CHEMISTRY II (For B. Sc. Physics)

(**Code: CCS102**, **Credit: 4,** Total Lectures-40+; **Instructors: Dr. Sanjeev Sharma, Dr. Ashish Thakur, Dr. Richa Bharti**)

Objectives & Academic Requirements: The emphasis of course is to provide students with the basic foundation in physical, organic and inorganic chemistry needed to develop an understanding of materials at a molecular level. The students are to be examined entirely on the basis of problems (seen/unseen) and assignments. Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in the examination.

Course Contents:

Unit I: Atomic Structure: Review of: Bohr's theory and its limitations, dual behaviour of matter and radiation, de Broglie's relation, Heisenberg Uncertainty principle. Hydrogen atom spectra. Need of a new approach to Atomic structure. What is Quantum mechanics? Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ^2, Schrödinger equation for hydrogen atom. Radial and angular parts of the hydogenic wavefunctions (atomic orbitals) and their variations for 1*s*, 2*s*, 2*p*, 3*s*, 3*p* and 3*d* orbitals (Only graphical representation). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1*s* and 2*s* atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers m_l and m_s. Shapes of *s*, *p* and *d* atomic orbitals, nodal planes. Discovery of spin, spin quantum number (*s*) and magnetic spin quantum number (m_s). Rules for filling electrons in various orbitals, Electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations. **[10hours]**.

Unit II: Chemical Bonding and Molecular Structure

Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy, Born-Haber cycle and its applications, polarizing power and polarizability.

Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements. Concept of resonance and resonating structures in various inorganic and organic compounds. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for *s-s*, *s-p* and *p-p* combinations of atomic orbitals, nonbonding combination 10 of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of *s-p* mixing) and heteronuclear diatomic molecules such as CO, NO and NO^+. Comparison of VB and MO approaches. **[10 hours]**.

Unit III: Fundamentals of Organic Chemistry

Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis. Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals. Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values. Aromaticity: Benzenoids and Hückel's rule. **Stereochemistry:** Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds). Threo and erythro; D and L; *cis – trans* nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E / Z Nomenclature (for upto two C=C systems). **[10 hours].**

Unit IV: Aliphatic Hydrocarbons Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.
Alkanes: (Upto 5 Carbons). *Preparation:* Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. *Reactions:* Free radical Substitution: Halogenation. **Alkenes:** (Upto 5 Carbons) *Preparation:* Elimination reactions: Dehydration of alkenes and dehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). *Reactions:* cis-addition (alk. KMnO4) and trans-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration-oxidation. **Alkynes**: (Upto 5 Carbons) *Preparation:* Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides.

Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alk. $KMnO_4$. [**10 hours**].

Reference Books:

1. Lee, J.D. *Concise Inorganic Chemistry* ELBS, 1991.
2. Cotton, F.A., Wilkinson, G. & Gaus, P.L. *Basic Inorganic Chemistry*, 3rd ed., Wiley.
3. Douglas, B.E., McDaniel, D.H. & Alexander, J.J. *Concepts and Models in Inorganic Chemistry*, John Wiley & Sons.
4. Huheey, J.E., Keiter, E.A., Keiter, R.L. & Medhi, O.K. *Inorganic Chemistry: Principles of Structure and Reactivity*, Pearson Education India, 2006.
5. Graham Solomon, T.W., Fryhle, C.B. & Dnyder, S.A. *Organic Chemistry*, John Wiley & Sons (2014).
6. McMurry, J.E. *Fundamentals of Organic Chemistry*, 7th Ed. Cengage Learning India Edition, 2013.
7. Sykes, P. *A Guidebook to Mechanism in Organic Chemistry*, Orient Longman, New Delhi (1988).
8. Eliel, E.L. *Stereochemistry of Carbon Compounds*, Tata McGraw Hill education, 2000.
9. Finar, I.L. *Organic Chemistry* (Vol. I & II), E.L.B.S.
10. Morrison, R.T. & Boyd, R.N. *Organic Chemistry*, Pearson, 2010.
11. Bahl, A. & Bahl, B.S. *Advanced Organic Chemistry*, S. Chand, 2010.

Evaluation Criteria:

1) Mid Term Examination [50 marks/25% weightage]
2) End Term Examination [100 marks/50% weightage]
3) Internal Assessment [25% weightage]: Aassignments/Problems solving/Quizzes.

PRACTICAL COURSE B.Sc. CHEMISTRY II (For B. Sc. Physics)

(**Code: CCS102L**, **Credit: 2,** Total Classes -40; **Instructor: Dr. Subhankar Chatterjee**)

Faculty will plan the experiments as per convenience and availability of instruments and other materials.

Section A: Inorganic Chemistry - Volumetric Analysis

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

Section B: Organic Chemistry

1. Detection of extra elements (N, S, Cl, Br, I) in organic compounds (containing upto two extra elements)
2. Separation of mixtures by Chromatography: Measure the R_f value in each case (combination of two compounds to be given)

(a) Identify and separate the components of a given mixture of 2 amino acids (glycine, aspartic acid, glutamic acid, tyrosine or any other amino acid) by paper chromatography

(b) Identify and separate the sugars present in the given mixture by paper chromatography.

Reference Books:

- Svehla, G. *Vogel's Qualitative Inorganic Analysis*, Pearson Education, 2012.
- Mendham, J. *Vogel's Quantitative Chemical Analysis*, Pearson, 2009.
- Vogel, A.I., Tatchell, A.R., Furnis, B.S., Hannaford, A.J. & Smith, P.W.G., *Textbook of Practical Organic Chemistry*, Prentice-Hall, 5th edition, 1996.
- Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry* Orient-Longman, 1960.

Central University of Himachal Pradesh
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TAB Shahpur, District Kangra, Himachal Pradesh-176206

HM-Course to be offered in Spring Semester 2018 by Department of Chemistry

Course Code: **ENV 508**

Course Name: **Environmental Ethics**

Name of Faulty: **Dr. Subhankar Chatterjee**

Credits Equivalent: 2 Credits (One credit is equivalent to 10 hours of lectures / organised classroom activity / contact hours; 5 hours of laboratory work / practical / field work / Tutorial / teacher-led activity and 15 hours of other workload such as independent individual/ group work; obligatory/ optional work placement; literature survey/ library work; data collection/ field work; writing of papers/ projects/dissertation/thesis; seminars, etc.)

Course Objectives:

- To become acquainted with concepts and methods of philosophical ethics that applies to issues regarding mankind's dealings with the natural world.
- To introduce students to know recent environmental issues, their cause and environmental impact
- To acquire knowledge related to these issues in national and international perspective and to validate why it is important to follow environmental ethics
- To give some future direction towards the protection and ethical use of the environment

Attendance Requirement:

Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in examination.

Evaluation Criteria:

1. Mid Term Examination: 25%

2. End Term Examination: 50%

3. Continuous Internal Assessment : 25% (Breakup is following)

a. Quiz/Class Test: 40%

b. Class activities: 20%

c. Assignment: 40%

Course Contents:

UNIT I **8 hrs**

Environmental Ethics: Definition. Principles. Need of the subject at present time. Moral standing. Human responsibilities towards nature, environment and other species. Anthropocentric ethics, intrinsic and instrumental values. Our relationship with nature/environment. Vital questions to be asked.

UNIT II **4 hrs**

The state of the World Environment: Significant global environmental issues. Human impact on the environment. Examining both the nature of the issues and their causes. Earth overshoot day. Environmental ethics and society.

UNIT III **4 hrs**

Water Pollution and Human Health. Pollution by microplastic, microbeads, microfibers: Sources, distribution, environmental impact. Effect of microplastic in ocean health and mechanism of pollution. Deleterious Effect in food chain, on Plankton and on corals health. Ocean pollution- a threat to human health. Way out and Governmental Policies.

UNIT IV **4 hrs**

Responsibility for the Environment. International and National efforts for Environment Protection. Sustainable living.

Suggested Readings:

1. Miller. G.T. 2004. Environmental Science. Thomson, California.
2. K.B. Chokkan, Pandya, H and Raghunathan, H (Eds), 2004, Understanding Environment. Sagar publication India Pvt. Ltd., New Delhi.
3. Barry, R. G., 2003. Atmosphere, weather and climate. Routledge Press, UK
4. Firor, J., and J. E. Jacobsen, 2002. The crowded greenhouse: population, climate change and creating a sustainable world. Yale University Press.
5. Harvey D., 2000, Climate and Global Climate Change, Prentice Hall.
6. Environmental Chemistry By G.S.Sodi
7. Geist, Helmut 2005. The causes and progression of desertification. Ashgate Publishing. ISBN 978-0-7546-4323-4
8. F. T. Mackenzie and J. A. Mackenzie, Our Changing Earth: An Introduction to Earth System Science and Global Environmental Change, Prentice Hall, 1995
9. World Resources 1992-1999: A Guide to the Global Environment, Oxford, 1992.

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Courses to be offered in Spring Semester 2018 by Department of Chemistry

Semester II

CORE COURSE (Compulsory)

CCS 407-ORGANIC CHEMISTRY II [Credit -4] [40 Lectures]

Faculties: Dr. Ashsih Thakur and Dr. Richa Bharti

UNIT I: **Pericyclic Reactions**

Molecular orbital symmetry, frontier orbitals of ethylene, 1,3-buta diene, 1,3,5-hexatriene and allyl systems. Classification of pericyclic reactions. Woodward – Hoffmann correlation diagrams. FMO and PMO approach, concept of aromaticity of pericyclic transition states. Selection rules and stereochemical aspects of electrocyclic reactions, cycloaddition and sigmatropic shifts. Electrocyclic reactions: conrotatory and disrotatory motions, 4n, 4n+2 and allyl systems. Cycloaddition reactions: antarafacial and suprafacial additions, 4n and 4n+2 systems; 2,2 addition of ketenes, 1,3 dipolar cycloadditions and cheleotropic reactions. Sigmatropic rearrangements: suprafacial and antarafacial shifts of H, sigmatropic shifts involving carbon moieties, 3,3- and 5,5-sigmatropic rearrangements. Sommelet-Hauser, Cope, Claisen, and aza-Cope rearrangements. Fluxional tautomerism. Ene reaction.

UNIT II: **Heterocyclic Chemistry**

Systematic nomenclature (Hantzch-Widman system) for monocycle and fused heterocycles. General approaches to heterocycle synthesis – cyclisation and cycloaddition routes. Umpolung, synthon approach; Stork annulation reactions and recent applications (synthesis of testosterone, estrone, progesterone, ranitidine, lansoprazole and/or recently discovered molecules etc.); Rearrangement and ring transformation involving 5- and 6-membered heterocycles with one heteroatom.

UNIT III: **Chemistry of Natural Products-Ia**

Structural types; Biogenesis; Structure Elucidation and chemistry of representative examples of the following classes of natural products. *Alkaloids*- Structural types General introduction to phenylethylamine, pyrrolidine, pyridine, indole, isoquinoline type alkaloids. Structure elucidation (by chemical and spectroscopical methods), synthesis, biogenesis, biosynthesis, biological activity of atropine, nicotine, coniine and papaverine.

UNIT IV: **Chemistry of Natural Products-Ib**

*Terpenoid*s – Isoprene rule; structure elucidation (by chemical and spectroscopical methods), synthesis, biogenesis, biosynthesis of representative examples of acyclic, monocyclic and bicyclic monoterpenes. Structural types – general introduction to sesqui-, di-, and tri-terpenes.

CCS 408- INORGANIC CHEMISTRY II [Credit -4] [40 Lectures]

Faculties: Dr. Shivender Saini

UNIT I: **Organometallic Chemisty-I**

The 18- electron rule for organometallic compounds of transition metals: Classification based on 18-electron rule: complexes of two, three, four, five six, seven, eight-electron pi-ligands: nomenclature. Exceptions to 18 electron rule: the 16-electron rule. Isolobal and isoelectronic relationship of complexes, Agostic interaction.
Metal-carbon-bonded compounds (compounds of the sigma electron ligands), Metal-alkyl, -allyl, -carbene, -carbonyl, -carbide and cyclopentadienyl complexes structure and bonding in η^2- ethylene and η^3- allylic compounds with typical examples, structure and bonding of $K[PtC_4H_4Cl_3]$, $[(Ph_3P)_2Pt(Ph\text{-}C{\equiv}C\text{-}Ph)]$, $[Co_2(CO)_6(Ph\text{-}C{\equiv}C\text{-}Ph)]$

UNIT II: **Organometallic Chemisty-II**

Elementary idea about homoleptic and non-homoleptic compounds: synthesis, reactivity, oxidative addition and reductive elimination reaction: insertion reactions and elimination; electrophilic and nucleophilic reactions; instability (decomposition pathway) and stabilization. Metallacycles.

UNIT III: **Molecular Clusters**

Main-group clusters: Geometric and electronic structure, three-, four- and higher connect clusters, the closo-, nido-, arachno-borane structural paradigm, styx No. of neutral and boron hydrides, Wade-Mingos and Jemmis electron counting rules, clusters with nuclearity 4-12 and beyond 12. Structure, synthesis and reactivity. Transition-metal clusters: Capping rules,

metal-ligand complexes vs heteronuclear cluster. Main-group Transition-metal clusters: Isolobal analogs of p-block and d-block clusters, limitations and exceptions. Clusters having interstitial main group elements, cubane clusters and naked or Zintl clusters. Metal-carbonyl clusters, structures, capping and electron counting. Molecular clusters in catalysis, clusters to materials, boron-carbides and metal borides. [Lipscomb topological diagrams, polyhedral skeletal electron pair theory (PSEPT); Illustrative examples from recent literature-*not in details*].

UNIT IV: **Bioinorganic Chemistry**

Reversible oxygenation in life process O_2-uptake proteins, myoglobin, hemoglobin, hemeerythrin, hemocyanin and model systems, electron transport proteins, Fe-S proteins, ferridoxin, rubredoxin and model systems, respiratory electron transport chains: cytochromes, photosynthetic electron transport chain, chlorophyll, PS-I and PS-II, Biological nitrogen fixation (Nitrogenase) and abiological nitrogen fixation; metalloenzymes: – catalase, peroxidase, urease, superoxide dismutase (SOD), cytochrome P 450, cytochrome C oxidase, carbonic anhydrase, carboxypeptidase; molybdoenzymes.
Metal dependent diseases Wilsons, Alzheimer, vitamin B_{12} and B_{12} -enzyme, Metal complexes in therapeutic use of chelated and non chelated compounds, Chelation therapy.

CCS 409- PHYSICAL CHEMISTRY II [Credit -4] [40 Lectures]

Faculties: Dr. S. Chatterjee + Dr. Ayan Chatterjee

UNIT I: **Quantum Mechanics**

Time independent Schrödinger equation, probability concept, concept of stationary state. Linear operators in quantum mechanics, Eigen value equation. Formal derivation of Heisenberg uncertainty principle: commutability and compatibility. Properties of the Hermitian operator, canonical commutation relations, Ehrenfest theorem. Applications: Particle-in-a box (1-, 2-, 3- dimensional), different potential functions and barrier problems, degeneracy, density of states. Simple harmonic oscillator: Ladder operator, properties of the eigen functions. Rigid rotor: Angular momentum operator, spherical harmonics. Hydrogen atom: Details of the solution, shapes of the orbitals.
Approximate method: Elementary perturbation theory, Variation theorem, Simple applications.

UNIT II: **Atomic structure and Spectroscopy**

Motion under central force: Conservation of angular momentum and its consequence. Motion of angular momentum under magnetic field. Larmor prescision. Quantization rule and quantum numbers. Zeeman effect. Stern Gerlach experiment. Spin-orbit interaction, conservation of total angular momentum J, Vector atom model. Anomalous Zeeman effect, Paschen-Beck effect. Multielectron system- Pauli exclusion principle. Term symbols for simple multi-electron system. Magnetic moment and Lande's g factor. Schrödinger equation for hydrogen atom (only qualitative idea), separation of radial and angular part. Orbits and Orbitals. Shape of orbitals.

UNIT III: **Chemical Kinetics and Reaction Dynamics-I**

Reaction Dynamics: Rates and mechanisms of photochemical, chain and oscillatory reactions (hydrogen-bromine, hydrogen – chlorine reactions, pyrolysis of acetaldehyde, decomposition of ethane and Belousov- Zhabotinsky reaction as examples), dynamics of barrier less chemical reactions in solutions, dynamics of uni molecular reactions (Lindemann-Hinselwood and Rice-Ramsperger-Kasel-Marcus [RRKM] theories). Correlation between Kinetics and mechanism & vice-varsa. Enzyme catalysis; Michaelis-Menten equation

UNIT IV: **Chemical Kinetics and Reaction Dynamics-II**

Fast Ractions: Luminescence and energy transfer processes. Study of kinetics by stopped flow and relaxation methods, flash photolysis and magnetic resonance method. Statistical formulation of chemical kinetics reaction dynamics: Intermolecular collision and its consequence. Role of intermolecular potential, elastic and inelastic collision. Thermodynamics of reaction rates. Activation energy- Experimental and zero point activation energy. Rate constant expression for chemical reaction based on Eyring equation with examples. Physical rate processes –viscosity and diffusion.

CORE -OPEN COURSE

CCS 544- STRUCTURE AND PROPERTIES OF SOLIDS (Credit-2) [20 Lectures]

Faculties: Dr. Dilbag Singh

UNIT I: Defects in solids, point, line and plane defects. Determination of equilibrium concentration of Schotky and Frenkel defects. Stoichiometric imbalance in crystals and non stoichiometric phases, color center in ionic crystals,

UNIT II: Band theory, band gap, metals and insulators, semiconductors, hoping semiconductors rectifiers and transistors, Bonding in metals; free electron theory, electronic specific heat.

UNIT III: Hall effect, electrical and thermal conductivity of metals, superconductors; meissner effect, elementary concepts of BCS theory, ferroelectricity, antiferroelectricity, piezoelectricity, liquid crystals, cooperative magnetism.

UNIT IV: Illustrative examples of ionic, covalent and hydrogen bonded solids; perovskite, ilmenite and rutile; spinel and inverse spinel, silicates: pyroxene, amphibole, talc, mica, clay, zeolite, ultramarine;

Attendance Requirement For all the courses:

Students are expected to attend all lectures in order to be able to fully benefit from the course. A minimum of 75% attendance is a must failing which a student may not be permitted to appear in examination.

Evaluation Criteria for all the courses:

1. Mid Term Examination: 25%
2. End Term Examination: 50%
3. Continuous Internal Assessment : 25% (Breakup is following)
    A. Quiz/Class test: 40%
    B. Presentation/ Assignment: 40%
    C. Class activities: 20%

CCS 406- PHYSICAL CHEMISTRY LAB I (Credit-2) [40 Classes]

Faculties: Dr. S. Chatterjee + Dr. Dilbag Singh

Faculty will plan the experiments as per convenience and availability of instruments and other materials.

SET I:

1. Spectrophotometric experiment - determination of composition of a complex (Job's method)

2. Determination of cmc of surfactants: conductometry and spectrophotometry.

3. Determination of molecular weight of macromolecules by viscometry.

4. Determination of dipole moment.

5. Analytical experiments: Study of distribution of an organic acid in an organic solvent and water – determination of association constant (with the help of Nernst distribution law), determination of van't Hoff factor.

6. Determination of transport number.

7. Molecular structure determination – gas phase vibrational rotational spectra of HCl/DCl.

SET II:

(A) Conductometry: 1. Determination of strengths of strong and weak acids in a mixture conductometrically

2. Determination of strengths of halides in a mixture conductometrically by precipitation titrations

3. Determination of concentrations of halides and halogen acids in a mixture conductometrically by precipitation titrations (system: HCl + KCl mixture by titration with standard NaOH and standard $AgNO_3$ solutions

4. Verification of Ostwald's dilution law conductometrically

5. Determination of critical micelle concentration (CMC) of a surfactant by conductometric method

(B) Potentiometry / pH-metry: 6. Determination of strengths of strong and weak acids in a mixture potentiometrically / pH-metrically (system: acetic acid + HCl)

7. Determination E° value of redox couples (i). Quinhydrone electrode (ii). Ferricyanide-ferrocyanide couple (iii). AgCl/Ag electrode

8. Determination of strengths of halides in a mixture potentiometrically by precipitation titrations (0.02N KBr + 0.02N KI mixture with standard 0.1N $AgNO_3$)

9. Determination of concentration by potentiometric / pH- metric titrations: (i). Acid-base titration (standard oxalic acid vs. NaOH, acetic acid vs. NaOH) (ii). Determination of ferrocyanide ion using standard bromate solution (iii). Determination of iodide ion by differential redox titration using standard bromated solution (iv) Determination of composition of zinc-ferrocyanide complex by potntiometric titration

(C) Colourimetry: 10. Determination of pKa of an indicator by colourimetric method (systems: methyl red, methyl orange, alizarin red –S in aqueous solution)

11. Kinetic studies on iodination of aniline (d) Polarimetry:

12. Determination of specific rotation and molar rotation of dextro-tartaric acid

13. Polarimetric determination of rate constant of reactions: (i). Inversion of sucrose (ii). Mutarotation of glucose (determination catalytic coefficients: k_{H+} and k_{H2O})

SET III:

Group-a: Phase-rule; 1. Determination of critical solution temperature (system: phenol water)

2. To construct the phase diagram of a three component system: (i).Chloroform acetic acid-water (ii). Benzene-acetic acid-water (iii). Nitrobenzene-acetic acid-water

Group-b: Adsorption; 3. To study the surface tension – concentration relationship of solutions (Gibbs equation)

Group-c: Kinetics; 4. Determination of rate constant of reactions: (i). Iodination of acetone (zero order) (ii). Decomposition of H_2O_2 (first order) (iii). Oxidation of iodide ion by bromate ion (second order)

5. Determination of rate constant of oxidation of iodide by H_2O_2 and to study the kinetics of iodine-clock reaction

Group-d: Thermodynamics & Equlibrium; 6. Determination of exchange capacities of ion-exchange resins and studies on ion-exchange equilibria.

7. Determination of solubility and solubility product of salts (systems: PbI_2, Potassium hydrogen tartarate)

8. Determination of partition coefficients of a solute between two immiscible solvents (systems: benzoic acid between benzene and water)

9. Determination of composition of complexes formed in solution (systems: Cu^{2+} - NH_3, Ag^+ - NH_3).

10. Determination of equilibrium constant of hydrolysis of an ester.

11. Determination of isoelectric point by viscosity measurement