substance, catalyst.
Thermodynamic treatment of Le Chattelier principle.

Module-2: Electrochemistry II- equilibrium electrochemistry 14M

Thermodynamics of Electrolytic solutions: 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.
Electrochemical cells: Types of electrochemical cells with examples. Cell reactions. Concept and definition of half-cell potential. Standard electrode potential (IUPAC convention).Thermodynamic derivation of Nernst equation (emf).Hydrogen electrode and standard hydrogen electrode. Calomel electrodes (normal, decinormal and saturated calomel), quinhydrone electrode, glass electrode and their uses. Half-cells of various kinds for different redox couples. Principles of determination of emf of cells (Pogendroff compensation principle). Representation of half cells and cells from cell/ half-cell equilibria, Types of concentration cells. Liquid junction potential and its minimization. Potentiometric titrations (acid- base and redox). Principles of determination of (i) standard electrode potential, (ii) ΔG, ΔH and ΔS of cell reactions from emf measurements.

Module-3: Electrochemistry III - ionic equilibrium 12M

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; dissociation constants of mono-, di-and triprotic acids (exact treatment). Solubility, Thermodynamic and concentration solubility product, Effect of added salts, common ion effect.
Salt hydrolysis, calculation of hydrolysis constant, degree of hydrolysis and pH for different salts (exact Treatment). Buffer solutions, derivation of Henderson equation and its applications, buffer capacity,

buffer range, buffer action. Qualitative treatment of acid -base titration curves (calculation of pH at various stages). Theory of acid–base indicators; selection of indicators and their limitations.

Module-4: Adsorption and surfactants **6M**

Physical and chemical adsorption. Freundlich and Langmuir adsorption isotherms. BET isotherm. Gibbs adsorption isotherm and surface excess, Surface active and surface inactive agents. Surfactants including Bio-surfactants, Micellisation of surfactants.

Practical (30 M)

Physical Chemistry Practical-II

(Exp -20 M, LNB-05 M and Viva-voce- 05 M)

1. Determination of concentration of supplied solution by surface tension measurement using calibration curve.
2. Determination of concentration of supplied solution by viscocity measurement using calibration curve.
3. Study of kinetics of acid-catalyzed hydrolysis of methyl acetate at two catalyst concentration.
4. Conductometric titration of a mixture of a strong acid and a weak acid.
5. Determination of Λ_o of a strong electrolyte conductometrically.
6. Determination of pH of a supplied solution using E versus pH curves involving Quinhydrone electrode.
7. Verification Beer's and Lambert's Law for $KMnO_4/K_2Cr_2O_7$ solution using a spectrophotometer.

Question Pattern for End Semester Examination

(HCHE3CC07L)

Module-1: A set of questions carrying a total of 27 to 30 marks to be set. Students will be required to answer questions of 18 marks only.

Module-2: A set of questions carrying a total of 21 to 24 marks to be set. Students will be required to answer questions of 14 marks only.

Module-3: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-4: A set of questions carrying a total of 9 to 11 marks to be set. Students will be required to answer questions of 6 marks only.

Reference Books for HCHE3CC07L

Theory:

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. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
7. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, Tata McGraw-Hill
8. Koltz & Rosenberg, Chemical Thermodynamics: Basic Concepts and Methods 7th Edition. Wiley-Interscience.
9. The Principles of Chemical Equilibrium 3rd Edition, Kenneth Denbigh, Cambridge University Press; 3rd Edition (1971).
10. The Principles of Chemical Equilibrium 3rd Edition, Kenneth Denbigh, Cambridge University Press; 4rd Edition (1981).
11. An Introduction To Electrochemistry, Samuel Glasstone, East-West Press (Pvt.) Ltd. (2006).
12. Principles of Physical Chemistry; Samuel H. Maron, Carl F. Prutton; The Macmillan Company; 4th edition (1970).
13. Silbey, R. J., Alberty, R. J. and Bawendi, M. G. Physical Chemistry; Wiley-India; 4th edition
14. Bevan Ott, J. and Boerio-Goates, J. Chemical Thermodynamics: Principles and Applications, Elsevier
15. Graetzel, M. &Infelta, P., The Bases of Chemical Thermodynamics; Overseas Press
16. Surface Chemistry Essentials, K. S. Birdi., CRC Press 1st Edition (November 28, 2013).
17. Arthur W. Adamson, Physical Chemistry of Surfaces, Wiley-Interscience; 6th Edition (August 18, 1997).
18. Duncan J. Shaw; Introduction to Colloid and Surface Chemistry, 4th Edition, Butterworths; 3rd edition (1980).
19. John O'M. Bockris, Amulya K. N. Reddy; Modern Electrochemistry Volume 2; Springer, Boston, USA.

Practical:

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

SEMESTER – 4		
Course name	**Inorganic Chemistry-IV and Inorganic Chemistry Practical-III**	
Course code	**HCHE4CC08L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- the nature of the ligand and the coordination complexes, their IUPAC names and their isomeric forms.
- Electronic Spectra and Magnetism of inorganic compounds.
- Chemistry of d- and f- Block Elements structure and bonding in certain specific compounds in d- and f- block elements
- will acquire knowledge on transition metal hydride, dihydrogen and dinitrogen complexes.

Theoretical (50 M)

Inorganic Chemistry-IV

Module-1: Coordination chemistry-II **13M**

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).

Module-2: Electronic spectra and magnetism **12M**

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).

Module-3: Chemistry of d- and f- block elements **13M**

Transition Elements: General comparison of 3d, 4d and 5d elements in term of electronic configuration, oxidation states, redox properties, coordination chemistry. Peroxo, superoxo and oxometallate.

Lanthanoids and Actinoids: General Comparison on Electronic configuration, oxidation states, colour, spectral and magnetic properties; lanthanide contraction, separation of lanthanides (ion-exchange method only).

Module-4: Transition metal hydride, dihydrogen and dinitrogen complexes 12M

Hydride as a ligand, transition metal complexes of hydrides (molecular structures), importance of hydride complexes. Molecular hydrogen complexes, structure and reactivity of dihydrogen complexes, dihydrogen bonding and H-H bond cleavage, dihydrogen/dihydride equilibrium. Molecular nitrogen as a ligand. Dinitrogen complexes of transition metal ions, activation and functionalization of molecular nitrogen by metal complexes.

Practical (30 M)

Inorganic Chemistry Practical-III

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

(i) Iodo/Iodimetric:

1. Estimation of Vitamin C
2. Estimation of Copper in brass
3. Estimation of Fe(III) and Cu(II) in a mixture

(ii) Complexometric titration:

1. Zn(II) in a Zn(II) and Cu(II) mixture.
2. Ca(II) and Mg(II) in a mixture.

(iii) Permanganometry and dichromometry

1. Estimation of Fe(III) and Ca(II) in a mixture
2. Estimation of Fe(III) and Cr(VI) in a mixture
3. Estimation of Fe(III) and Mn(II) in a mixture

Question Pattern for End Semester Examination
(HCHE4CC08L)

Module-1: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-2: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-3: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-4: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Reference Books for HCHE4CC08L

Theory:

1. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
2. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
3. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
4. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.

5. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
6. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
7. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
8. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Practical:

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

SEMESTER – 4		
Course name	**Organic Chemistry-IV and Organic Chemistry Practical-IV**	
Course code	**HCHE4CC09L**	Credits: 6 Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- nucleophilic behaviours of the α-carbon of the carbonyl compounds, reactivity of carbonyl compounds, related name reactions and organometallics.
- nitrogen compounds and rearrangements
- carbohydrates-its reactions and synthesis
- applications of UV and IR spectroscopic techniques in the characterization of organic compounds.
- identification of solid and liquid organic compounds by system chemical analysis including detection of element(s), functional group(s); preparation of derivatives, determination of melting points and literature survey.

Theoretical (50 M)

Organic Chemistry-IV

Module-1: Exploitation of acidity of α-H of C=O and organometallics 13M

Exploitation of acidity of α-H of C=O: Formation of enols and enolates; kinetic and thermodynamic enolates; reactions (mechanism with evidence):halogenation of carbonyl compounds under acidic and basic conditions, Hell-Volhard-Zelinsky (H. V. Z.) reaction, nitrosation, SeO_2 (Riley) oxidation; condensations (mechanism with evidence): Aldol,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 and silyl enol ethers) in connection with alkylation, acylation and aldol type reaction.

Grignard reagent, *Organolithium, 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 behaviour of Grignard reagents; comparison of reactivity among Grignard, organolithiums and organocopper reagents; Reformatsky reaction; Blaise reaction; concept of *umpolung*.

Module-2: Nitrogen compounds and rearrangements 12M

Nitro compounds (aliphatic and aromatic): Ppreparation and reaction (with mechanism): reduction under different conditions; Nef carbonyl synthesis, Henry reaction and conjugate addition of nitroalkane anion.

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, formation and reactions of phenylenediamines, diazomethane and diazoacetic ester.

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

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

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.

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

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**,** Sommelet Hauser rearrangement, Fischer-Hepp rearrangement, *N*-azo to *C*-azo rearrangement, Bamberger rearrangement, Orton rearrangement and benzidine rearrangement.

Module-3: Carbohydrates 12M

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 (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.

Module- 6: Spectroscopy I 13M

UV Spectroscopy: Introduction;types of electronic transitions, end absorption; transition dipole moment and allowed/forbidden transitions; chromophores and auxochromes; Bathochromic andHypsochromic 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; 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.

Practical (30 M)

Organic Chemistry Practical-IV (30 M)

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

Identification of the pure compounds

Solid compounds: oxalic acid, tartaric acid, citric acid, succinic acid, resorcinol, urea, glucose, cane sugar, benzoic acid, salicylic acid, beta-naphthol, lactose and starch.

Liquid Compounds: formic acid, acetic acid, methyl alcohol, ethyl alcohol, acetone, aniline, dimethylaniline, benzaldehyde, chloroform, nitrobenzene, benzylalcohol and glycerin.

Question Pattern for End Semester Examination
(HCHE4CC09L)

Module-1: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-2: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-3: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-4: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Reference Books for HCHE4CC09L

Theory:

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

7. Finar, I. L. Organic Chemistry (Volume 1 & 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Smith, B. M. March's Advanced organic Chemistry: Reaction, Mechanism and Structure, Seventh Edition.
9. Kemp, W. Organic Spectroscopy, third edition, Palgrave.
10. Pavia, Lampman, Kriz, Vyvyan, Introduction to Spectroscopy, Cengage Learning India Private Limited.
11. Silverstein, R. M., Webster F. X., Spectrometric Identification of Organic Compounds, John Wiley & Sons.
12. P. S. Kalsi, Spectroscopy of Organic Compounds, New Age International Private Limited.
13. Williams, D., Fleming, I. Spectroscopic Methods In Organic Chemistry, McGraw-Hill Education

Practical:

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).
6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
7. Vogel, A. I A Text Book of Practical Organic Chemistry Including Qualitative organic Analysis. Third edition. ELBS and Longman group Limited.

SEMESTER – 4

Course name	Physical Chemistry-IV and Physical Chemistry Practical-III	
Course code	HCHE4CC010L	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

Objectives: At the end of studying this course a student

- principle and applications quantum mechanics.
- molecular spectroscopy, magnetic resonance spectroscopy.
- solid state and phase equilibrium.
- the determinationestimation by conductometric titration, redox titration, pH metric titration and spectrophotometric methods.

Theoretical (50 M)

Physical Chemistry-IV

Module-1: Quantum mechanics I- principles and applications **20M**

Introduction, de Broglie hypothesis-the principle and example applications.

Schrodinger equation (SE), wave function and its interpretation. The time-independent form of SE - characteristic features. Stationary state wave functions- significance, probabilistic interpretation and acceptability conditions. Orthonormality of wave functions-definition.

Elementary concepts of operators- relevant properties and identities. Linear operator, eigen functions and eigen values; commutator of operators. Hermitian operators- definition and properties. Operators and observables.

Vector representations of state, inner product, operator actions, expectation values and Schrodinger equation.

Postulates of Quantum Mechanics.

Measurements and Heisenberg's Uncertainty relation (without derivation)- the microscope experiment. The fundamental commutator and uncertainty relation. Non-commuting operators and uncertainty relation.

Eigen functions as basis. Expansion in Eigen functions.

Quantum Free-Particle (normalisation of wave function excluded).

Particle in a box (PB): Solution of the Schrodinger equation for one-dimensional (1-D) box problem. Distinctive features of the eigen spectrum. Calculations expectation values of x, x^2, p_x p_x^2 and the uncertainty product $\Delta x.\Delta p_x$. Classical Limit and correspondence principle. Extension of the problem to two and three dimensions and the concept of degeneracy.

Simple Harmonic Oscillator: Setting up of one Schrödinger equation and characteristic features s of the energy spectrum and the wave functions. The exact wave functions for the ground and the first excited states. Comparison with classical oscillator. Calculation of the average values of x, x^2, p_x , p_x^2 and the uncertainty product.

Module-2: Molecular spectroscopy and magnetic resonance spectroscopy 16M

Molecular spectroscopy: B. O. approximation (mention only), Characteristic features of spectral lines (spacing and intensity) and the factors influencing the spectral intensities- selection rules, Lambert-Beer's Law and population effect.

Rotational spectroscopy of diatomic molecules: rigid rotor model, determination of bond length, effect of isotopic substitution, effect of nuclear spin (mention only).

Vibrational spectroscopy of diatomic molecules: SHO model, selection rules, spectra, anharmonicity and its consequences on energy levels and selection rules. Overtones and hot bands.

Vibrational-Rotational spectra of diatomic and linear triatomic molecules.

Raman Effect: Characteristic features and conditions of Raman activity with suitable illustrations. Rotational and vibrational Raman spectra. Polarisation of Raman scattering.

Rule of mutual exclusion with examples. Examples of molecular structure elucidation using spectral data.

Magnetic Resonance Spectroscopy: Introduction, basis of magnetic resonance spectroscopy, nmr active nuclei, the nmr spectrometer (Principle and schematic representation); chemical shift and δ scale, Shielding constant and its dependence on different contributions (elementary physical idea only). Qualitative discussion of spin-spin coupling and line structure splitting. Equivalent nuclei (in respect of two protons) and its simple consequences.

Applications of magnetic resonance spectroscopy.

Module-3: Solid state 7M

Types of solid, Bragg's law of diffraction. Laws of crystallography (Haüy's law and Steno's law). Permissible symmetry axes in crystals. Indexing of planes, Miller indices. Lattice, space lattice, Module-cell, crystal planes, Bravais lattice. Distance between consecutive planes [cubic, tetragonal and orthorhombic lattices]. Relation between molar mass and Module- cell dimension for cubic system. Applications of Bragg's law and powder method in determination of patterns of NaCl and KCl. Packing of uniform hard sphere close packed arrangements (fcc and hcp). Tetrahedral and octahedral voids. Void space in p-type, F-type and I-type cubic systems.

Module-4: Phase equilibrium 7M

Definitions of phase, number of components and degrees of freedom. Gibbs' Phase rule and its derivation using the concept of chemical potential. Definition of phase diagram. First order phase transition and Clapeyron equation: Clausius- Clapeyron equation – derivation and uses.

Phase Equilibria for one component system – Water, carbon dioxide and sulphur. (Phase rule treatment and the phase diagrams only).

Condensed state phase diagram, solid-liquid phase diagram studies, eutectic mixtures. Systems having congruent and incongruent melting points- Bi-Cd, Sb-Tb, KI-H_2O, NaCl-H_2O, Sn-Mg, Na_2SO_4-H_2O mixtures only. Nernst distribution law-derivation and applications.

Practical (30 M)

Physical Chemistry Practical-III

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

At least 5-6 experiments are to be done in this semester. More experiments may be included to the following set of experiments. The following experiments may be replaced by equivalent/better experiments in a semester.

1. Determination of the strength of HCl and NaCl in their mixture by conductometric titration.
2. Determination of E^0 of Fe^{2+}/ Fe^{3+} and strength of a Mohr's salt solution against standard $K_2Cr_2O_7$/$KMnO_4$ solution.
3. Determination of $K_{sp}$of AgCl of and the strength of a silver nitrate solution by potentiometric titration of a $AgNO_3$ solution against a standard KCl solution.
4. Determination of the K_a of a weak mono-basic acid and the strength of its solution by pH-metric titration against a strong base.
5. Study of kinetics of decomposition of H_2O_2 catalysed by $FeCl_3$.
6. Determination of the solubility and solubility product of a sparingly soluble salt by conductometric method.
7. Kinetics of alkaline fading of crystal violet spectrophotometrically.

Question Pattern for End Semester Examination
(HCHE4CC010L)

Module-1: A set of questions carrying a total of 30 to 35 marks to be set. Students will be required to answer questions of 20 marks only.

Module-2: A set of questions carrying a total of 24 to 26 marks to be set. Students will be required to answer questions of 16 marks only.

Module-3: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module-4: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Reference Books for HCHE4CC010L

Theory:

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. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
7. Principles of Physical Chemistry; Samuel H. Maron, Carl F. Prutton; The Macmillan Company; 4th edition (1970).
8. Silbey, R. J., Alberty, R. J. and Bawendi, M. G. Physical Chemistry; Wiley-India; 4th edition
9. Beiser, A. Concepts of Modern Physics; McGraw-Hill
10. Eisberg, R.&Resnick, R. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles; Wiley
11. Levine, I. N. Quantum Chemistry; PHI Learning Private Limited
12. Lowe, J. P. Quantum Chemistry; Academic Press

13. Griffith, D. J. Introduction to Quantum Mechanics; Pearson education
14. Banwell, C. N. and Elaine, M. M. Fundamentals of Molecular Spectroscopy; McGraw-Hill Education
15. Sathyanarayana, D. N Introduction to Magnetic Resonance Spectroscopy ESR, NMR, NQR; I K International Publishing House Pvt. Ltd.
16. Abraham, R. J., Fisher, J. and Loftus, P. Introduction to NMR Spectroscopy; Wiley
17. Balci, M. Basic 1H- and 13C-NMR Spectroscopy; Elsevier.
18. James Keeler, Understanding NMR Spectroscopy, Wiley-Blackwell; 2nd edition (13 April 2010).
19. Charles Kittel, Introduction to Solid State Physics, Wiley; Eighth edition (2012).
20. Roger S. Macomber, Introduction to NMR Spectroscopy, Wiley-Interscience; 1st Edition (December 23, 1997).

Practical:

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

SEMESTER – 5		
Course name	**Inorganic Chemistry-V, Physical Chemistry-V and Physical Chemistry Practical-IV**	
Course code	**HCHE5CC011L**	Credits: 6 Full Marks: 100

Number of lectures required: 105
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance

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

- bioinorganic chemistry and organometallic chemistry**.**
- quantum mechanics – its applications to two-body systems, variation theorem, elementary discussions of atomic and molecular electronic structures.
- Colligative properties and colloids.
- the Physicochemical experiments.

Theoretical (50 M)

Inorganic Chemistry-V and Physical Chemistry-V

Group-A

Module-1: Bioinorganic chemistry 13M

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: Haemoglobin, Myoglobin, Hemocyanine and Hemerythrin. Hydrolytic enzymes: carbonate bicarbonate buffering system and carbonic anhydrase and carboxyanhydrase A. Toxic metal ions and their effects, chelation therapy (examples only), Pt and Au complexes as drugs (examples only), metal dependent diseases (examples only)

Module-2: Organometallic chemistry I 12M

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.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.

Group-B

Module-1: Quantum Mechanics II- Applications to Two-Body Systems, Variation Theorem, Elementary Discussions of Atomic and Molecular Electronic Structures. 18M

The Two-Body Systems: The statement of the problem and the concept of reduced mass and reduced coordinates. Setting up the Schrodinger equation for the two-body problemsin the rectangular Cartesian coordinates and the separation of the centre-of-mass motion and the internal motion (outlines only). The Schrodinger equation for the internal motion in spherical polar coordinates (the final form only).

Two-Body Rigid Rotor and Angular momentum: Schrödinger equation for rigid rotor in spherical polar coordinates and the separation of variables (outlines only).Solution of the φ part. Rigid rotor wave

functions -spherical harmonics, features of the wave functions, quantum numbers. The rigid rotor energy spectrum- characteristic features.

Angular momentum- Definitions, commutation relations and eigen spectrum (without derivation) significance of the results.

The rigid rotor Hamiltonian in terms of angular momentum (L) and the L^2 operator in spherical polar coordinates (final form only).L_Z operator in spherical polar coordinates (final form only) and its eigen spectrum.

Hydrogen atom and hydrogen-like ions: Setting up of Schrödinger equation in spherical polar coordinates, Separation of variables, Solution of angular Part (φ part only), quantization of energy (only final energy expression); Real wave functions. Average and most probable distances of electron from nucleus;

Setting up of Schrödinger equation for many-electron atoms (He, Li). -need for approximation methods.

Statement of variation theorem and example applications to simple systems.

Chemical Bonding: Linear combination of atomic orbitals (LCAO) method.

Born-Oppenheimer approximation. Separation of nuclear and electronic moions (outlines only)

Covalent bonding: valence bond (VB) and molecular orbital (MO) 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. Introduction to MO treatment of simple diatomic and prototype AH_2 systems (basic ideas).

Module-2: Colligative properties and colloids 7M

Colligative properties: Thermodynamic treatment of colligative properties viz. Elevation of boiling point, depression of freezing point and van't-Hoff osmotic pressure equation of solutions using the concept of chemical potential and their interrelationships. Abnormal colligative properties.

Lyophobic and lyophilic sols, Origin of charge of colloids, coagulation and Schultz-Hardy rule. Zeta potential and Stern double layer (qualitative idea). Electro kinetic phenomena (qualitative idea only). Stability of colloids and zeta potential, Tyndall effect.

Practical (30 M)

Physical Chemistry Practical-IV

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

At least 5-6 experiments are to be done in this semester for this paper. More experiments may be included to the following set of experiments. The following experiments may be replaced by equivalent/better experiments in a semester.

1. Determination of the ionisation constants of a poly-basic acid and the strength of its solution by pH-metric titration against a strong base.
2. Determination of the degree of dimerization and the dimerization constant of benzoic acid in an organic solvent by partition method.
3. Kinetics study of saponification reaction conductometrically.
4. Verification of Ostwald dilution law and determination of dissociation constant of a weak acid conductometrically.
5. Determination of the indicator constant of an acid-base indicator spectrophotometrically.
6. Studies on perdisulphate kinetics(spectrophotometrically)

7. Determination of heat of neutralization of a strong acid *vs* strong base.
8. Studies on kinetics of auto-catalyzed reaction between potassium permanganate and oxalic acid.

Question Pattern for End Semester Examination
(HCHE5CC011L)

Group-A

Module-1: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-2: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Group-B

Module-1: A set of questions carrying a total of 27 to 30 marks to be set. Students will be required to answer questions of 18 marks only.

Module-2: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Reference Books for HCHE5CC011L

Group-A

Theory:

1. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
2. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
3. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
4. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
5. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
6. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
7. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
8. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Group-B

Theory:

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. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
7. An Introduction to Electrochemistry, Samuel Glasstone, East-West Press (Pvt.) Ltd. (2006).
8. Principles of Physical Chemistry; Samuel H. Maron, Carl F. Prutton;The Macmillan Company; 4th edition (1970).
9. Silbey, R. J., Alberty, R. J. and Bawendi, M. G. Physical Chemistry; Wiley-India; 4th edition
10. Beiser, A. Concepts of Modern Physics; McGraw-Hill
11. Eisberg, R. & Resnick, R. Quantum Physics of Atoms, Molecules, Solids, Nuclei, and Particles; Wiley
12. Levine, I. N. Quantum Chemistry; PHI Learning Private Limited
13. Lowe, J. P. Quantum Chemistry; Academic Press; Second Edition
14. Griffith, D. J. Introduction to Quantum Mechanics; Pearson education
15. Ghosh, P. K. & Shukla, P. K. Atomic Electronic Structure: Atomic Orbitals; PHI Learning Private Limited
16. Wardle, B. Principles and Applications of Photochemistry; Wiley Gil, V. Orbitals in Chemistry; Cambridge
17. Albright, T. A., Burdett, T. A., Whangbo, M.-H. Orbital Interactions in Chemistry, Wiley.
18. Gil, V. Orbitals in Chemistry; Cambridge
19. Albright, T. A., Burdett, T. A., Whangbo, M.-H. Orbital Interactions in Chemistry, Wiley.
20. Paul C. Hiemenz, R. Rajagopalan, Principles of Colloid and Surface, CRC Press; 3rd Edition (March 18, 1997).

Practical:

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

SEMESTER – 5		
Course name	**Organic Chemistry-V and Organic Chemistry Practical-V**	
Course code	**HCHE5CC012L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		

*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance

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

- ^{1}H NMR and Mass spectroscopy in the structure determination of organic compounds.
- conformation and reactivity of cyclic molecules and preparation and reactions of polyaromatic hydrocarbons.
- pericyclic reactions
- properties, synthesis and reactions of heterocyclic compounds.
- TLC and column Chromatographic techniques in separation of organic amino acids and dyes.

Theoretical (50 M)

Organic Chemistry-V

Module-1: Organic spectroscopy II **13M**

NMR Spectroscopy: Introduction;nuclear spin;NMR active molecules;basic principles of Proton Magnetic Resonance; choice of solvent and internal standard; 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 ; 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.

Mass Spectroscopy: Basic principle, McLafferty rearrangement metastable peak, General fragmentation mode, Retro-Diels Alder reaction, determination of presence and isotopic pattern for one halogen atom.

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

Module-2: Cyclic stereochemistry and carbocycles **12M**

Alicyclic compounds: Concept of I-strain (Baeyer's strain theory); conformational analysis: cyclohexane, mono and disubstituted cyclohexane; 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), nucleophilic substitution (S_N1, S_N2, S_Ni, NGP), merged substitution-elimination; rearrangements; oxidation of cyclohexanol, esterification, saponification, lactonisation, epoxidation, pyrolytic *syn* elimination and fragmentation reactions.

Polynuclear hydrocarbons and their derivatives: Synthetic methods include Haworth, Bardhan-Sengupta, Bogert-Cook and other useful syntheses (with mechanistic details); fixation of double bonds and Fries rule;reactions (with mechanism) of naphthalene, anthraceneand phenanthrene and their derivatives.

Module-3: Pericyclic reactions **13M**

Mechanism, stereochemistry, regioselectivity in case of

Electrocyclic reactions: FMO approach involving 4π- and 6π-electrons (thermal and photochemical) and corresponding cycloreversion reactions.
Cycloaddition reactions: FMOapproach, 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.

Module-4: Heterocycles **12M**

Heterocyclic compounds: Biological importance of heterocycles referred in the syllabus; 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 approachand mechanistic details): indole: Fischer,quinoline: Skraup, isoquinoline: Bischler-Napieralski synthesis.

Practical (30 M)

Organic Chemistry Practical-V

(Exp-20 M, LNB-05 M and Viva Voce 05 M)

A. *Chromatographic Separations*

1. TLC separation of a mixture containing 2/3 amino acids.
2. TLC separation of a mixture of dyes (fluorescein and methylene blue).
3. Column chromatographic separation of mixture of dyes.
4. Paper chromatographic separation of a mixture containing 2/3 amino acids.
5. Paper chromatographic separation of a mixture containing 2/3 sugars.

B. *Spectroscopic Analysis of Organic Compounds:*

1. Assignment of labelled peaks in the ^{1}H NMR spectra of the known organic compounds explaining the relative δ-values and splitting pattern.
2. Assignment of labelled peaks in the IR spectrum of the same compound explaining the relative frequencies of the absorptions (C-H, O-H, N-H, C-O, C-N, C-X, C=C, C=O, N=O, C≡C, C≡N stretching frequencies; **characteristic bending vibrations are included**).
3. The students must record full spectral analysis of **at least 15 (fifteen)** compounds from the following list:
   4-Bromoacetanilide (ii) 2-Bromo-4-methylacetophenone (iii) Vanillin (iv) 2-Methoxyacetophenone (v) 4-Aminobenzoic acid (vi) Salicylamide (vii) 2-Hydroxyacetophenone (viii) 1,3-Dinitrobenzene (ix) *trans*-Cinnamic acid (x) Diethyl fumarate (xi) 4-Nitrobenzaldehyde (xii) 4-Methylacetanilide (xiii) Mesityl oxide (xiv) 2-Hydroxybenzaldehyde (xv) 4-Nitroaniline (xvi) 2,3-Dimethylbenzonitrile (xvii) Pent-1-yn-3-ol (xviii) 3-Nitrobenzaldehyde (xix) 3-Aminobenzoic acid (xx) Ethyl-3-aminobenzoate (xxi) Ethyl-4-aminobenzoate (xxii) 3-Nitroanisole (xxiii) 4-Oxo-pentanoic acid (xxiv) Benzylacetate (xxv) Diethylmaleate.

Question Pattern for End Semester Examination
(HCHE5CC012L)

Module-1: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Module-2: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-3: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only

Module-4: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Reference Books for HCHE5CC012L

Theory:

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 & 2), 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.
13. Fleming, I. Pericyclic Reactions, 2nd edition, OUP Oxford.
14. Smith, B. M. March's Advanced organic Chemistry: Reaction, Mechanism and Structure, Seventh Edition.
15. Kemp, W. Organic Spectroscopy, third edition, Palgrave.

16. Pavia, Lampman, Kriz, Vyvyan, Introduction to Spectroscopy, Cengage Learning India Private Limited.
17. Silverstein, R. M., Webster F. X., Spectrometric Identification of Organic Compounds, John Wiley & Sons.
18. P. S. Kalsi, Spectroscopy of Organic Compounds, New Age International Private Limited.
19. Williams, D., Fleming, I. Spectroscopic Methods In Organic Chemistry, McGraw-Hill Education.
20. Lowry, T. H.; Richardson, K. S. Mechanism and Theory in Organic Chemistry: International Student 3rd Ed., Addison-Wesley Publishing.
21. Joules. J. A., Mills, K Heterocyclic Chemistry, 5th edition, Wiley-Blackwell.

Practical:

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).
6. Practical Workbook Chemistry (Honours), UGBS, Chemistry, University of Calcutta, 2015.
7. Vogel, A. I A Text Book of Practical Organic Chemistry Including Qualitative organic Analysis. Third edition. ELBS and Longman group Limited.

DISCIPLINE SPECIFIC ELECTIVE COURSES

1. **Any one from HCHE5DS11L and HCHE6DS12L**
2. **Any one from HCHE5DS21L and HCHE5DS22L**

SEMESTER – 5

Course name	Polymer and Supramolecular Chemistry and Polymer Chemistry Practical	
Course code	HCHE5DS11L	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for Attendance		

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

- Introduction and Classification of polymer chemistry.
- Kinetics and determination of molecular weight of polymers.
- Solution properties of polymers.
- Preparation, characterization and applications of polymers.
- Supramolecular chemistry.

Theoretical (50 M)

Polymer and Supramolecular Chemistry

Module-1: Polymer I **10M**

*Introduction and Classification of polymers***:** History of polymeric materials, Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers,

*Functionality and its importance***:** Relationships between functionality, extent of reaction and degree of polymerization. Bifunctional systems, Poly-functional systems.

*Types of polymerization***:** Criteria for synthetic polymer formation, classification of polymerization processes, chain growth, condensation and ring opening polymerization (ROP).

Glass transition temperature (Tg) and itsdetermination: Free volume theory, Factors affecting glass transition temperature (Tg).

Module-2: Ploymer II **10M**

*Kinetics of Polymerization***:** Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization. Mechanism of ring opening polymerization.

Determination of molecular weight of polymers (*Mn*, *Mw*, etc) by end group analysis, Colligative property measurement, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

Module-3: Ploymer III **10M**

Polymer solution: Criteria for polymer solubility, conformational change of dissolved polymer. Solubility parameter, thermodynamics of polymer solutions, ideal dilute polymer solution, osmotic pressure of polymer solution, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory-

Huggins theory. Solution viscosity, parameters for characterizing polymer solution viscosity. Molecular size and intrinsic viscosity, molecular weight from intrinsic viscosity. Structure and property relationship, upper and lower critical solution temperature.

Module-4: Ploymer IV **10M**

Synthesis, structure properties and some important application of following polymers (Physical, thermal, Flow & Mechanical Properties). Polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides, polysulfide polymers and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydienes, Polycarbonates, Conducting Polymers, polyacetylene, polyaniline. Organometallic polymers, ferrocene based polymers.

Module-5: Supramolecular chemistry **10M**

Various type of non-covalent interactions- electrostatic, H-bonding, π–π interaction, cation-π etc. Historical background and Elementary idea of supramolecular chemistry, molecular recognition, host/guest chemistry, self-assembly. Emil Fischer's lock and key theory and induced fit model. Definitions of crown ethers, lariat ethers, cryptands, cryptates, alkalides, electrides, catenanes, rotaxanes, pseudo rotaxanes. Synthesis, Properties and application crown ethers and cryptand. Kinetic and thermodynamic stability. Macrocyclic and chelate effect.

Practical (30 M)

Polymer Chemistry Practical (30 M)

(Exp-20 M, LNB-05 M and Viva Voce 05)

Polymer synthesis

1. Preparation of urea-formaldehyde resin
2. Preparations of novalac resin/ resold resin.
3. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

1. Determination of molecular weight by viscometry:
   a. Polyacrylamide-aq.$NaNO_2$ solution
   b. (Poly vinyl proplylidine (PVP) in water

Polymer analysis

1. Estimation of the amount of HCHO in the given solution by sodium sulphite method
2. IR studies of polymers

*at least 5 experiments to be carried out.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Question Pattern for End Semester Examination

(HCHE5DS11L)

Module-1: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-2: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-3: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-4: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-5: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Reference Books for HCHE5DS11L

1. M.P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed., Oxford University Press, 1999.
2. H.R. Allcock, F.W. Lampe & J.E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003)
3. F.W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984)
4. J.R. Fried, Polymer Science and Technology, 2nd ed. Prentice-Hall (2003)
5. P. Munk & T.M. Aminabhavi, Introduction to Macromolecular Science, 2nd ed. John Wiley & Sons (2002)
6. L. H. Sperling, Introduction to Physical Polymer Science, 4th ed. John Wiley & Sons (2005)
7. M.P. Stevens, Polymer Chemistry: An Introduction 3rd ed. Oxford University Press (2005).
8. Carraher's Polymer Chemistry, 9th ed. by Charles E. Carraher, Jr. (2013).
9. R.B. Seymour & C.E. Carraher: Polymer Chemistry: An Introduction, Marcel Dekker, Inc. New York, 1981.
10. G. Odian: Principles of Polymerization, 4th Ed. Wiley, 2004.
11. F.W. Billmeyer: Textbook of Polymer Science, 2nd Ed. Wiley Interscience, 1971.
12. P. Ghosh: Polymer Science & Technology, Tata McGraw-Hill Education, 1991.
13. R.W. Lenz: Organic Chemistry of Synthetic High Polymers. Interscience Publishers, NewYork, 1967.
14. J. W. Steed and J. L. Atwood, Supramolecular Chemistry, Second Edition,Wiley.
15. Robert O. Ebewele, Polymer Science and Technology, CRC Press; 1st Edition (23 March 2000).

SEMESTER – 5	
Course name	**Green Chemistry and Green Chemistry Practical**

Course code	HCHE5DS12L	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- principles and applications of green chemistry.
- preparation organic compounds by green methods.

Theoretical (50 M)

Green Chemistry

Module-1: Introduction and principles of Green Chemistry 20M

*Introduction to Green Chemistry***:** What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry; Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.

Principles of Green Chemistry and Designing a Chemical synthesis: Twelve principles of Green Chemistry with their explanations and examples and special emphasis on the following: 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 reducingtoxicity; Green solvents–supercritical fluids, water as a solvent for organic reactions, ionic liquids, PEG, solventless processes.

Energy requirements for reactions – alternative sources of energy: use of microwaves and ultrasonic energy.

Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry.

Module-2: Examples of Green Synthesis/ Reactions and some real world cases 20M

Examples of Green Synthesis/ Reactions and some real world cases: Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis). 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 Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine). Green counterpart of common organic reactions: Aldol, Friedel-Crafts, Michael, Knoevenagel, Cannizzaro, benzoin condensation and Dieckmann condensation. Rearrangement reactions by green approach: Fries rearrangement, Claisen rearrangement, Beckmann rearrangement, Baeyer-Villiger oxidation.

Module-3: Future Trends in Green Chemistry 10M

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Combinatorial green chemistry; Proliferation of solventless reactions. Green chemistry in sustainable development.

Practical (30 M)

Green Chemistry Practical

(Exp-20 M, LNB-05 and Viva-05 M)

(Any SIX of the following list)

1. Acetylation of primary amine (preparation of acetanilide).
2. [4+2] Cycloaddition reaction (Diels-Alder reaction between furan and maleic anhydride).
3. Preparation of biodiesel from vegetable/waste cooking oil.
4. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.
5. Pinacol-pinacolone rearrangement reaction (preparation of benzopinacolone).
6. Solid state synthesis of benzilic acid from benzil.
7. Benzoin condensation using thiamine hydrochloride as a catalyst instead of potassium cyanide.
8. Green multicomponent synthesis (three component coupling).
9. Base catalysed aldol condensation (synthesis of dibenzal propanone from benzaldehyde and acetone).
10. Bromination of *trans*-stilbene using bromide/bromate mixture.
11. Preparation and characterization of gold nanoparticles using tea leaves.
12. Extraction of D-limonene from orange peel using liquid carbon dioxide.
13. Electrophilic aromatic substitution reaction (nitration of salicylic acid).
14. Green radical coupling reaction.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Question Pattern for End Semester Examination
(HCHE5DS12L)

Module-1: A set of questions carrying a total of 30 to 35 marks to be set. Students will be required to answer questions of 20 marks only.

Module-2: A set of questions carrying a total of 30 to 35 marks to be set. Students will be required to answer questions of 20 marks only.

Module-3: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Reference Books for HCHE5DS12L

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).
1. Lancaster, M. Green Chemistry: An Introductory Text RSC Publishing, 2nd Edition, 2010.
2. Ahluwalia, V. K & Kidwai, M. R. New Trends in Green Chemistry, Anamalaya Publishers, 2005.
3. Bandyopadhyay, C.; An insight into Green Chemistry, Books and Allied (P) Ltd.

SEMESTER – 5

Course name	Analytical Chemistry and Analytical Chemistry Practical	
Course code	HCHE5DS21L	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- extraction of various noble metals
- the principles and applications of spectrophotmetry, chromatography.
- complexometric, permanganometric, gravimetric, colorometric, flame photometric, fluorometric titration.
- TLC and column chromatographic techniques in purification of organic compounds

Theoretical (50 M)

Analytical Chemistry

Module-1: Extractions **12M**

Extraction of noble metals: rhenium (Re), ruthenium (Ru), rhodium (Rh), palladium (Pd), silver (Ag), osmium (Os), iridium (Ir), platinum (Pt), and gold (Au).

Module-2: Spectrophotometry **12M**

Flame photometry and colorometry: Introduction to flame photometry and its application in detecting alkali metal ions; Introduction to colorometry and its application in estimating transition metal ions, e.g, iron (III), iron(II), manganese and also phosphate ion. Fluorometry: Introduction to fluorometry and its application in chemical analyses and medical diagnosis

Module-3: Estimation **13M**

Redox reactions and their importance, permanganometry and applications, dichromometry and applications, iodometry and applications, iodimetry and applications, complexometry and applications, gravimetry and applications.

Module-4: Chromatography **13M**

Chromatography: Classification, principle and efficiency of the technique. Mechanism of separation: adsorption, partition & ion exchange. Ion exchange resign and their exchange capacities, principal and simple applications o0f ion exchange separation. Chromatographic separations: TLC, paper column chromatographic techniques and their simple applications, R_f values and their significance, migration rate of solutes, band broadening and column efficiency, column resolution. Chiral chromatographic techniques using chiral columns (GC and HPLC).

Practical (30 M)

Analytical Chemistry Practical

(Exp-20 M, LNB-05 and Viva-05 M)

1. Estimation of Fe(III) by complexometry.
2. Estimation of Mn(II) by permanganometry.
3. Estimation of Ni(II) by gravimetry.
4. Estimation of Fe(III) by colorometry.
5. Estimation of Mn(II) by colorometry.
6. Detection by flame photometry.
7. Detection by fluorometry.
8. Separation and identification of monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the R_f values.
9. Separation and identification of aromatic amine and nitro compounds present in the given mixture by thin layer chromatography. Reporting the R_f values.
10. Separation by column chromatography.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Question Pattern for End Semester Examination

(HCHE5DS21L)

Module-1: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-2: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-3: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only

Module-4: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Reference Books for HCHE5DS21L

1. Mendham, J. Vogel's Quantitative Chemical Analysis; Pearson Education; 6th edition (2009).
2. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R. Vogel's Textbook of Practical Organic Chemistry; Pearson Education; 5th Edition
3. Cotton, F. A., Wilkinson, G., Murillo, C. A., Bochmann, M. Advanced Inorganic Chemistry, 6ed, Wiley.
4. Lakowicz, J. Principles of Fluorescence Spectroscopy, Springer US, 3rd Edition.

Practicals:

1. Mendham, J. Vogel's Quantitative Chemical Analysis; Pearson Education; 6th edition (2009).
2. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R. Vogel's Textbook of Practical Organic Chemistry; Pearson Education; 5th Edition.

SEMESTER – 5		
Course name	**Inorganic Materials of Industrial Importance and Inorganic Materials of Industrial Importance Practical**	
Course code	**HCHE5DS22L**	Credits: 6 Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- inorganic materials of industrial importance including glass, ceramics, cements, fertilizers, explosives, suface coating agents, batteries and alloys etc.
- principle of catalysis, properties and application of catalysts.
- analysis of inorganic materials of industrial importance.

Theoretical (50 M)

Inorganic Materials of Industrial Importance

Module-1: Silicate Industries **10M**

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. Hightechnology 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 thesetting process, quick setting cements.

Module-2: Fertilizers and Chemical explosives **10M**

Fertilizers: 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.

*Chemical explosives***:** Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX).Introduction to rocket propellants.

Module-3: Surface Coatings: **10M**

Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings.Paints and pigments-formulation, composition and related properties. Oil paint, Vehicle, modified oils, Pigments, toners and lakes pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, additives, Metallic coatings (electrolytic and electroless), metal spraying and anodizing.

Module-4: Batteries and Alloys **10M**

Batteries: Primary and secondary batteries, battery components and their role, Characteristics of Battery.Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery.Fuel cells, Solar cell and polymer cell.

Alloys: Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation) and surface treatment (Arand heat treatment, nitriding, carburizing). Composition and properties of different types of steels.

Module-5: Catalysis: **10M**

General principles and properties of catalysts, homogenous catalysis (catalytic steps and examples) and heterogenous catalysis (catalytic steps and examples) and their industrial applications, Deactivation or regeneration of catalysts. Phase transfer catalysts, application of zeolites as catalysts.

Practical (30 M)
Inorganic Materials of Industrial Importance Practical
(Exp-20 M, LNB-05 and Viva-05 M)

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. Electroless metallic coatings on ceramic and plastic material.
5. Determination of composition of dolomite (by complexometric titration).
6. Analysis of (Cu, Ni); (Cu, Zn) in alloy or synthetic samples.
7. Analysis of Cement.
8. Preparation of pigment (zinc oxide).

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Question Pattern for End Semester Examination
(HCHE5DS22L)

Module-1: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-2: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-3: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-4: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-5: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Reference Books for HCHE5DS22L

Theory

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).

Practical

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).

SEMESTER – 6		
Course name	**Inorganic Chemistry-VI, Organic Chemistry-VI and Inorganic Chemistry Practical-IV**	
Course code	**HCHE6CC13L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- preaparation and reaction of organometallic complexes including metallocenes .
- reaction kinetics and mechanism of inorganic compounds.
- organic synthesis by retrosynthetic approach.
- synthesis and properties biomolecules.
- preparations of inorganic compounds and Spectral Analyses.

Theoretical (50 M)

Inorganic Chemistry-VI and Organic Chemistry-VI

Group-A

Module-1: Organometallic Chemistry II **12M**

Reactions of organometallic complexes: substitution, oxidative addition, reductive elimination and insertion reactions.

Metallocenes: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Fluxional molecules, quadruple and quintuple bonds.

Module-2: Reaction Kinetics and Mechanism of coordination complexes. **13M**

Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans-effect and its application in complex synthesis, theories of trans effect, 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.

Group-B

Module-1: The Logic of Organic Synthesis **12M**

Retrosynthetic analysis: Disconnections; synthons, donor and acceptor synthons; natural reactivity and *umpolung*; latent polarity in bifunctional compounds: 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).

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); diastereoselectivity: addition of nucleophiles to C=O adjacent to a stereogenic centre: Felkin-Anh model.

Module-2: Biomolecules **13M**

Aminoacids: Synthesis with mechanistic details: Strecker, Gabriel; acetamido malonic ester, azlactone, Bücherer hydantoin synthesis, synthesis involving diketopiperizine, isoelectric point, zwitterions; electrophoresis, reaction (with mechanism): ninhydrin reaction, Dakin-West reaction; resolution of racemic amino acids.

Protein: 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 Module- determination (Edman, Sanger and 'dansyl'methods); partial hydrolysis; specific cleavage of peptides; use of CNBr. Primary, secondary, tertiary and quaternary structure of proteins. Classification of proteins; Denaturation of proteins.

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.

Practical (30 M)

Inorganic Chemistry Practical-IV (30 M)

(Exp-20, LNB-05 and Viva-05)

Inorganic preparations:

1. $[Cu(CH_3CN)_4]PF_6/ClO_4$
2. *Cis* and *trans* $K[Cr(C_2O_4)_2(H_2O)_2]$
3. Potassium tris(oxalato)ferrate(III)
4. Tris-(ethylenediamine) nickel(II) chloride.
5. $[Mn(acac)_3]$ and $Fe(acac)_3]$ (acac= acetylacetonate)

Instrumental Techniques:

1. Measurement of 10Dq by spectrophotometric method.
2. Determination of λ_{max} of $[Mn(acac)_3]$ and $[Fe(acac)_3]$ complexes.

Question Pattern for End Semester Examination

(**HCHE6CC13L**)

Group-A

Module-1: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-2: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Group-B

Module-1: A set of questions carrying a total of 18 to 21 marks to be set. Students will be required to answer questions of 12 marks only.

Module-2: A set of questions carrying a total of 20 to 23 marks to be set. Students will be required to answer questions of 13 marks only.

Reference Books for HCHE6CC13L

Group-A

Theory:

1. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
2. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
3. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
4. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
5. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
6. Mingos, D.M.P., Essential trends in inorganic chemistry. Oxford University Press (1998).
7. Winter, M. J., The Orbitron, http://winter.group.shef.ac.uk/orbitron/ (2002). An illustrated gallery of atomic and molecular orbitals.
8. Burgess, J., Ions in solution: basic principles of chemical interactions. Ellis Horwood (1999).

Practical:

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

Group-B

Theory:

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 and 2), 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.
13. Warren, S. Organic Synthesis: The Disconnection Approach, Wiley.
14. Corey, E. J. and Cheng, X.-M.The Logic of Chemical Synthesis, 1st edition, Wiley-Interscience.

SEMESTER – 6

Course name	Physical Chemistry-VI, Catalysis and Physical Chemistry Practical-V	
Course code	HCHE6CC14L	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

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

- Phase rule and third Law of Thermodynamics.
- theory of electronic spectroscopy and photochemistry.
- statistical thermodynamics.
- basic principles of catalysis and its applications.
- physicochemical experiments

Theoretical (50 M)

Physical Chemistry-VI and Catalysis

Group-A (30 L, 25 M)

Module-1: Phase Rule-II and Third Law of Thermodynamics. 8M

Binary liquid mixture: Ideal mixtures: Liquid vapour equilibrium in two-component system. Non ideal: deviation from ideality, Boiling point composition diagram for two components completely miscible liquid mixtures. Principle of fractional distillation, azeotrope, Duhem-Margules equation, Konowaloff rule, Lever rule. Partially miscible liquid pairs- aniline-water, phenol-water, nicotine-water, triethylamine -water systems. Immiscible liquid pair-steam disllation.

The Third Law: Nernst's heat theorem. The third law of thermodynamics. Limiting values of thermal properties at absolute zero. Estimation of absolute entropies of pure substances. Production of low temperatures by adiabatic demagnetisation. Inaccessibility of absolute zero.

Module-2: Molecular Spectroscopy II: Electronic spectroscopy and photochemistry 9M

Electronic Spectroscopy: Potential energy curves (diatomic molecules). Frank-Condon principle and vibrational structure of electronic spectra. Bond dissociation and principle of determination of dissociation energy. Decay of excited states by radiative and non-radiative paths- their relative time scales. Kasha's rule. Fluorescence and phosphorescence. Illustrations with Jablonsky diagram.

Photochemistry: Grothers-Draper law, Stark- Einstein law of photochemical equivalence. Photochemical reactions vs thermal reactions. Quantum yield. Photostationary state. Photosensitized reactions. Actinometry. Kinetics of HI decomposition, dimerisation of anthracene. Chemiluminiscence. Elementary idea of excimer and exciplex.

Module-3: Statistical thermodynamics 8M

Macrostates and microstates. Thermodynamic probability and the equilibrium state. Entropy and probability. Boltzmann distribution formula. Applications to barometric distribution, molecular partition function and thermodynamic properties, Maxwell's speed distribution. Gibbs' paradox.

Heat capacity of solids: Equipartition principle and Dulong-Petit Law, Einstein's theory of heat capacity of solids and its limitations, Debye's T^3- Law.

Group-B

Module-1: Basic Principles of Catalysis **11M**

General principles and properties of catalysts.

Homogeneous catalysis: mechanism of catalytic actions, acid- base catalysis. Primary kinetic salt effect.

Heterogeneous catalysis: catalytic steps and examples,

Enzyme Catalysis: Michaelis – Menten equation, Lineweaver – Burk plot, turnover number, significance of K_m. Elementary idea of enzyme inhibition. Micellar catalysis

Module-2: Applications of Catalysis **7M**

Homogenous Catalysis: examples and applications in organic synthesis

Heterogeneous Catalysis: examples and applications in organic synthesis

Organocatalysis: examples and applications in organic synthesis

Module-3: Study of the following industrial processes **7M**

Alkene hydrogenation (Wilkinson's Catalyst), Hydroformylation, Wacker Process, Synthetic gasoline (Fischer Tropsch reaction), Ziegler-Natta catalysis for olefin polymerization.

Practical (30 M)

Physical Chemistry Practical-V

(Exp-20 M, LNB-05 M and Viva Voce 05)

At least 5-6 experiments are to be done in this semester for this paper. More experiments may be included to the following set of experiments. The following experiments may be replaced by equivalent/better experiments in a semester.

1. Determination of the ionisation constants of a poly-basic acid and the strength of its solution by pH-metric titration against a strong base.
2. Determination of CMC of a micelle from Surface Tension Measurement / conductance measurement.
3. Verification of Ostwald's dilution law and determination of Ka of weak acid conductometrically.
4. Kinetic study of inversion of cane sugar using a Polarimeter (Preferably Digital).
5. Study of kinetics of $K_2S_2O_8$ + KI reaction, spectrophotometrically.
6. Determination of solubility of a sparingly soluble salt in water, in presence of electrolytes with common ions, in presence of neutral electrolytes and study of the effects of ionic strength of the medium on the solubility and solubility product of the salt.
7. Determination of pH of unknown solution (buffer), by colour matching method

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Question Pattern for End Semester Examination

(**HCHE6CC14L**)

Group-A

Module-1: A set of questions carrying a total of 12 to 14 marks to be set. Students will be required to answer questions of 8 marks only.

Module-2: A set of questions carrying a total of 14 to 16 marks to be set. Students will be required to answer questions of 9 marks only.

Module-3: A set of questions carrying a total of 12 to 14 marks to be set. Students will be required to answer questions of 8 marks only.

Group-B

Module-1: A set of questions carrying a total of 17 to 19 marks to be set. Students will be required to answer questions of 11 marks only.

Module-2: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module-3: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Reference books for HCHE6CC14L
Group-A

Theory:

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. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
7. Zemansky, M. W. &Dittman, R.H. Heat and Thermodynamics, TataMcGraw-Hill
8. Principles of Physical Chemistry; Samuel H. Maron, Carl F. Prutton;The Macmillan Company; 4th edition (1970).
9. Bevan Ott, J. and Boerio-Goates, J. Chemical Thermodynamics: Principles and Applications, Elsevier
10. Moore, W. J. Physical Chemistry, Orient Longman
11. Roy, B. N. Fundamentals of Classical and Statistical Thermodynamics; Wiley Student Edition.
12. Banwell, C. N. and Elaine, M. M. Fundamentals of Molecular Spectroscopy; McGraw-Hill Education
13. Wardle, B. Principles and Applications of Photochemistry; Wiley
14. K. K. Rohatgi-Mukherjee, Fundamentals of Photochemistry, New Age Int. Publisher.

Practical:

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

Group-B

1. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
2. Castellan, G. W. Physical Chemistry, Narosa.
3. Engel, T. & Reid, P. Physical Chemistry, Pearson.
4. Levine, I. N. Physical Chemistry, Tata McGraw-Hill.
5. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
6. Powell, P. *Principles of Organometallic Chemistry*, Chapman and Hall, 1988.
7. Collman, J. P. *et al. Principles and Applications of Organotransition MetalChemistry*. Mill Valley, CA: University Science Books, 1987.
8. Crabtree, R. H. *The Organometallic Chemistry of the Transition Metals*. New York, NY: John Wiley, 2000.
9. Martin, S., Heterogeneous Catalysis and its Industrial Applications, 1st ed., Springer Nature.
10. Housecroft, C. E., Sharpe, A. G.,Inorganic Chemistry, 5^{th} edition, Pearson.
11. Carey, F.A., Sundberg, R. J. Advanced Organic Chemistry: Reaction and Synthesis (Part B), Springer India Private Limited.

DISCIPLINE SPECIFIC ELECTIVE COURSES

1. **Any one from HCHE5DS31L and HCHE6DS32L**
2. **Any one from HCHE5DS41L and HCHE5DS42L**

SEMESTER – 6

Course name	Computer Application and Computer Application Practical	
Course code	HCHE6DS31L	Credits: 6 Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance		

Objectives: At the end of studying this course a student

- computer its language, coding of data etc.
- computer programming language like FORTRAN which is used worldwide for chemistry students.
- principles on numerical analysis.

Theoretical (50 M)

Computer Application

Module-1: Basics **15M**

Generation of computer, architecture of computer. Binary to decimal inter conversions of numbers. Hierarchy of computer languages-Machine language, High level language.Compiler and Interpreter. Object and Source Program**.** Storing of data in a computer : BIT, BYTE, Word. Coding of data – ASCII.

Module-2: Computer Programming Basics (FORTRAN) **15M**

Programming with FORTRAN 77/90/95 : Introduction, Keywords, Constants and Variables – integer, real, complex, logical, character, single & double precision, subscripted. Fortran expressions. I/O statements-formatted and unformatted. Program execution control-logical if, ifthen-else, etc. Arrays-Dimension statement. Repetitive computations – Do. Nested Do, etc. Sub-programs : Function sub program and Subroutine sub program. Applications of FORTRAN-examples.

Module-3: Numerical Methods **20M**

Principles of numerical analysis-elementary concepts.

Numerical methods to find real Roots of algebraic equations: Iteration method, Newton-Raphson method and Binary bisection method.

Numerical Differentiation: Newton's forward interpolation method.

Numerical Integration: Trapezoidal and Simpson's rules.

Numerical Solution of Simultaneous Equations: Solution of two linear equations involving two variables by Gauss elimination method.

Numerical Solution of First Order Ordinary Differential Equation: Runge-Kutta Method-EulerMethod.

Curve fitting: Least square method (Linear).

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Practical (30 M)
Computer Application Practical (30 M)
(Exp-20, LNB-05 and Viva-05)

(At least 6 experiments are to be performed.)

1. Evaluation of functional values.
2. Solution of quadratic equations.
3. Approximate sum of series.
4. Sorting of real numbers.
5. Simple matrix operations.
6. Numerical integration.
7. Numerical solution of quadratic equations.
8. Numerical solution of ordinary differential equations.
9. Running standard programs.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Question Pattern for End Semester Examination
(HCHE6DS31L)

Module-1: A set of questions carrying a total of 23 to 26 marks to be set. Students will be required to answer questions of 15 marks only.

Module-2: A set of questions carrying a total of 23 to 26 marks to be set. Students will be required to answer questions of 15 marks only.

Module-3: A set of questions carrying a total of 30 to 35 marks to be set. Students will be required to answer questions of 20 marks only.

Reference Books for HCHE6DS31L

1. Sinha, P. K.; Sinha, P. Computer Fundamentals, 6th edn. B P B Publication, 2011.
2. Noggle, J. H. Physical chemistry on a Microcomputer. Little Brown & Co. (1985).
3. V. Rajaraman, Computer Programming in FORTRAN 77, Prentice Hall, 1997.
4. Martin Cwiakala, Schaum's Outline of Programming with FORTRAN 77, 1995.
5. Numerical Methods that Work; Forman S. Acton; Mathematical Association of America, Washington DC, 1990.
6. Introduction to Numerical Analysis; F. B. Hildebrand; Dover Publications; Second edition (June 1, 1987).
7. C. Xavier; Fortran 77 and Numerical Methods; New Age International Publishers.
8. V. Rajaraman; Computer Programming in FORTRAN 77 (with an Introduction to FORTRAN 90), 4th Edition; Prentice Hall Of.
9. Madhumangal Pal; FORTRAN 77 with Numerical & Statistical Analysis; Asian Books Pvt. Ltd. (2002).

10. Walter S. Brainerd, Charles H. Goldberg, Jeanne C. Adams; Programmer's Guide to FORTRAN 90 3rd Edition, Springer (October 12, 1995).
11. Michael Metcalf, John Reid, Malcolm Cohen; FORTRAN 95/2003 Explained (Numerical Mathematics and Scientific Computation) 3rd Edition.

SEMESTER – 6		
Course name	**Industrial Chemicals and Environment and Industrial Chemicals and Environment Practical**	
Course code	Paper – **HCHE6DS32L**	Credits: 6 Full Marks: 100
Number of lectures required: 105		

*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance

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

- industrial chemicals.
- environment and its segments ecosystems.
- the determination/estimation of industrial chemicals and environment.

Theoretical (50 M)
Industrial Chemicals and Environment

Module-1: Industrial gases and inorganic chemicals industrial gases and metallurgy 20M

Industrial Gases and Inorganic Chemicals 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 Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology**.**

Module-2: Environment and its segments Ecosystems. 20M

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, NOx, H_2S and other foul smelling gases. Methods of estimation of CO, NOx, SOx 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.

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.

Module-3: Energy, environment and biocatalysis 10M

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

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Practical (30M)
Industrial Chemicals and Environment Practical
(Exp-20, LNB-05 and Viva-05)

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 (CO3 2- , 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.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Question Pattern for End Semester Examination
(HCHE6DS32L)

Module-1: A set of questions carrying a total of 30 to 35 marks to be set. Students will be required to answer questions of 20 marks only.

Module-2: A set of questions carrying a total of 30 to 35 marks to be set. Students will be required to answer questions of 20 marks only.

Module-3: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Reference Books for HCHE6DS32L

Theory:

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

7. G.T. Miller, Environmental Science 11th edition. Brooks/ Cole (2006).
8. Mishra, Environmental Studies. Selective and Scientific Books, New Delhi (2005).

Practical:

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.

SEMESTER – 6		
Course name	**Natural Products and Drugs and Natural Products and Drugs Practical**	
Course code	**HCHE6DS41L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		

*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance

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

- natural products including Lipids, alkaloids, terpenes, polyketides and polyethers.
- Synthesis and uses and mechanism of action of some common drugs.
- extraction important ingredients from products.

Theoretical (50 M)

Natural Products and Drugs

Module-1: Lipids **10M**

Introduction to lipids, classification. Oils and fats: Common fatty acids present in oils and fats, Omega fatty acids, Biological importance of triglycerides, phospholipids and glyco-lipids.

Module-2: Alkaloids **10M**

Classification, Natural occurrence and general structural features; Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, lysergic acid, Chloroquine, papaverine and Reserpine and synthesis of Reserpine, Quinine, Lysergic acid, Papaverine.

Module-3: Terpenoids and Polyketides and polyethers **10M**

Terpenoids: Occurrence, classification, isoprene rule and importance of geranal, menthol and camphor. Elucidation of structure menthol.

*Polyketides and polyethers***:** Classification, natural occurrence and general structural features.

Module-4: Drugs **20M**

Definition,classification, mechanism of action of different drugs.

Synthesis of Paracetamol, Aspirin, L-DOPA, Phenytoin, Nifedipine, Amlodipine, Vitamin C, Penicillin V, Reserpine, Tetracycline and Ranitidine.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Practical (30 M)

Natural Products and Drugs Practical (30 M)

(Exp-20, LNB-05 and Viva-05)

(Any three extractions of the following list)

1. Extraction of caffeine from tea.
2. Extraction of lycopene from tomato.
3. Extraction of albumin from egg white.
4. Extraction of curcumin from turmeric.
5. Extraction of beta carotene from carrot.

6. Extraction of casein from milk.

Synthesis

1. Synthesis of Phenytoin.
2. Synthesis of 2,3,4,9-Tetrahydro-1*H*-carbazol.
3. Synthesis of Glucose derivatives.
4. Synthesis of 2,6-Dimethyl-3,5-dicarbethoxy-1,4-dihydropyridine.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Question Pattern for End Semester Examination
(HCHE6DS41L)

Module-1: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-2: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-3: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-4: A set of questions carrying a total of 30 to 35 marks to be set. Students will be required to answer questions of 20 marks only.

Reference Books for HCHE6DS41L

Theory:

5. Dewick P. M.; Medicinal Natural Products: A Biosynthetic Approach 3rd edition WILEY.
6. Stanforth, S. P.; Natural Product Chemistry at a Glance, Wiley-Blackwell; 1st edition (26 June 2006)
7. Carey, F.A., Sundberg, R. J. Advanced Organic Chemistry: Reaction and Synthesis (Part B), Springer India Private Limited.
8. Warren, S. Organic Synthesis: The Disconnection Approach, Wiley.
9. Corey, E. J. and Cheng, X.-M.The Logic of Chemical Synthesis, 1st edition, Wiley-Interscience.
10. Korolkovas, A., Essentials of Medicinal Chemistry, Second Edition, Wiley-India.
4. Sounders, J., Top Drugs: Top Synthetic Route, OUP.

Practical:

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).

SEMESTER – 6		
Course name	**Molecular Modelling and Drug Design and Computational Calculations Practical**	
Course code	**HCHE6DS42L**	Credits: 6, Full Marks: 100

Number of lectures required: 105
*15 Marks are reserved for internal assessment (to be taken from the mid-semester exam) & 5 marks for attendance

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

- molecular modelling and drug design.
- computational calculations including energy minimization, bond properties, electron density, electrostatic potential maps etc.

Theoretical (50 M)
Molecular Modelling and Drug Design

Module-1: Introduction to molecular modelling **10M**

Introduction. Useful Concepts in Molecular Modelling: Coordinate Systems. Potential Energy Surfaces.Molecular Graphics.Surfaces.

Module-2: Force fields **10M**

Bond Stretching.Angle Bending.Introduction to nonbonded interactions. Electrostatic interactions.van der Waals Interactions. Hydrogen bonding in Molecular Mechanics.Force Field Models for the Simulation of Liquid Water.

Module-3: Energy minimization and computer simulation **10M**

Minimization and related methods for exploring the energy surface. Non-derivative method, First and second order minimization methods. Computer simulation methods.Simple thermodynamic properties and Phase Space.Boundaries. Analyzing the results of a simulation and estimating Errors

Module-4: Molecular dynamics & Monte Carlo simulation **10M**

Molecular Dynamics Simulation Methods.Molecular Dynamics using simple models. Molecular Dynamics with continuous potentials. Molecular Dynamics at constant temperature and pressure. Metropolis method.Monte Carlo simulation of molecules.

Module-5: Structure prediction and drug design **10M**

Structure prediction - Introduction to comparative Modeling.Sequence alignment. Constructing and evaluating a comparative model. Predicting protein structures by 'Threading', Molecular docking. Structure based de novo ligand design, QSAR.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Practical (30 M)
Computational Calculations Practical
(Exp-20, LNB-05 and Viva-05)

1. Compare the optimized C-C bond lengths in ethane, ethene, ethyne and benzene.
2. Visualize the molecular orbitals of the ethane σ bonds and ethene, ethyne, benzene and pyridine π bonds.
3. (a) Perform a conformational analysis of butane. (b) Determine the enthalpy of isomerization of *cis* and *trans* 2-butene.
4. Visualize the electron density and electrostatic potential maps for LiH, HF, N_2, NO and CO and comment. Relate to the dipole moments. Animate the vibrations of these molecules.
5. (a) Relate the charge on the hydrogen atom in hydrogen halides with their acid character. (b) Compare the basicities of the nitrogen atoms in ammonia, methylamine, dimethylamine and trimethylamine.
6. (a) Compare the shapes of the molecules: 1-butanol, 2-butanol, 2-methyl-1-propanol, and 2-methyl-2-propanol. Note the dipole moment of each molecule. (b) Show how the shapes affect the trend in boiling points: (118 ºC, 100 ºC, 108 ºC, 82 ºC, respectively).
7. Build and minimize organic compounds of your choice containing the following functional groups. Note the dipole moment of each compound: (a) alkyl halide (b) aldehyde (c) ketone (d) amine (e) ether (f) nitrile (g) thiol (h) carboxylic acid (i) ester (j) amide.
8. (a) Determine the heat of hydration of ethylene. (b) Compute the resonance energy of benzene by comparison of its enthalpy of hydrogenation with that of cyclohexene.
9. Arrange 1-hexene, 2-methyl-2-pentene, (*E*)-3-methyl-2-pentene, (*Z*)-3-methyl-2- pentene, and 2,3-dimethyl-2-butene in order of increasing stability.
10. (a) Compare the optimized bond angles H_2O, H_2S, H_2Se. (b) Compare the HAH bond angles for the second row dihydrides and compare with the results from qualitative MO theory.

**Note: Software*: ChemSketch, ArgusLab (www.planaria-software.com), TINKER 6.2 (dasher.wustl.edu/ffe), WebLab Viewer, Hyperchem, VMD, or any similar software.

Note: This course has been newly introduced vide BOS meeting dated 31/05/2019.

Question Pattern for End Semester Examination
(HCHE6DS42L)

Module-1: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-2: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-3: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-4: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module-5: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Reference Books for HCHE6DS42L

1. A.R. Leach, Molecular Modelling Principles and Application, Longman, 2001.
2. J.M. Haile, Molecular Dynamics Simulation Elementary Methods, John Wiley and Sons, 1997.
3. Satya Prakash Gupta, QSAR and Molecular Modeling, Springer – Anamaya Publishers, 2008.

CHEMISTRY GENERAL ELECTIVE SYLLABUS

SEMESTER – 1	
Course name	**Essentials of Chemistry-I and Essentials of Chemistry-I Practical**

Course code	HCHE1GE01L	Credits : 6 Full Marks : 100
Number of lectures required : 105		
*15 Marks are reserved for internal assessment(to be taken from the mid-semester exam) & 5 marks for attendance		

&

SEMESTER – 2		
Course name	**Essentials of Chemistry-I and Essentials of Chemistry-I Practical**	
Course code	**HCHE2GE01L**	Credits : 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment(to be taken from the mid-semester exam) & 5 marks for attendance		

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

- fundamentals of organic chemistry and stereochemistry
- aliphatic and aromatic hydrocarbons .
- arylhalides substitution and elimination reactions and organometallic compounds.
- Atomic Structure of and chemical periodicitry.
- Kinetic theory of gases, real gases and chemical thermodynamics.

Theoretical (50 M)
Essentials of Chemistry-I

Module-1: Fundamentals of organic chemistry and stereochemistry 7 M

Electronic displacements: inductive effect, resonance and hyperconjugation; nucleophiles and electrophiles; reactive intermediates: carbocations, carbanions and free radicals.

Stereochemistry: Different types of isomerism; geometrical and optical isomerism; concept of chirality and optical activity (upto two carbon atoms); asymmetric carbon atom; interconversion of Fischer and Newman representations; enantiomerism and diastereomerism, *meso* compounds; *threo* and *erythro,* D and L, *cis* and *trans* nomenclature; CIP Rules: *R/S* (only one chiral carbon atoms) and *E/Z* nomenclature.

Module-2: Aliphatic and aromatic hydrocarbons 7 M

Aliphatic Hydrocarbons: Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structures.

Alkanes: (up to 5 Carbons). *Preparation:* catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis.

Alkenes: (up to 5 Carbons). *Preparation:* elimination reactions: dehydration of alcohols and dehydrohalogenation of alkyl halides; *cis* alkenes (partial catalytic hydrogenation) and *trans* alkenes (Birch reduction). *Reactions:* addition of bromine, addition of HX [Markownikoff's (with mechanism) and anti-Markownikoff's addition], hydration, ozonolysis.

Alkynes: (up to 5 Carbons). *Preparation:* acetylene from CaC2; by dehalogenation of tetra halides and dehydrohalogenation of vicinal dihalides.

Reactions: formation of metal acetylides, hydration reaction.

*Aromatic Hydrocarbons***:** Benzene: Preparation: from phenol, by decarboxylation, from acetylene. *Reactions*: electrophilic substitution reaction (general mechanism); nitration (with mechanism), halogenations (chlorination and bromination), and Friedel-Crafts reaction (alkylation and acylation) (up to 4 carbons on benzene).

Module-3: Aryl halides, substitution and elimination reactions and organometallic compounds 6 M

Aryl Halides: Preparation: (chloro- and bromobenzene): from phenol, Sandmeyer reactionand effect of nitro substituent (activated nucleophilic substitution

SN1 and SN2 reactions; eliminations: E1 and E2 reactions (elementary mechanistic aspects); Saytzeff and Hofmann eliminations.

Organometallic Compounds: Introduction; *Grignard reagents*: *Preparations* (from alkyl and aryl halide); Reformatsky reaction.

Module-4: Atomic Structure 8 M

Bohr's theory for hydrogen atom (simple mathematical treatment), atomic spectra of hydrogen and Bohr's model, Sommerfeld's model, quantum numbers and their significance, Pauli's exclusion principle, Hund's rule, electronic configuration of many-electron atoms, *Aufbau* principle and its limitations.

Module- 5: Chemical Periodicity: 7M

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

Module-6: Kinetic Theory of Gases, Real gases and liquids 7M

Kinetic Theory of Gases and Real gases: Concept of pressure and temperature; Collision of gas molecules; Collision number and mean free path. Nature of distribution of velocities, Maxwell's distribution of speed and kinetic energy; Average velocity, root mean square velocity and most probable velocity; Principle of equipartition of energy Deviation of real gases from ideal behavior; compressibility factor; Boyle temperature; Andrew's and Amagat's plots; van der Waals equation and its features; Existence of critical state, Critical constants in terms of van der Waals constants; Law of corresponding states.

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

Module-7: Chemical Thermodynamics 8M

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, ΔU and ΔH for reversible, irreversible and free expansion of gases.

Standard states; Heats of reaction; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; Laws of thermochemistry, Kirchhoff's equations. Statement of the second law of thermodynamics; Concept of heat reservoirs and heat engines; Carnot cycle; Physical

concept of Entropy; Entropy change of systems and surroundings for various processes and transformations; Auxiliary state functions (G and A) and Criteria for spontaneity and equilibrium.

Practical (30 M)

Essentials of Chemistry-I Practical

(Exp.-20 M, LNB-05 M, Viva Voce-05 M)

Organic chemistry practical

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

Inorganic chemistry practical (demonstration only)

Quantitative inorganic 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 Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator.

Question Pattern for End Semester Examination
(HCHE1GE01L& HCHE2GE01L)

Module 1: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module 2: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module 3: A set of questions carrying a total of 9 to 11 marks to be set. Students will be required to answer questions of 6 marks only.

Module 4: A set of questions carrying a total of 15 to 17 marks to be set. Students will be required to answer questions of 10 marks only.

Module 5: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module 6: A set of questions carrying a total of 12 to 14 marks to be set. Students will be required to answer questions of 8 marks only.

Module 7: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Reference Books for HCHE1GE01L& HCHE2GE01L

Theory:

1. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.
2. Carey, F. A., Guiliano, R. M. Organic Chemistry, Eighth edition, McGraw Hill Education, 2012.

3. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
5. Eliel, E. L. & Wilen, S. H. Stereochemistry of Organic Compounds, Wiley: London, 1994.
6. Nasipuri, D. Stereochemistry of Organic Compounds, Wiley Eastern Limited.
7. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
8. Fleming, I. Molecular Orbitals and Organic Chemical Reactions, Reference/Student Edition, Wiley, 2009.
9. James, J., Peach, J. M. Stereochemistry at a Glance, Blackwell Publishing, 2003.
10. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
11. Douglas, B.E. and McDaniel, D.H. Concepts & Models of Inorganic Chemistry Oxford, 1970.
12. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
13. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
14. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
15. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
16. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
17. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
18. Zemansky, M. W. & Dittman, R.H. Heat and Thermodynamics, TataMcGraw-Hill
19. Koltz & Rosenberg, Chemical Thermodynamics: Basic Concepts and Methods 7th Edition.
20. Silbey, R. J., Alberty, R. J. and Bawendi, M. G. Physical Chemistry; Wiley-India; 4th edition
21. Bevan Ott, J. and Boerio-Goates, J. Chemical Thermodynamics: Principles and Applications, Elsevier
22. Graetzel, M. &Infelta, P., The Bases of Chemical Thermodynamics; Overseas Press.

Practical:

8. Vogel, A. I. Elementary Practical Organic Chemistry, Part 1: Small scale Preparations, CBS Publishers and Distributors.
9. University Hand Book of Undergraduate Chemistry Experiments, edited by Mukherjee, G. N. University of Calcutta, 2003.
10. Mendham, J., A. I. Vogel's Quantitative Chemical Analysis 6th Ed., Pearson, 2009.

SEMESTER – 3		
Course name	**Essentials of Chemistry-II and Essentials of Chemistry-II Practical**	
Course code	**HCHE3GE02L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment(to be taken from the mid-semester exam) & 5 marks for attendance		

&

SEMESTER – 4		
Course name	**Essentials of Chemistry-II and Essentials of Chemistry-II Practical**	
Course code	**HCHE4GE02L**	Credits: 6, Full Marks: 100
Number of lectures required: 105		
*15 Marks are reserved for internal assessment(to be taken from the mid-semester exam) & 5 marks for attendance		

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

- alcohols, phenols and ethers and carbonyl compounds
- carboxylic acids and their derivatives, amines and diazonium salts.
- amino acids and carbohydrates.
- redox reactions
- p-block elements
- coordination chemistry
- chemical kinetics
- ionic equilibria and electromotive force.

Theoretical (50 M)

Essentials of Chemistry-II

Unit 1: Alcohols, phenols and ethers and carbonyl compounds 7M

Alcohols: (up to 5 Carbons).

Preparation: 1°-, 2°- and 3°- alcohols: using Grignard reagent, reduction of aldehydes, ketones, carboxylic acid and esters; *Reactions:* With sodium, oxidation (alkaline KMnO4, acidic dichromate).

Diols: Pinacol- pinacolone rearrangement (with mechanism) (*with symmetrical diols* only).

Phenols: Preparation: cumene hydroperoxide method, from diazonium salts; acidic nature of phenols; *Reactions:* electrophilic substitution: nitration and halogenations; Reimer -Tiemann reaction, Schotten – Baumann reaction, Fries rearrangementand Claisen rearrangement.

Ethers: Preparation: Williamson's ether synthesis; *Reaction*: cleavage of ethers with HI.

Aldehydes and Ketones (aliphatic and aromatic): (Formaldehye, acetaldehyde, acetone and benzaldehyde): *Preparation:* from acid chlorides, from nitriles and from Grignard reagents; general properties of aldehydes and ketones; *Reactions:* with HCN, NaHSO3, NH2-G derivatives and with Tollens' and Fehling's reagents; iodoform test; aldol condensation (with mechanism); Cannizzaro reaction (with mechanism), Wittig reaction, benzoin condensation; Clemmensen reduction, Wolff-Kishner reduction

Module-2: Carboxylic acids and their derivatives and amines and diazonium salts 7M

Carboxylic acids (aliphatic and aromatic): strength of organic acids: comparative study with emphasis on factors affecting pK values; *Preparation:* acidic and alkaline hydrolysis of esters (*B*Ac2 and *A*AC2 mechanisms only) and from Grignard reagents.
*Carboxylic acid derivatives (*aliphatic*):* (up to 5 carbons). *Preparation:* acid chlorides, anhydrides, esters and amides from acids; *Reactions:* Interconversion among acid derivatives. *Reactions:*Claisen condensation; Perkin reaction.
Amines (aliphatic and aromatic): strength of organic bases; *Preparation*: from alkyl halides, Hofmann degradation;
Reactions: with HNO2 (distinction of 1°-, 2°- and 3°- amines), Schotten – Baumann reaction , Diazo coupling reaction (with mechanism).
Diazonium salts: Preparation: from aromatic amines; *Reactions:* conversion to benzene, phenol, benzoic acid and nitrobenzene.
Nitro compounds (aromatic): reduction under different conditions (acidic, neutral and alkaline).

Module-3: Amino acids and carbohydrates 6M
Amino Acids: Preparations (glycine and alanine only)*:* Strecker synthesis, Gabriel's phthalimide synthesis; general properties; zwitterion, isoelectric point.
Carbohydrates: classificationand general properties; glucose and fructose: constitution; osazone formation; oxidation-reduction reactions; ascending (Kiliani –Fischer method) and descending (Ruff's method) in monosaccharides (aldoses only); mutarotation

Module-4: Comparative study of p-block elements and redox reactions 8M
Group trends in electronic configuration, modification of pure elements, common oxidation states, inert pair effect, and their important compounds in respect of the following groups of elements: i) B-Al-Ga-In-Tl ii) C-Si-Ge-Sn-Pb iii) N-P-As-Sb-Bi iv) O-S-Se-Te v) F-Cl-Br-I

Redox reactions: 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

Module-5: Coordination chemistry 7M
Werner's coordination theory, 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

Module-6: Chemical kinetics 7M
Introduction of rate law, Order and molecularity; Extent of reaction; rate constants; Rates of First, second and nth order reactions and their Differential and integrated forms (with derivation); Pseudo first order reactions; Determination of order of a reaction by half-life, differential method and isolation method. Mechanism- rate determination approximation and steady state approximation. Temperature dependence of rate constant; Arrhenius equation, energy of activation. Theories of reaction rate- collision theory and transition state theory (outlines only), catalysis

Module-7: Ionic equilibria and electromotive force 8M

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; Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts; Buffer solutions; Solubility and solubility product of sparingly soluble salts – applications of solubility product principle, acids and bases.

Electromotive force: 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; Electrochemical series;

Concentration cells with and without transference, liquid junction potential; pH determinationusing hydrogen electrode and quinhydrone; Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation)

Practical (30 M)

Essentials of Chemistry-II Practical

(Exp.-20 M, LNB-05 M, Viva Voce-05 M)

Qualitative semimicro analysis of mixtures containing two radicals. Emphasis should be given to the understanding of the chemistry of different reactions.

Cations: Na^+, K^+, Ca^{2+}, Ba^{2+}, Al^{3+}, Cr^{3+}, Mn^{2+}/Mn^{4+}, Fe^{3+}, Co^{2+}/Co^{3+}, Ni^{2+}, Cu^{2+}, Zn^{2+}, Sn^{2+}/Sn^{4+}, NH_4^+.
Anions: Cl^-, Br^-, I^-, SCN^-, S^{2-}, SO_4^{2-}, NO_3^-, PO_4^{3-}, BO_3^{3-}, CrO_4^{2-} / $Cr_2O_7^{2-}$

- Water or dilute HCl soluble samples are to be set only
- Same ionic species in their different valence state need not to be distinguished.

Demo only

Experiment 1: Study of viscosity of unknown liquid (glycerol, sugar) with respect to water.
Experiment 2: Determination of surface tension of a liquid using Stalagmometer

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Question Pattern for End Semester Examination (HCHE3GE02L& HCHE4GE02L)

Module 1: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module 2: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module 3: A set of questions carrying a total of 9 to 11 marks to be set. Students will be required to answer questions of 6 marks only.

Module 4: A set of questions carrying a total of 12 to 14 marks to be set. Students will be required to answer questions of 8 marks only.

Module 5: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module 6: A set of questions carrying a total of 10 to 12 marks to be set. Students will be required to answer questions of 7 marks only.

Module 7: A set of questions carrying a total of 12 to 14 marks to be set. Students will be required to answer questions of 8 marks only.

Reference Books for HCHE3GE02L& HCHE3GE02L

Theory:

1. Smith, J. G. Organic Chemistry, Tata McGraw-Hill Publishing Company Limited.
2. Carey, F. A., Guiliano, R. M. Organic Chemistry, Eighth edition, McGraw Hill Education, 2012.
3. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Carey, F.A., Sundberg, R. J. Advanced Organic Chemistry: Structure and Mechanism (Part A), Springer India Private Limited.
5. Sykes, P. A guidebook to Mechanism in Organic Chemistry, Pearson Education, 2003.
6. Morrison, R. N. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Robinson, M. J. T., Stereochemistry, Oxford Chemistry Primer, Oxford University Press, 2005.
8. Atkin, P. Shriver & Atkins' Inorganic Chemistry, 5th Ed., Oxford University Press (2010).
9. Cotton, F.A., Wilkinson, G. and Gaus, P.L., Basic Inorganic Chemistry 3rd Ed.; Wiley India.
10. Sharpe, A.G., Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005.
11. Huheey, J. E.; Keiter, E.A. & Keiter, R.L. Inorganic Chemistry, Principles of Structure and Reactivity 4th Ed., Harper Collins 1993, Pearson,2006.
12. Atkins, P. W. & Paula, J. de Atkins' Physical Chemistry, Oxford University Press.
13. Glasstone, S. & Lewis, G.N. Elements of Physical Chemistry.
14. John O'M. Bockris, Amulya K. N. Reddy; Modern Electrochemistry Volume 2; Springer, Boston, USA.

Practical:

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