DEPARTMENT OF CHEMISTRY
FACULTY OF SCIENCE

UNIVERSITY OF RAJSHAHI

Syllabus for
The Degree of Bachelor of Science with Honours
[B. Sc. Honours] in Chemistry
Session: 2017−2018
Examination 2021

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PREFACE

The word “Chemistry” has been derived from the Greek word “Chemeia”, meaning, “the art of metal working”. Obviously modern chemistry involves a great deal more than this. It has become an interdisciplinary science and today no scientific work can escape chemistry. Chemistry plays vital roles in our lives, namely agricultural products, chemicals, fertilizers, medicines and drugs, plastics, alloys, electronic components, paper, wood products etc.

With all the importance in modern civilization, chemistry has earned immense attention in present education.

B.Sc. Honours degree is conferred by Rajshahi University to the candidates who complete the courses and clear the examinations set for the aforesaid degree.
The B. Sc. Honours Examination in Chemistry shall consist of the

- i) B.Sc. Honours Part−I Examination of 950 marks (9.5 units, 38 credits) at the end of the 1st academic year,
- ii) B.Sc. Honours Part−II Examination of 950 marks (9.5 units, 38 credits) at the end of the 2nd academic year,
- ii) B.Sc. Honours Part−III Examination of 1050 marks (10.5 units, 42 credits) at the end of the 3rd academic year,
- iv) B.Sc. Honours Part−IV Examination of 1050 marks (10.5 units, 42 credits) at the end of the 4th academic year.

For obtaining B.Sc. Honours degree in Chemistry a student shall have to take total courses of 4000 marks, of which Chemistry courses of 3400 marks and related courses including Mathematics, Physics and Statistics of 600 marks distributed over four academic years. In addition, a non-credit English course of 50 marks shall have to be taken. The Chemistry, Physics, Mathematics, Statistics and English courses are prefixed by Chem, Phys, Math, Stat and Eng, respectively. The prefixes are followed by a 3(three)-digit number of which the central digits 1, 2 and 3 refer to the sectional courses of Chemistry, viz., Physical, Organic and Inorganic Chemistry, respectively and that 4, 5, 6 and 7 refer to related courses of Physics, Mathematics, Statistics and English, respectively. The first and the last digits of a course number represent the Honours years and the sectional or subject course numbers, respectively. The letters F and H at the end of the courses indicate a full a half unit course and the letters V and L imply Viva-voce and Laboratory courses, respectively.

THE DEPARTMENT AND THE FACULTY MEMBERS

The Department of Chemistry started functioning as a small discipline in 1958 at the First Science Building under the leadership of Late Dr. Kazi Abdul Latif. The academic programme started in the same year with a batch of 15 M.Sc. (Previous) students. A three years Honours course was introduced in 1962, which was transformed to four years course in 1997. The Department was shifted to its present location in 1968. Since then, it has flourished into one of the biggest departments of Rajshahi University. The growth was made possible through proper academic planning and execution of those by using available financial support from various heads. An all out effort of the well-trained faculty members played the vital role for rapid and sustained growth in the academic and research arena. The vitality of the faculty whose research interest includes programmes of the frontiers of physical, organic, inorganic, analytical, polymer, industrial, agro-environmental and nanochemistry and nanosciences. The department is committed to provide stimulating educations at its highest level of attainment to graduate and postgraduate students. All the major areas of research thrust being pursued in the department are of theoretical importance as well as practical utility.

The present enrolment of students at the B.Sc. (4 years) Honours level is about 400 and in (one year/two years) M.Sc. level 80. Besides, there are 12 M.Phil. and 7 Ph.D. fellows. The students of M.Sc. level are distributed among physical, organic and inorganic branches and are specialized in the relevant field. About 20 of the students at the Masters level (thesis group) carry on research in partial fulfillment of the requirement for the degree.

At present there are 37 members of teaching staff and 40 supporting laboratory and office staffs catering the needs of the students and the research scholars.

<u>Implication of students ID</u>

The first 2 digits indicate the year of enrolment; next 3 digits, the Hall; next 2 digits, the faculty; and the last 3 digits, the class roll number.

digit	digit	digit	digit	digit	digit	digit	digit	digit	digit
↓		↓			↓		↓		
Year of enrolment		Hall			Faculty		Class roll number		

To assist prospecting students for getting an idea about research interest, a list of the faculty members with area(s) of research is given below (*on leave):

Professor

Name		Field(s) of Specialization
Md Saidul Islam *B.Sc.Honours, M.Sc.(Rajshahi)* *M.Phil (Rajshahi),* *Ph.D. (IIT, Roorkee, India)*		**Inorganic** (Coordination and Environmental Chemistry)
Md Nazrul Islam *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Delhi, India)*		**Physical** (Solution Chemistry: Molecular Interactions in Binary and Ternary Solutions)
Md Belayet Hossain Howlader *B.Sc.Honours, M.Sc.(Jahangirnagar)* *Ph.D. (Glamorgan, UK)*		**Inorganic** (Organometallic and Coordination Chemistry)
Choudhury Md Zakaria *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (St. Andrews University, UK)*		**Inorganic** (Ferrocene Chemistry and Crystal Engineering)
Md Akhter Farooque *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Okayama, Japan)*		**Inorganic** (Coordination Chemistry and Photochemical Reactions)
Hasan Ahmad *B.Sc.Honours, M.Sc.(Rajshahi),* *Ph.D. (Kobe, Japan)*		**Organic** (Polymer Colloid Chemistry and Composite Materials)
Harendra Nath Roy *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (IIT, Kharagpur, India)*		**Organic** (Synthetic Organic Chemistry)
Md Yeamin Reza *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Saga, Japan)*		**Inorganic** (X-ray Crystallography in Complex Chemistry)
Md Habibur Rahman *B.Sc.Honours, M.Sc.(Rajshahi),* *Dip. in Chemistry and Chem. Engg. (TIT, Japan), Ph.D. (IACS, Jadavpur, India)*		**Physical** (Polymer Chemistry and Physics)

Name		Field(s) of Specialization
Md Shahed Zaman *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Iwate, Japan)*		**Organic** (Natural Product and Synthetic Chemistry)
S M Monjurul Alam *B.Sc.Honours, M.Sc.(Rajshahi),* *M.Phil (UK), Ph.D. (Malaysia)*		**Inorganic** (Environmental and Analytical Chemistry, Separation Science and Bioinorganic Chemistry)
Md Tariqul Hassan *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (TIT, Japan)*		**Organic** (Polymer and Organic Synthetic Chemistry)
A B M Hamidul Haque *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Rajshahi)*		**Organic** (Natural Product and Synthetic Chemistry)
Md Nazrul Islam *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (India)*		**Inorganic** (Coordination Chemistry)
Laila Arjuman Banu *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Rajshahi)*		**Inorganic** (Coordination Chemistry)
Md Nurul Islam *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (KIT, Japan)*		**Physical** (Agro-environmental Chemistry, Peptide Chemistry: Drug Design and Synthesis, Solution Chemistry)
Md Monirul Islam *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Hokkaido University, Japan)*		**Physical** (Nanoscience and Spectroelectrochemistry)
Md Kudrat-E-Zahan *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Yamagata, Japan)* *Visiting Scientist (Sakarya University, Turkey)*		**Inorganic** (Coordination chemistry, Solution Chemistry and Nanoscience)
Md Mahbubor Rahman *B.Sc. Honours, M.Sc.(Rajshahi)* *Ph.D. (University of Lyon1, France)* *Postdoc. (Ghent University, Belgium)*		**Organic** (Polymer Colloids, Magnetic Nanoparticles, Biomaterials)

Name		Field(s) of Specialization
Associate Professor		
Tapan Kumar Biswas *B.Sc.Honours, M.Sc.(Rajshahi)*		**Physical** (Solution and Electroanalytical Chemistry)
Md Nazmul Islam *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Rajshahi)*		**Physical** (Environmental Chemistry, Risk Assessment)
Md Shahidul Islam *B.Sc.Honours, M.Sc.(Rajshahi University)* *Ph.D. (Kyushu Institute of Technology, Japan)*		**Organic Chemistry** (Peptide Synthesis, Drug Design and Synthesis)
Mohd. Roushown Ali *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (TIT, Japan)*		**Organic** (Synthetic Organic Chemistry)
Md Motahar Hossain *B.Sc.Honours, M.Sc.(Rajshahi)* *Diploma (TIT, Japan)* *Ph.D. (Hokkaidu University, Japan)*		**Inorganic** (Electrochemistry, Coordination Chemistry and Analytical Chemistry)
Md Rabiul Karim *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D.(UM, Malaysia)*		**Inorganic** (Materials Chemistry: Liquid Crystalline Materials)
Md Abdul Mannan *B.Sc.Honours, M.Sc.(Rajshahi)* *M.Eng.(Japan), Ph.D. (Japan)*		**Organic** (Advanced Organic-Inorganic Hybrid Solar Cell Materials, Thin Films and Surface Chemistry)
Mst Sabina Yasmin *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Malaysia)*		**Organic** (Natural Product and Synthetic Chemistry)
Bilkis Zahan Lumbiny *B.Sc.Honours, M.Sc.(Dhaka)* *Ph.D. (South Korea)*		**Organic** (Physico-Organic and Theoretical Chemistry: Synthesis, Kinetics and Molecular Drug Design)
Md Masuqul Haque *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (South Korea)*		**Inorganic** (Solid State Chemistry)
Md Rezaul Haque Ansary *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Malaysia)*		**Inorganic** Coordination and Pharmaceutical Chemistry, Micro and Nanoparticle Based Drug Delivery)

Md Ashraful Alam *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Rajshahi)*		**Organic** (Polymer Synthesis and Characterization)
A A S Mostofa Zahid *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (South Korea)*		**Physical** (Nano- and Electrochemistry)
Dulal Chandra Kabiraz *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Japan)*		**Physical** (Biosensor, Nanochemistry and Solution Chemistry)
Assistant Professor		
Md Abdur Rahman* *B.Sc.Honours, M.Sc.(Rajshahi)*		**Organic** (Inorganic /Organic Composite Material Chemistry)
Md Ali Ashraf *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (China)*		**Inorganic** (Metal Complexes, Metal-Organic Materials, Catalysis and Water Splitting)
Md Shamim Hossan * *B.Sc.Honours, M.Sc.(Rajshahi)*		**Physical**
Md Faruk Hossen* *B.Sc.Honours, M.Sc.(Rajshahi)* *Ph.D. (Malaysia)*		**Inorganic**

Mission

The Department of Chemistry at Rajshahi University is poised to play a central role for producing graduates in chemistry, a core discipline of chemical sciences. The courses of chemistry are divided into basic (organic, inorganic and physical), advanced (modern synthesis, spectroscopy, analytical, quantum and theoretical), and applied courses (polymer, nanoscience, medicinal chemistry etc.).

Vision

The chemistry curriculum has been designed to provide the undergraduates with a sound knowledge in the fundamental areas of modern chemistry. The curriculum will prepare the chemistry students to structure and interpret the concepts and to understand chemical reactions/processes on atomic/molecular-scale and properties of matter, a prerequisite for the entrance at the M.Sc. level.

B. Sc. Honours Part–I Examination, 2018
Session: 2017–2018

The courses and distribution of marks are as follows:

Courses	Course Titles	Units	Credits	Marks
Chem 111F	Introductory Physical Chemistry	0.75	3	75
Chem 112F	Chemical Thermodynamics	0.75	3	75
Chem 121F	Fundamental Organic Chemistry–I	0.75	3	75
Chem 122F	Structural Aspects of Organic Compounds	0.75	3	75
Chem 131F	Basic Inorganic Chemistry	0.75	3	75
Chem 132F	Qualitative and Quantitative Inorganic Analysis	0.75	3	75
Chem 101VH	Viva-voce in Chemistry–I	0.50	2	50
Chem 101LF	Chemistry Practical–I	1.50	6	150
Phys 141F	Mechanics, Properties of Matter and Sound	0.75	3	75
Phys 142F	Electricity and Magnetism	0.75	3	75
Math 151F	Algebra and Matrices	0.75	3	75
Math 152F	Differential and Integral Calculus	0.75	3	75
	Total	**9.50**	**38**	**950**
Eng 171H	Functional English (noncredit course)	0.50	0	50

N.B. Minimum 45 lectures should be delivered for each 3 credit theory course.

Each and every course includes 80% final and 20% in-course examinations. The final examination of each 75 marks (80%) theory course shall be of four hours duration. In-course marks comprise of 15% tutorial or terminal and 5% class attendance. The class teachers of each course shall submit the average marks of in-course examinations (two or three) in a sealed envelope to the chairman of the relevant examination committee within three weeks from the last class held. The relevant **examination committee** shall prepare the result by adding the average marks of each in-course to the average marks obtained in the final examination of respective course and send a copy of the average marks of each in-course to the controller of examinations.

All practical courses include 70% practical examination and 30% continuous Lab assessment. The practical examination of 70% of 150 marks (1.50 unit, 6 credits) shall be of 36 (thirty six) hours duration (6 days). The students are required to submit a report after each practical class to the class teacher(s) for evaluation. After evaluation, the report shall be returned to the students. The class **teacher(s)** shall submit the average marks of all Lab evaluation in a sealed envelope to the **chairman** of the relevant **examination committee** within three weeks from the last Lab class held. The examination committee shall send a copy of each of the consolidated **practical** and **Lab evaluation** marks to the **controller** of examinations.

Viva-voce examination (**Chem 101VH**) includes the assessment of the students through oral examination (of all the courses) by the **members** of the relevant examination committee. The **examination committee** shall send a copy of the marks to the **controller** of examinations.

N.B. Students having less than 60% class attendance shall not be allowed to sit for the examination.

Course: Chem 111F
Introductory Physical Chemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course presents introduction to the physical chemistry. After implementation of the course, **s**tudents will be able to understand the principles of chemical calculations and data treatment, dynamics and interactions of gas molecules, physical properties of liquids and structural relation of molecules with their physico-chemical properties. The gained knowledge will help them to process data, explain behaviour of liquid gases and predict the structure of molecules.

1. **Chemical Calculations** (12 lectures)**: Units and dimensions of physical quantities:** theory of dimensions, uses of dimensions, SI units, conversion of units. Handling numbers: scientific notation. Reporting measured values: uncertainties in

measured quantities and significant figure conventions. Reporting calculated results: rounding off numbers. Solving problems: the factor-label method. The mole concept and chemical stoichiometry: composition stoichiometry and reaction (equation) stoichiometry. **Errors in measurements:** concept and classification of errors, propagation of errors and their computation. Presenting experimental data: tables and plots. Extracting physical quantities from linear plots: least-squares fitting and linear regression of data.

2. **Kinetic Theory of Gases** (7 lectures): Characteristics of gases; ideal gas and its equation; kinetic molecular theory of gases; the kinetic gas equation; the average kinetic energy of a gas molecule; heat capacity of gases and the principle of equipartition of energy; distribution of molecular speeds: Maxwell's law, most probable, average and root-mean-square (RMS) speeds; diffusion and effusion of gases and their interpretation in terms of the kinetic theory; molecular collisions and mean free path.
3. **Real Gases** (8 lectures): States of aggregation of matter and intermolecular forces: ionic interactions and van der Waals' forces; equations of state of real gases: van der Waals' equation and its limitations, Virial equation; liquefaction of gases: principles and methods, behaviour of gases near liquefaction temperature, critical phenomena, continuity of state, law of corresponding states and the reduced equation of state.
4. **The Liquid State** (10 lectures)**:** Characteristics of liquids, gases and solids, liquid-vapour equilibrium, molecular interpretation of vapour pressure. Boiling point, critical temperature and the heat of vaporization (Trouton's law, Crafts' rule); surface tension and surface free energy, temperature dependence and determination of surface tension. Viscosity and viscosity coefficient, measurement of viscosity coefficient, effect of temperature, pressure and other factors on viscosity, viscosity of liquid mixtures.
5. **Physical Properties and Chemical Constitution** (8 lectures): Classification of physical properties: additive, constitutive, intensive and extensive; some physical properties in relation to molecular structure: molar volume, parachor, rheochor, molar refraction, optical activity, dipole moment, molar polarization, magnetism and magnetic susceptibility.

Recommended Books

1. John R. Taylor: An Introduction to Error Analysis: Study of Uncertainty in Physical Measurements (2nd edn. 1997)
2. D.A. Skoog, D.M. West and F.J. Holler: Fundamentals of Analytical Chemistry (9th edn. 2013)
3. J. N. Miller and J. C. Miller: Statistics and Chemometrics for Analytical Chemistry (6th edn. 2010)
4. Peter W. Atkins and Julio de Paula: Atkins' Physical Chemistry (10th edition).
5. N. Kundu and S. K. Jain: Physical Chemistry
6. Samuel Glasstone: Textbook of Physical Chemistry

Course: Chem 112F
Chemical Thermodynamics
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course describes the concept and applications of chemical thermodynamics. At the end of the course, students will enrich their knowledge about the energetics of physical and chemical changes, phase and reaction equilibria. The students can apply their achievements to predict the stabilities of reactants and products and optimize the physical and chemical processes.

1. **First Law of Thermodynamics** (10 lectures). Scope of thermodynamics, thermodynamic variables, concepts of systems, boundary, surroundings, work, heat; reversible and irreversible pressure-volume works, internal energy and first law of thermodynamics, exact and inexact differentials; enthalpy, heat transactions at constant pressure and volume, heat capacities and relation between different heat capacities, internal pressure, Joule's and Joule-Thomson experiments, Joule-Thomson coefficient, first law and perfect gas, reversible isothermal and reversible adiabatic processes in perfect gas, calculation of heat, work, change in internal energy and enthalpy in thermodynamic processes, state functions and path functions, molecular nature of internal energy.

2. **Thermochemistry** (7 lectures)**.** Standard states of pure substance; thermochemical equations; endothermic and exothermic processes; standard enthalpy of reaction; temperature dependence of reaction enthalpies – Kirchhoff's equation; laws of thermochemistry; calorimetric measurements and estimation of thermodynamic properties: bond activity and energies, enthalpy of reactions, formation, combustion, neutralization, solutions, dilution, fusion, vaporization, sublimation, hydrogenation**.**

3. **The Second and Third Laws of Thermodynamics** (10 lectures)**.** Necessities of second law; spontaneous and nonspontaneous processes; statements of second law; heat engine, Carnot cycle, concept of entropy; entropy changes in cyclic, reversible isothermal, reversible adiabatic processes, phase transition, heating, reversible and irreversible state changes of perfect gas; reversibility, irreversibility and equilibrium with respect to entropy; molecular nature of entropy; entropy and universe; third law of thermodynamics: absolute and conventional entropy, Nernst heat theorem, statistical view of entropy, calculation of conventional entropy, residual entropy.

4. **Thermodynamics of Material Equilibrium** (8 lectures). Concept of material equilibrium; entropy and equilibrium; concepts of Gibbs and Helmholtz energies; criteria for spontaneity; significance of Gibbs and Helmholtz energies; thermodynamic relations for systems in equilibria: thermodynamic equation of

states, Gibbs equations, Maxwell relations; calculation of changes in state functions; chemical potential and material equilibrium; phase equilibrium; reaction equilibrium.

5. **Reaction Equilibrium in Ideal Gas Mixtures** (10 lectures). Spontaneous chemical reactions; standard Gibbs energy of reaction; chemical potentials in pure ideal gas and ideal gas mixtures; ideal gas reaction equilibrium; equilibrium constants in terms of partial pressure, concentration and mole fraction; pressure and temperature dependence of equilibrium constants; calculation of equilibrium composition of ideal gas mixtures; molecular interpretation of the equilibrium constant; response of equilibrium to changes of pressure, temperature, inert gas, catalysts and concentration of reacting gas components.

Recommended Books

1. Ira N. Levine: Physical Chemistry (6^{th} edition)
2. Peter W. Atkins and Julio de Paula: Atkins' Physical Chemistry (10^{th} edition)
3. R.G. Mortimer: Physical Chemistry
4. Thomas Engel and Philip Reid: Physical Chemistry
5. I. Koltz and Rosenberg: Chemical Thermodynamics
6. N. Kundu and S. K. Jain: Physical Chemistry

Course: Chem 121F
Fundamental Organic Chemistry–I
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

After completing the course the student shall be able to demonstrate the physical and chemical properties, uses of aliphatic and aromatic hydrocarbons, ethers, epoxides, alcohols, phenols and conformation of alicyclic compounds. They will earn tempo to synthesize new aliphatic/aromatic compounds through this preliminary idea.

1. **Aliphatic Hydrocarbons:**

   a. **Alkanes** (5 lectures)**:** Source, nomenclature, preparations and properties, free-radical substitution; halogenations, mechanism and orientation of halogenations, relative reactivities of alkanes toward halogenations, ease of abstraction of hydrogen atoms, stability of free-radicals, nitration, sulphonation, thermal and catalytic reactions; oxidation (heat of combustion), cracking, reforming, aromatization, knocking, and octane and cetane number.

b. **Alkenes** (5 lectures)**:** Source, nomenclature, preparations and properties, electrophilic and free-radical addition; addition of H_2 (heat of hydrogenation and stability of alkenes), X_2, HX, H_2SO_4, H_2O, $KMnO_4$, OsO_4, halohydrin formation, dimerization, alkylation, addition of free radicals, polymerization, allylic substitution and ozonolysis, Markovnikov rule, regioselectivity and Kharasch's effect.

2. **Alkynes** (3 lectures)**:** Source, nomenclature, preparations and properties; addition of H_2, X_2, HX, H_2O, HOX, oxidation with $KMnO_4$ and O_3, acidity of alkynes and uses of metal acetylide in organic synthesis.

3. **Alcohols** (6 lectures)**:** Classification, nomenclature, synthesis of alcohols; planning, limitations and properties, reactions with HX, PX_3, PX_5, $SOCl_2$ and different organic acids, dehydration with H_2SO_4, Al_2O_3, P_2O_5 and oxidation of alcohols, reaction with copper powder at higher temperature, Victor Meyer and Lucas test. Dihydric and trihydric alcohols, synthesis and their physical and chemical properties.

4. **Ethers and Epoxides** (4 lectures)**:** Nomenclature, preparations, Williamon's synthesis, properties, uses and reactions of ethers, ether as protecting groups, crown ethers, preparation of epoxides, and reactions of epoxide; acid-catalyzed cleavage, base-catalyzed cleavage and cleavage with Grignard reagents.

5. **Cycloalkanes** (6 lectures)**:** Nomenclature and preparation of cyclopropane, cyclobutane, cyclopentane and cyclohexane, reaction with various reagents. Conformers of ethane, propane and butane, Baeyer strain theory and its weakness, Sachse-Mohr modifications, angle strain, torsional strain, dihedral angle and flagpole-flagpole interactions in cyclohexane, configuration, conformation and stability of different cyclohexane conformers and their relative stability.

6. **Aromatic Hydrocarbons** (8 lectures)**:** Structure of benzene (Kekule, molecular orbital and resonance structure), conditions for aromaticity, the Huckel $(4n+2)\pi$ rule and its application to different cyclic systems, nomenclature of benzene derivatives, effect of substituent groups, determination of relative reactivity, orientation and synthesis, electrophilic aromatic substitution reactions: nitration, halogenation, sulphonation, Friedel-Crafts' alkylation, acylation and their mechanism.

7. **Phenols and Naphthols** (8 lectures)**:** Nomenclature, preparations, properties and uses, acidity of phenols, coloured complexes with $FeCl_3$, electrophilic substitution reactions; halogenations, nitration, sulphonation, Friedel-Crafts' alkylation, acylation, coupling, role of pH on coupling ractions, Kolbe, Reimer-Tiemann, Lederer-Manasse, Gattermann, Bucherer reaction, Houben-Hoesch and Elbs persulfate oxidation, identification of phenols. Preparation, acidic character and uses of α and β-naphthols, reaction with HNO_2, H_2SO_4, colored reaction with $FeCl_3$, Williamson's synthesis, oxidation and reduction.

Recommended Books

1. R. T. Morrison and R. N. Boyd : Organic Chemistry
2. I. L. Finar : Organic Chemistry Vol. I
3. J. D. Roberts and M. C. Caserio : Basic Principles of Organic Chemistry
4. L. F. Fieser and M. Fieser : Introduction to Organic Chemistry
5. A. Bahl and B. S. Bahl : Advanced Organic Chemistry
6. Seyhan Edge : Organic Chemistry

Course: Chem 122F
Structural Aspects of Organic Compounds
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

At the end of the course, the students shall know and recall the fundamental principles of organic chemistry that include chemical bonding, structural isomerism, stereochemistry, chemical reactions and mechanism. They will also know the basic principle of infra-red spectroscopy and methods of purification of organic compounds which will guide them to investigate simple organic compounds.

1. **Structure of Organic Molecules** (7 lectures): Covalent bond (σ and π bond), bond energy, bond length, bond angle, hybridization of orbitals (sp, sp^2 and sp^3 hybridization), shape of molecules, intra- and inter-molecular forces, bond dissociation energy (homolysis and heterolysis), electronegativity (polar and non-polar molecules), dipole moment, resonance and hydrogen bonding.

2. **Isomerism** (7 lectures): Definition, classification, chiral centre, symmetric, asymmetric, dissymmetric and stereogenic centre, plane polarized light, specific rotation, criteria of optical isomerism of an organic molecule (elements of symmetry), configurations (D and L system), definition with examples of enantiomers, diastereomers, racemic modification and meso compounds, resolution of racemic mixture, geometrical isomerism of olefins and their nomenclature.

3. **The Fundamental Aspects of Reaction Mechanisms** (10 lectures): Inductive, electromeric, mesomeric and hyperconjugative effect, carbocations and carbanions, their stability, attacking reagents (electrophiles and nucleophiles) and their role, free radical and ionic mechanism, energy of activation, transition state and intermediates.

4. **Aromatic Nitro Compounds** (5 lectures)**:** Nomenclature, preparation, reactions; electrophilic and nucleophilic substitution, various types of reduction, preparation and uses of TNB and TNT.

5. **Purification of Organic Compounds** (6 lectures): Purity criteria of organic compounds, techniques of separation and identification of organic compounds; crystallization, sublimation, distillation, fractional distillation, distillation under reduced pressure, steam distillation and chromatography; separation of two or three component mixtures in organic compounds using chemical and chromatographic methods (TLC, PTLC and CC).

6. **Detection of Elements and Functional Groups** (10 lectures):
   a. **Chemical Method:** Detection of nitrogen, halogens, sulphur and phosphorous, detection of different functional groups, preparation of derivatives and different reactions in the entire analysis.
   b. **IR Spectroscopic Means:** Basic principle of IR, modes of vibration and its uses to different functional groups.

Recommended Books

1. R. T. Morrison and R. N. Boyd : Organic Chemistry
2. I. L. Finar: Organic Chemistry, Vol. I
3. J. D. Roberts and M. C. Caserio : Basic Principles of Organic Chemistry
4. A. Bahl and B. S. Bahl : Advanced Organic Chemistry
5. V. R. Dani : Organic Spectroscopy
6. D. Williams and I. Fleming : Spectroscopic Methods in Organic Chemistry
7. Y. R. Sharma : Elementary Organic Spectroscopy; Principles and Chemical Applications
8. P. S. Kalsi : Spectroscopy of Organic Compounds

Course: Chem 131F
Basic Inorganic Chemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

The course is designed to introduce the students with the fundamental concepts on atomic structure, basic quantum mechanics, radioactivity, and periodic classification and periodic properties of elements. The student will learn to explain the formation of covalent bond and its nature. They will also learn the different types of chemical reactions emphasizing the redox reactions.

1. **Atomic Structure** (8 lectures): Fundamental particles, nuclear charge, atomic spectra, Bohr atomic model, four quantum numbers, distribution of electrons in atoms, Aufbau principle, Pauli exclusion principle, Hund's rule of maximum multiplicity.
2. **Basic Quantum Mechanics** (6 lectures): Dual nature of electromagnetic radiation, black body radiation, photoelectric effect and Compton effect, particle and wave nature of electron, de Broglie relation, Heisenberg uncertainty principle, preliminary idea of orbitals, physical significance of *s*, *p* and *d* orbitals.
3. **Radioactivity** (10 lectures): Nuclear charge, mass and radius, packing fraction, binding energy, neutron-proton ratio and stability of nuclei, natural and artificial radioactivity, group displacement laws, radioactive series, laws of disintegration, units of radioactivity, nuclear potential barrier, artificial transmutation. Isotope: definition, detection, separation and applications.
4. **Periodic Table** (8 lectures): Periodic law, classification of elements, modern periodic table in the light of electronic configurations of elements, different types of elements, periodic properties, atomic, covalent and ionic radii, ionization energy, electronegativity, electron affinity, effective nuclear charge.
5. **Chemical Bonding** (6 lectures): Covalent bond, formation of hydrogen molecule, potential energy diagram and its interpretation, sigma- and pi-bonds, bond energy, bond length and bond angle, ionic characteristics of covalent bond, polarity of bonds and electric dipole moments.
6. **Types of Reactions** (7 lectures): Combination, decomposition, displacement, redox and complicated types of reactions, oxidation number, method of balancing redox reactions, ionic representation of the equations of redox reaction, redox potential, electrochemical series and its application in redox reactions.

Recommended Books

1. F. A. Cotton and G.Wilkinson : Basic Inorganic Chemistry
2. J. E. Huheey : Inorganic Chemistry: Principles of Structure and Reactivity
3. W. L. Jolly : Modern Inorganic Chemistry
4. B. R. Puri and L.R. Sharma : Principles of Inorganic Chemistry
5. S. Z. Haider : Modern Inorganic Chemistry
6. M. C. Day and J. Selbin : Theoretical Inorganic Chemistry
7. Satya Prakash, Tuli, Basu and Madan : Advanced Inorganic Chemistry
8. Manas Chanda : Atomic Structure and Chemical Bond
9. R. D. Madan : Modern Inorganic Chemistry

Course: Chem 132F
Qualitative and Quantitative Inorganic Analysis
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

The course provides the students with the knowledge of theories of acids and bases, strength of acids and bases, principles of inorganic qualitative analysis and identification of basic and acid radicals. The course also provides the knowledge of quantitative analysis which includes titrimetric analysis (neutralization, redox and precipitation titrations) and the methods of gravimetric analysis.

1. **Theories of Acids and Bases** (6 lectures): Arrhenius, protonic, Lewis and Usanovich concepts of acids and bases, strength of acids and bases, hydrolysis of salts.

2. **Principles of Qualitative Inorganic Analysis** (15 lectures): Solubility and solubility product, common ion effect and their applications in the precipitation reactions, analytical group classification of metal ions. Principles and reactions involved in the detection of acid and basic radicals, interfering radicals and their separation.

3. **Titrimetric Analysis** (15 lectures): Significant number and its importance, units of mass, weight and concentration. Analytical and equilibrium concentrations, molarity, normality, ppm, equivalent weight, primary standard substances and standard solution, equivalence point and end point.
   (a) **Neutralization titrations**: Strong acid–strong base, strong acid–weak base and weak acid–strong base titration, titration curves, acid–base indicator, pH and buffer solution.
   (b) **Redox titrations**: Redox reactions, reducing and oxidizing agents, Ce(IV)–Fe(II), MnO_4^-–Fe(II), $Cr_2O_7^{2-}$–Fe(II), iodometric titrations, redox indicators.
   (c) **Precipitation titrations**: Principle, titration curves, Mohr, Volhard and Fajans method of titration.

4. **Gravimetric Methods** (9 lectures): Mechanism of precipitate formation, particle size and purity, colloidal precipitates, coagulation, peptization, coprecipitation, precipitation from homogeneous solution, organic and inorganic precipitating agents, applications, merits and demerits of gravimetric methods.

Recommended Books

1. A. I. Voge l: A Textbook of Quantitative Inorganic Analysis
2. I. Vogel : Inorganic Qualitative Analysis
3. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch: Fundamentals of Analytical Chemistry (9th Ed.)

4. G. D. Christian : Analytical Chemistry (6th Ed.)
5. H. V. Anderson : Chemical Calculations
6. R. D. Madan : Modern Inorganic Chemistry
7. B. R. Puri and L. R. Sharma : Principles of Inorganic Chemistry
8. Darrell D. Ebbing : General Chemistry
9. Raymund Chang: General Chemistry

Course: Chem 101LF
Chemistry Practical–I
Examination: 36 hours (6 days)
Full Marks: 150 (1.50 units, 6 credits)

The relevant teacher(s) of the section shall evaluate continuously the Lab classes out of 15 marks and submit the average marks of Lab evaluation in sealed envelope to the Chairman of the relevant Examination Committee within three weeks from the last Lab class held. The average final marks shall be computed by the Examination Committee.

The total marks for the practical course shall be obtained by adding the two marks (i) **Experiment** and (ii) **Continuous Lab Assessment**. The **examination committee** shall send a copy of the consolidated marks to the **controller of examinations**.

Section – A
Physical Chemistry Practical–I
Examination: 12 hours (Two days)
Full Marks: 50
(i) Experiment: 35, (ii) Continuous Lab Assessment: 15

Intended Learning Outcomes (ILO)

This course concerns with some basic experiments in thermochemistry and stoichiometry. Upon completion of the course, students will be familiar with the calculation of standard deviation of replicant measurements, data collection, handling and manipulations, calibration of laboratory equipment and calibration curve, stoichiometry and chemical compositions. The achieved knowledge will help the students to predict the quality of reported data, determine stoichiometry and composition of unknown compounds, and evaluate the energetics of thermochemical processes.

1. Prerequisites for Practical Physical Chemistry
   (a) Laboratory procedures, safety regulations.
   (b) Significant figures, scientific notations, rounding off numbers, practice exercises for the use of calculator, plotting of data and finding of slope and intercept.

(c) Calibration of volumetric apparatus, viz. density bottle, pipette, burette, measuring flask, etc.

2. Determination of formula and composition of a suitable hydrate, e.g. $CuSO_4.5H_2O$, $NiSO_4.7H_2O$, $CoCl_2.6H_2O$.
3. Studies on the (i) stoichiometry of the lead nitrate and potassium chromate system, (ii) decomposition of the metal halate ($KClO_3$).
4. Determination of empirical formula of copper sulphide.
5. Mass and density measurements:
   (a) Determination of the density of a solid by (i) dimensional and (ii) water displacement (Archimedes' principle) method.
   (b) Determination of the density of a liquid / solution by (i) Finagles, (ii) density bottle / pycnometer method.
   (c) Measurement of density of solution at different molar concentration and determination of the unknown concentration of a solution.
6. Determination of molar volume of hydrogen gas at S.T.P.
7. Determination of the molar gas constant, R
8. Determination of the molar masses of hexane and cyclohexane by Dumas method/ Victor Mayers's method.
9. Determination of the coefficient of viscosity of a liquid/solution by Ostwald's viscometer method.
10. Measurement of the coefficient of viscosity of urea solution at different concentrations and determination of the unknown concentration of a given solution.
11. Thermochemistry
    (a) Determination of the heat capacity of a supplied calorimeter and measurement of the heat of solution of inorganic salts in water (NaOH/ KNO_3 in H_2O)
    (b) Determination of the heat capacity of a supplied calorimeter and measurement of the heat of neutralization of an aq. strong acid with an aq. strong base. HCl (aq.) + NaOH (aq.)
    (c) Determination of the heat capacity of a supplied calorimeter and measurement of the heat of neutralization of an aq. strong acid with solid strong base, HCl (aq.) + NaOH(s), and verification of the Hess's law.
    (d) Determination of the heat of formation of magnesium oxide.

NB: **Practical experiments relevant to the theoretical courses may be done, subject to the availability of the Lab facilities.**

Recommended Books

1. D. P. Shoemaker et al: Experiment in Physical Chemistry
2. G. S. Weiss et al: Experiments in General Chemistry
3. A. Findlay: Practical Physical Chemistry

4. R. C. Das: Experimental Physical Chemistry
5. J. N. Gurtu: Advanced Experimental Chemistry
6. K. K. Sharma: An Introduction of Practical Chemistry
7. J. C. Muhler et al: Introduction to Experimental Chemistry
8. J. Rose: A Textbook of Practical Physical Chemistry
9. J. B. Yadav: Advanced Practical Physical Chemistry
10. Newcomb, Wilson et al: Experiments in Physical Chemistry
11. Daniels et al: Practical Physical Chemistry
12. Brennan et al: Experiments in Physical Chemistry
13. S.R. Palit: Practical Physical Chemistry
14. C.D. Hodgman et al: Handbook of Chemistry and Physics
15. R.C. West et al: CRC Handbook of Physics and Chemistry
16. L.A. Lange: Handbook of Chemistry

Section – B
Organic Chemistry Practical–I
Examination: 12 hours (Two days)
Full Marks: 50
(i) Experiment: 35, (ii) Continuous Lab Assessment: 15

Intended Learning Outcomes (ILO)

After finishing the course the students shall graft idea on determination of the melting and boiling points, detection of element and functional groups of organic compounds through some simple reactions. These ideas will help them to frame a simple organic molecule.

Systematic Identification of Organic Compounds

(a) Determination of melting point of solid and boiling point of liquid organic compounds.

(b) Detection of N, S and halogens in organic compounds.

(c) Solubility test and classification of the compound.

(d) **Identification of Functional Groups using Chemical Method:** primary amine, secondary amine, substituted amide, nitro, simple amide and imide, carboxylic, phenolic, carbonyl, aromatic hydrocarbon etc.; Preparation of derivative, conclusion, naming and structure of compound.

N.B. Identification of the compound under investigation should be systematic.

Recommended Books

1. A. I. Vogel: Elementary Practical Organic Chemistry, [Part-I, Small Scale Preparation; Part-II, Qualitative Organic Analysis; Part-III, Quantitative Organic Analysis]
2. A. I. Vogel: A Textbook of Practical Organic Chemistry
3. Shriner, Fusion and Curtin: The Systematic Identification of Organic Compounds
4. H. T. Clarke and B. Haynes: A Hand Book of Organic Analysis

Section – C
Inorganic Chemistry Practical–I
Examination: 12 hours (Two days)
Full Marks: 50
(i) Experiment: 35, (ii) Continuous Lab Assessment: 15

Intended Learning Outcomes (ILO)

The students will learn the separation and identification of different basic and acid radicals. They will also be able to interpret the separation techniques and the reactions involved therein.

Inorganic Qualitative (semi-micro/macro analysis): Systematic qualitative analysis of **two samples of a mixture of compounds**, each sample containing **not more than four radicals**, of which **there shall not be more than three basic radicals** and not more than **two acid radicals.**

(a) **Basic Radicals:** Silver, lead, mercury, bismuth, copper, cadmium, tin, arsenic, antimony, iron, aluminium, chromium, manganese, zinc, cobalt, nickel, calcium, barium, strontium, magnesium, potassium, sodium and ammonium.

(b) **Acid Radicals**: Carbonate, sulphite, sulfide, sulphate, nitrate, nitrite, chloride, bromide, iodide, phosphate and borate.

Recommended Books

1. A. B. Garrett, H. H. Sisler: Semimicro Qualitative Analysis
2. A. I. Vogel: Inorganic Qualitative Analysis
3. L. J. Curtman: Semi-micro Qualitative Chemical Analysis
4. Gilreath: Inorganic Qualitative Analysis.

Course: Phys 141F
Mechanics, Properties of Matter and Sound
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course focuses on classical mechanics and sound waves. At the end of the course, students will accumulate their knowledge on force laws, kinematics of particles, properties of matter and interaction of sound waves with matter. They will develop sound background on physics for understanding chemistry.

Group A: Mechanics and Properties of Matter (Marks: 50)

1. **Vector Analysis:** Vectors and scalars, addition and multiplication of vectors, triple scalar and vector products, derivatives of vectors, gradient, divergence, curl and their physical significance, curvilinear coordinates and their transformation.

2. **Conservation of Energy and Linear Momentum:** Conservative and non-conservative forces and systems, conservation of energy and momentum, center of mass.

3 **Rotational Motions:** Rotational variable, rotation with constant angular acceleration, relation between linear and angular kinematics, torque on a particle, angular momentum of a particle, kinetic energy of rotation and moment of inertia, combined translational and rotational motion of a rigid body, conservation of angular momentum.

4. **Oscillatory Motions:** Hooke’s law and vibration, simple harmonic motion, combination of harmonic motions, damped harmonic motion, forced oscillation and resonance.

5. **Gravitation:** Center of gravity of extended bodies, gravitational field, potential and their calculations, escape velocity.

6. **Surface Tension:** Surface tension as a molecular phenomenon, surface tension and surface energy, capillary rise or fall of liquids, pressure on a curved membrane due to surface tension.

7. **Elasticity:** Moduli of elasticity, Poisson’s ratios, relations between elastic constants and their determination, cantilever.

Recommended Books

1. Ahmed and Nath: Mechanics and Properties of Matter
2. Constant: Theoretical Physics (part I)
3. Emran, et al: General Properties of Matter

4. Halliday and Resnick: Physics (I and II)
5. Haque: General Physics
6. Mathur: Elements of Properties of Matter
7. Newman and Searle: General Properties of Matter
8. Spiegel: Vector Analysis
9. Symon: Mechanics

Group B: Sound (Marks: 25)

1. **Wave in Elastic Media:** Mechanical waves, types of waves, superposition principle, wave velocity, power and intensity in wave motion, interference of waves, complex waves, standing waves and resonance.
2. **Sound Waves:** Audible, ultrasonic, and infrasonic waves, propagation and speed of longitudinal waves, vibrating systems and sources of sound, beats, Doppler Effect.

Recommended Books

1. Halliday and Resnick: Physics (I and II),
2. Emran: Textbook of Sound
3. Coulson: Waves
4. Saha: Textbook of Sound
5. Wood: Textbook of Sound

Course: Phys 142F
Electricity and Magnetism
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course concentrates on fundamental aspects, laws, properties and applications of electricity and magnetism. After completing the course, students will be able to apply the laws related to electricity and magnetism, and understand the electrical and magnetic behavior of materials. The achievement will lead the students to predict the electrical and magnetic responses to material.

1. **Electrostatics:** Electric dipole: electric field due to a dipole, dipole on external electric field, Gauss's law and its applications.
2. **Capacitors:** Parallel plate capacitors with dielectrics, dielectrics and Gauss's law, susceptibility, permittivity and dielectric constant, energy stored in an electric field.
3. **Electric Current:** Electron theory of conductivity, conductor, semiconductors and insulators, superconductors, current and current density, Kirchhoff's law and its applications.
4. **Magnetism:** Magnetic dipole, field due to a dipole, mutual potential energy of two small magnets, magnetic shell, energy in a magnetic field, magnetometers.
5. **Electromagnetic Induction:** Faraday's experiment, Faraday's laws, Ampere's law, motional e.m.f., self and mutual inductance, galvanometers– moving cell ballistic and deadbeat types.
6. **Thermoelectricity:** Thermal e.m.f., Seebeck, Peltier and Thomson effects, laws of addition of thermal e.m.f., thermoelectric power.
7. **DC and AC Circuits:** DC circuits with LR, RC, LC and LCR in series, AC circuits with LR, RC, LC and LCR in series.
8. **AC and DC Meters:** Ammeter, voltmeter, ohmmeter, watt meter, frequency meter, AC/DC bridge, digital voltmeter.

Recommended Books

1. Acharyya: Electricity and Magnetism
2. Admas and Page: Principles of Electricity
3. Constant: Theoretical Physics
4. Din: Electricity and Magnetism
5. Emran et al.: Textbook of Magnetism, Electricity and Modern Physics
6. Halliday and Resnick: Physics (I and II)
7. Kip: Fundamentals of Electricity and Magnetism

Course: Math 151F
Algebra and Matrices
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course focuses on theory and solution strategy of problems related to algebra and matrices. At the end of this course, students will learn the theories, analytical and numerical solutions of equations, methods of interpolation, complex number, series, sequence, matrices and determinants. The achievement will help the students to understand theories and solve the mathematical problems in chemistry.

1. **Theory of equations**: Theorems and relation between roots and coefficients, analytical solution of equations.
2. **Numerical Solution of Equations:** Direct iteration method, bisection method, secant method, Newton-Rapson method.
3. **Interpolation and Approximation:** Lagrange interpolation, Newton interpolation and divided difference, interpolation error, Hermite interpolation, piece-wise polynomial interpolation, cubic splines**.**
4. **Complex Numbers**: Introduction, Argand diagram, Exponential and De Moivre's theorem, Hyperbolic functions, differentiation of hyperbolic functions, Inverse hyperbolic functions, Logarithmic function.
5. **Sequence and Series:** Convergence and divergence of infinite series, comparison tests, d'Alembert's ratio test and Cauchy's test; absolute convergence of series; alternating series test, Taylor and Maclaurin series, Gregory's series, power series and applications of power series.
6. **Determinants and Matrices**. Concepts and properties of determinants, Cramer's rule, concepts and algebra of matrices, inverse of matrices, orthogonal and unitary matrices, eigenvalue problems, eigenvalues and eigenvectors of Hermitian matrices, diagonalization of matrices, applications of eigenvalue problems.

Recommended Books

1. Jeremy Dunning-Davies: Mathematical Methods for Mathematicians, Physical Scientists and Engineers
2. David Z. Goodson: Mathematical Methods for Physical and Analytical Chemistry
3. D. A. McQuarrie: Mathematics for Physical Chemistry
4. S. S. Sastry: Introductory Methods of Numerical Analysis

Course: Math 152F
Differential and Integral Calculus
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course emphasizes on the differentiation and integration of functions of single and multiple variables. Upon the completion of this course, students will grasp the tactics of differentiation and integration of functions analytically and numerically and learn some special differential and integral functions required for higher studies. The achievement will help the students to understand theories and solve the mathematical problems in chemistry.

1. **Functions and Differentiation:** Concept of functions, limits and continuity of functions, derivative of function with geometrical interpretation, differentiability of functions, differentiation of various functions, successive differentiation and Leibniz's theorem, Rolle's theorem and mean-value theorem with geometrical interpretations, Cauchy's formula, indeterminate forms, Taylor's theorem, Maclaurin's theorem, extreme values of functions, concavity and convexity.
2. **Functions of Several Variables:** Introduction, partial derivatives, the chain rule, homogeneous functions, Taylor's theorem for a function of several variables, extreme values of functions of several variables: Lagrange multipliers.
3. **Numerical Differentiation:** Introduction; numerical differentiation: errors in numerical differentiation, cubic splines method, differentiation formulae with function values; maximum and minimum values of a tabulated function.
4. **Integration:** Methods of integration: Integration of rational algebraic functions, integration of irrational fractions, standard forms, integration by substitution or change of variable, trigonometrical integrals, integration by parts; definite integrals, limit of a sum; improper integrals, properties of definite integrals, line, surface and volume integrals.
5. **Functions Defined by Integrals:** Gamma function, beta function, error function, Dirac delta function.
6. **Numerical Integration**: Various rules of numerical integration, Euler-Maclaurin formula, numerical integration with different step sizes, Gaussian integration, numerical double integration.

Recommended Books

1. Jeremy Dunning-Davies: Mathematical Methods for Mathematicians, Physical Scientists and Engineers
2. David Z. Goodson: Mathematical Methods for Physical and Analytical Chemistry
3. D. A. McQuarrie: Mathematics for Physical Chemistry
4. S. S. Sastry: Introductory Methods of Numerical Analysis

Course: Eng 171H
Functional English
Examination: 3 hours
Full Marks: 50 (0.50 unit, 0.0 credit)
(40 lectures: 2 lectures per week)

<u>Intended Learning Outcomes (ILO)</u>

At the end of this course, the students will be able to write scientific reports and findings. Ultimately it will improve their English language proficiency, essential for their study and communication.

1. Review of parts of speech, articles, basic sentence structures with punctuations, nouns (c and unc) and verbs (tr and intr), pre- and postmodifiers, tense and its forms (conjugation and sequence of tenses), clauses, structures of simple, compound and complex sentences, narration, voice, transformation of sentences and corrections.
2. Translation, paragraph writing, report writing on a small project scientific/technical terminologies and their applications.

Recommended Books

1. Ahmed Sadruddin: Learning English, the Easy Way
2. A. J. Thomson and A.V. Martinet: A Practical English Grammar
3. Swales John: Writing Scientific English
4. Swan Michael: Practical English Uses
5. Wren and Martin: English Grammar and Composition
6. G. H. Vallins: Good English
7. A. S. Hornby: The Teaching of Structural Words and Sentence Patterns (Stages 1 and 2)
8. A. S. Hornby: The Teaching of Structural Words and Sentence Patterns (Stages 3 and 4)
9. A. S. Hornby: A Guide to Patterns and Usage of English
10. A. S. Hornby: The Advanced Learner's Dictionary.

B. Sc. Honours Part–II Examination, 2019

Session: 2018–2019

The courses and distribution of marks are as follows:

Courses	Course Titles	Units	Credits	Marks
Chem 211F	Solutions and Phase Equilibria	0.75	3	75
Chem 212F	Electrochemistry	0.75	3	75
Chem 221F	Fundamental Organic Chemistry–II	0.75	3	75
Chem 222F	Fundamental of Organic Synthesis	0.75	3	75
Chem 231F	Chemical Bonding and Group Chemistry	0.75	3	75
Chem 232F	Environmental Chemistry	0.75	3	75
Chem 201VH	Viva-voce in Chemistry–II	0.50	2	50
Chem 201LF	Chemistry Practical–II	1.50	6	150
Phys 241F	Heat, Radiation and Optics	1.00	4	100
Phys 242LH	Physics Practical	0.50	2	50
Math 251F	Differential Equations	0.75	3	75
Math 252F	Analytical Geometry	0.75	3	75
	Or			
Stat 261F	Statistical Methods of Data Analysis	0.75	3	75
	Total	**9.50**	**38**	**950**

N.B. Minimum 45 lectures should be delivered for each 3 credit theory course.

All theory courses include 80% final examination and 20% in-course. The **Final examination** of 80% of each 100 marks (1.0 unit, 4 credits) and each 75 marks (0.75 unit, 3 credits) theory full course shall be of 4 (four) hours duration. In-course comprises of 15% tutorial or terminal and 5% class attendance. The class **teachers** of each course shall submit the average marks of in-courses in a sealed envelope to the **chairman** of the relevant **examination committee** within three weeks from the last class held. The relevant **examination committee** shall prepare the result by adding the average marks of each in-course to the average marks obtained in the final examination of respective course, and send a copy of the average marks of each in-course to the controller of examinations.

All practical courses include 70% practical examination and 30% continuous Lab assessment. The practical examination of 70% of 150 marks (1.50 unit, 6 credits) practical course shall be of 36 (thirty six) hours duration (6 days), and of 50 marks (0.5 unit, 2 credits) physics practical shall be of 12 (twelve) hours duration (2 days). The students are required to submit a report after each practical class to the class teacher(s) for evaluation. After evaluation the report shall be returned to the students. The class **teacher(s)** shall submit the average marks of all Lab evaluation in a sealed envelope to the **chairman** of the relevant **examination committee** within three weeks from the last Lab class held. The examination committee shall send a copy of each of the consolidated **practical** and **Lab evaluation** marks to the **controller** of examinations.

Viva-voce examination (**Chem 201VH**) includes the assessment of the students through oral examination (of all the courses) by the **members** of the relevant examination committee. The **examination committee** shall send a copy of the marks to the **controller** of examinations.

N.B. Students having less than 60% class attendance shall not be allowed to sit for the examination.

Course: Chem 211F
Solutions and Phase Equilibria
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course concerns with some applications of chemical thermodynamics. Upon completion of the course, students will be able to explain partial molar properties, excess thermodynamic properties, colligative properties, phase diagrams and thermodynamic stabilities of binary systems. The achieved knowledge can be utilized to design solvent purification through distillation and crystallization.

1. **Thermodynamics of Solutions** (10 lectures): Partial molar quantities: partial molar volume, chemical potential and other partial molar quantities, relations between partial molar quantities, thermodynamic quantities of mixing, determination of partial molar quantities; ideal solutions: chemical potential, Raoult's law, standard states and mixing quantities; ideally dilute solutions: standard states, Henry's law, solubility of gases in liquids; non-ideal solutions: activities and activity coefficients, symmetrical and unsymmetrical conventions for standard states, excess functions, determination of activities and activity coefficients, Gibbs-Duhem equation, activities in terms of molarity and molality.
2. **Colligative Properties** (7 lectures)**:** Lowering of vapour pressure of a solvent due to dissolved solute, Raoult's law and the molecular weight of the solute, elevation of boiling point and depression of freezing point. Separations of solid solutions, osmosis and laws of osmotic pressure, mechanism of action of semipermeable membrane, osmosis in physiology and biochemistry, relation between osmotic pressure and other colligative properties, abnormal colligative properties of solutions.

3. **Phase Equilibria in Unitary Systems** (8 lectures). Phases and number of phases, thermodynamic criteria of stability and transition of phases, degree, freedom and components, Gibbs phase rule and its derivation, representative phase diagram of one component systems such as water, carbon dioxide and helium, temperature and pressure dependence of phase stability and phase transition, locations and slopes of phase boundaries, Clapeyron and Classius-Clapeyron equations for solid–liquid, liquid–vapor and solid–vapor boundaries, effect of total pressure on vapor pressure, classification and molecular interpretation of phase transitions.
4. **Fluid Phase Equilibria in Binary Systems** (12 lectures): Binary liquid mixtures and classification; completely miscible liquid pairs: vapor pressure of ideal solutions and Raoult's law, vapor pressure curves against vapor and liquid compositions, non-ideal solutions, Duhem-Margules equation, Konovalov's rule, lever rule, simple and fractional distillations, high and low boiling azeotropes; partially miscible liquid pairs: vapor pressure, upper and lower critical solution temperatures, water-phenol, water-triethylamine and water-nicotine systems; completely immiscible liquid pairs: steam distillation, Nernst's distribution law and its thermodynamic derivation, validity, deviations and applications.
5. **Solid-Liquid Phase Equilibria in Binary Systems** (8 lectures). Condensed phase rule; thermal analysis; solubility measurements; simple eutectic system; systems forming congruent and incongruent melting compounds; systems forming completely and partially miscible solid solutions; cryohydric systems; solution-vapor equilibrium of cryohydrate systems; efflorescence and deliquescence.

Recommended Books

1. Ira N. Levine: Physical Chemistry (6^{th} edition)
2. N. Kundu and S. K. Jain: Physical Chemistry
3. Peter W. Atkins and Julio de Paula: Atkins' Physical Chemistry (10^{th} edition).
4. R.G. Mortimer: Physical Chemistry
5. Thomas Engel and Philip Reid: Physical Chemistry
6. I. Koltz and Rosenberg: Chemical Thermodynamics

Course: Chem 212F
Electrochemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course concentrates on ionics and electrochemical cells. After completing the course, students will gain knowledge on fundamental electrochemistry and its applications. They will be able to flourish their achievements in the sectors of electrolysis, solvent design, energy conversion and energy storage.

1. **Ionic Equilibrium** (10 lectures): Classification of electrolytes, Ostwald dilution law, ionization of water, pH and pOH of solutions, acid ionization equilibria, calculations involving K_a, polyprotic acids, base ionization equilibria, hydrolysis of salts, common ion effects on equilibria, buffers, Henderson-Hasselbalch equation, principles of buffer action, buffer capacity and buffer range, preparation of buffer solutions, calculations involving buffers.
2. **Equilibrium Properties of Electrolytes** (9 lectures). Structure of solutions: classification of solvents, liquid structure, ion solvation, ion association. Interionic Interactions: Debye-Huckel limiting law, more rigorous Debye-Huckel treatment of the activity coefficient, osmotic coefficient, advanced theory of activity coefficients of electrolytes, mixtures of strong electrolytes, methods of measuring activity coefficients.
3. **Transport Processes in Electrolyte Solutions** (8 lectures**)**. Classification of conductors, conductivity of electrolytes, interionic forces and conductivity, Wien and Debye-Falkenhagen effects, conductometry, transport numbers. Diffusion and migration in electrolyte solutions: time dependence of diffusion, simultaneous diffusion and migration, diffusion potential and the liquid junction potential, diffusion coefficient in electrolyte solutions, methods of measurement of diffusion coefficients.
4. **Electrochemical Cells** (8 lectures). Electrolytic cells, Faraday's laws of electrolysis, significance of Faraday's laws, Galvanic (voltaic) cells, potential of voltaic cell and measurements, reversible and irreversible cells, reversible electrodes, sign conventions, reactions in reversible cells, standard cells, free energy and heat change in reversible cells, concentration cell without and with transference, concentration cell with single electrolyte, determination of activity coefficient and transference number.
5. **Electrode Potentials** (10 lectures**)**. Concepts and origin of electrode potentials, single (absolute) electrode potential, standard electrode potential, Nernst's equation, primary reference electrode and hydrogen scale, sign of electrode potential, secondary reference electrodes and classification, determination of standard potential, electrochemical series, factor affecting electrode potential, applications of electrode potential measurements: equilibrium constant, dissociation constant, instability constant, solubility product, potentiometric titration, oxidation-reduction titration, determination of pH using hydrogen, quinhydrone and glass electrodes.

Recommended Books

1. J. Koryta, J. Dvorak and L. Kavan: Principles of Electrochemistry
2. N. Kundu and S. K. Jain: Physical Chemistry
3. Samuel Glasstone: An Introduction to Electrochemistry
4. C. M. A. Brett A. M. O. Brett: Electrochemistry - Principles, Methods, and Applications
5. Peter W. Atkins and Julio de Paula: Atkins' Physical Chemistry (10th edition).

Course: Chem 221F
Fundamental Organic Chemistry–II
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course would generate interest and ability in discovering as well as gathering knowledge about various alkyl and aryl halides, carbonyl compounds, carboxylic acids and amines. The students shall also be able to know the aromatic characteristics of heterocyclic compounds.

1. **Halides (Alkyl- and Aryl-)** (10 lectures): Definition, classification, nomenclature, preparations and properties of alkyl halides, nucleophilic substitution reactions; substitution by hydroxyl, alkynyl, alkoxy, thiol, thioether, amino, ester, cyano, isocyano, nitrite and nitro groups, substitution reaction with malonic and acetoacetic ester, formation of Grignard reagents and its reactions with oxygen, water, alcohols, carbon dioxide, aldehydes, ketones, esters, anhydrides, acyl halides, amides and nitriles, electrophilic aromatic substitution, low reactivity of aryl and vinyl halides, nucleophilic aromatic substitution (reactivity, orientation and mechanism).

2. **Aldehydes and Ketones (Aliphatic and Aromatic)** (10 lectures)**:** Definition of carbonyl compound and shape of carbonyl group, preparation, activity difference between aldehyde and ketone, nucleophilic additions; addition of Grignard reagents, cyanide, alcohol, thiol, ammonia derivatives, role of pH on the addition reaction with ammonia derivatives, oxidation, reduction of carbonyl compounds by various methods and mechanism, haloform reaction, aldol and Cannizzaro reaction of aldehydes and ketones.

3. **Carboxylic Acids (Aliphatic and Aromatic)** (9 lectures)**:** Preparations, properties, resonance and inductive effects on the strength of carboxylic acids, reactions with various reagents, decarboxylation reaction, functional derivatives

of carboxylic acids (acid chlorides, acid anhydrides, amides and esters); preparation, their reactions and reactivity differences with various nucleophiles.

4. **Amines (Aliphatic and Aromatic)** (8 lectures)**:** Definition, structure, preparations, classification, nomenclature, basicity differences, reactions with various reagents, Schiff's base, degradation of aromatic amides, separation of amines, diazotization reaction, coupling reactions, role of pH on the coupling reaction and its application to different synthetic products.

5. **Heterocyclic Compounds** (8 lectures)**:** Aromatic character, preparation and reactions of furan, thiophene, pyrrole, indole, pyrazoles, imidazoles, oxazoles, thiazoles, pyridine, quinoline, isoquinoline, pyrans, pyrones and diazines.

Recommended Books

1. R. T. Morrison and R.N. Boyd : Organic Chemistry
2. I . L. Finar : Organic Chemistry Vol. I and II
3. J. D. Roberts and M. C. Caserio: Basic Principles of Organic Chemistry
4. E. L. Eliel : Stereochemistry of Carbon Compounds
5. A. Streitwieser, C. H. Heathcock and E. M. Kosower : Introduction to Organic Chemistry
6. P. S. Kalsi : Stereochemistry Conformation and Mechanism

Course: Chem 222F
Fundamentals of Organic Synthesis
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

The students shall earn knowledge on the general concepts of organic synthesis, purification and primary characterization by UV and IR spectroscopy. They will also have idea on chemical reactions of compounds like dyes and pigment, sulphonic acids, azides, polynuclear aromatic hydrocarbons and difunctional compounds.

1 **General Concept of Organic Synthesis** (8 lectures)**:** Drying of solid organic compounds, drying of liquids or solutions of organic compounds in organic solvents, technique of extraction with solvents, calculation of the amount of substrate/reactant, reagents and products of the organic synthesis; benzoic acid and *p*-chloroaniline, use of decolorizing carbon.

2 **Dyes and Pigments (13 lectures**):

a. *Basic Concept of Dyes and Pigments* (6 lectures): Definition of chromophores, chromes, auxochrome, phosphorescence and fluorescence, MOT approach to colour, classification of dyes, crieteria of dyes, azo dyes and triphenylmethane dyes (mordant and disperse) and xanthene dyes (preparation, properties and uses).

b. *Application of UV Spectroscopy to Colored Compounds* (7 lectures):

Basic principle and instrumentations, nature of electronic excitation and origin of UV band; Beer-Lambert law, determination of λ_{max} and concentration, role of solvent in UV-spectra, red shift, blue shift, hyper and hypo-chromic effects, effects of conjugation, solvents, substituents and geometry on λ_{max} shifting.

3. **Aromatic Sulphonic Acids and their Derivatives** (6 lectures): Nomenclature, preparation, synthesis of sulphones, phenols, carboxylic acids, amines, thiophenols, nitro derivatives from aromatic sulphonic acids and desulphonation.

4. **Aromatic and Aliphatic Azides** (5 lectures): Preparation of Azides, physical and chemical properties, reductions and its reaction with double and triple bonded compounds.

5. **Polynuclear Aromatic Hydrocarbons** (6 lectures)**:** Sources, structure, general methods of synthesis and reactions of naphthalene, anthracene, phenanthrene, biphenylmethane, stilbene and their derivatives.

6. **Difunctional Compounds** (7 lectures)**:** Nomenclature, preparations and properties of dicarboxylic acids, hydroxy acids, *β*-keto acids and dienes; synthetic uses of acetoacetic ester and malonic ester.

Recommended Books

1. P. Sykes: A Guide Book to Mechanism in Organic Chemistry
2. G. T. Morison and R. N. Boyd: Introduction to Organic Chemistry
3. I. L. Finar: Organic Chemistry, Vol. 1
4. A. I. Vogel: Textbook of Practical Organic Chemistry
5. D. L. Pavia, G. M. Lampman, G. S. Kriz and J. A. Vyvyan: Introduction to Spectroscopy
6. Y. R. Sharma: Elementary Organic Spectroscopy; Principles and Chemical Applications
7. P. S. Kalsi: Spectroscopy of Organic Compounds
8. A. Bahl and B. S. Bahl: Advanced Organic Chemistry

Course: Chem 231F
Chemical Bonding and Group Chemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

At the end of the course, the students will be able to understand the energetics of ionic bond formation, theories of covalent bond in terms of VBT and MOT, metallic bond, van der Waals' forces, and hydrogen bond. They will learn to elucidate the shape of molecules of non-transition elements with the help of VSEPR and hybridization concepts. A brief chemistry of some main group elements has been included.

1. **Chemical Bonds**
   (a) **Ionic bond** (8 lectures): Definition, energetics of ionic bond formation, Born-Haber cycle, lattice energy calculation, Born-Lande, Born-Mayer and Kapustiniskii equation, stability and properties of ionic solids, crystal structures of NaCl, CsCl, ZnS, CaF_2, TiO_2 and CdI_2, covalent character of ionic bonds.

   (b) **Covalent bond** (7 lectures): Wave mechanical treatment of covalent bond, valence bond theory (VBT), Heitler-London treatment and some improvements. Fundamental ideas of the molecular orbital theory (MOT), electronic configurations of simple molecules in terms of MO concept such as He_2, N_2, O_2, F_2, HF, CO and NO, comparison between VB and MO theories.

   (c) **Metallic bond** (3 lectures): Properties of metal, free electron model, valence bond theory and molecular orbital theory (band theory).

   (d) V**an der Waals' forces** (2 lectures): Dipole-dipole interactions, dipole-induced dipole interactions and London dispersion forces.

   (e) **Hydrogen bond** (3 lectures): Definition, intermolecular and intramolecular hydrogen bonding, effect of H-bonding on physical and chemical properties of compounds, dimerization of acids, structure of ice and HF_2^- , hydrogen bonding in biological systems.

2. **Molecular Geometry** (5 lectures): Valence shell electron pair repulsion theory (VSEPR); shapes of molecules of non-transition elements. The concept of hybridization of orbitals; linear, trigonal planar, tetrahedral, square planar, trigonal bipyramid, square pyramid and octahedral molecules.

3. **Chemistry of the Main Group Elements**
   (a) **Alkali and alkaline earth metals** (3 lectures): Properties of the elements, their oxides, hydroxides, hydrides and halides.

   (b) **Boron and carbon group elements** (3 lectures): Allotropes of carbon, properties of the elements, their oxides, hydrides and halides.

(c) **Chemistry of nitrogen, phosphoros and sulfur** (3 lectures): Allotropes of phosphorus and sulfur, oxides and oxyacids of nitrogen, phosphorous and sulfur.

(d) **Interhalogens, polyhalides and pseudohalogens** (3 lectures): Preparation, structure and properties.

4. **Boron Hydrides** (5 lectures): Reactions, structure and bonding, molecular orbital concepts, the styx number, synthesis and reactivity of neutral boron hydrides, carboranes.

Recommended Books

1 J. H. Huheey: Inorganic Chemistry: Principles of Structure and Reactivity

2 F. A. Cotton and G. Wilkinson: Advanced Inorganic Chemistry

3 Shriver and Atkins: Inorganic Chemistry

4 A. G. Sharpe: Inorganic Chemistry

5 J. D. Lee: Concise Inorganic Chemistry

6 W. L. Jolly: Modern Inorganic Chemistry

7 Gurdeep Raj: Advanced Inorganic Chemistry (Vol. 1)

8 R. D. Madan: Inorganic Chemistry

Course: Chem 232F
Environmental Chemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

The objectives of the course are to provide the students with the knowledge of spheres of the environment, natural cycles of environment, tropospheric and stratospheric chemistry, catalytic and non-catalytic destruction of ozone layer. The course also provides the knowledge of pollution in air, water and soil caused by different ways and their adverse effects.

1. **Introduction to Environmental Chemistry** (9 lectures): Environmental science and environmental chemistry, definition of environmental terms, spheres of the environment, the natural cycles of environment: hydrological, oxygen, nitrogen, phosphorus and sulfur cycles; aqueous carbonate equilibria.

2. **Chemistry of Atmosphere** (12 lectures):

   (a) **Chemistry of troposphere**: sources of the trace constituents in atmosphere, principle of the reactivity in troposphere, oxidation of methane, oxidation of other hydrocarbons, free radical mechanism, oxidation of sulphur dioxide.

(b) **Chemistry of stratosphere**: Chemistry of the ozone layer, light absorption by molecules, biological consequences, catalytic and non-catalytic processes, X catalysts, role of different chemicals (CFCs, CFC replacement and halogen-containing compounds) in ozone layer destruction.

3. **Air Pollution** (9 lectures): General considerations, pollution caused by carbon dioxide, carbon monoxide, oxides of nitrogen and sulfur, hydrocarbons and photochemical oxidants, particulates, temperature inversion, photochemical smog, acid rain and greenhouse effect.

4. **Water Pollution** (9 lectures): General considerations, different pollutants: pollution caused by heavy metals, detergents, synthetic organic insecticides and oil, dissolved oxygen (DO), biological oxygen demand (BOD) and chemical oxygen demand (COD).

5. **Soil Pollution** (6 lectures): Basic concepts of soil constituents, main causes of soil pollution; indicators, monitoring and assessment of soil pollution; effects of soil pollution; mitigation of soil pollution.

Recommended Books

1. H. S. Stocker and S. L. Seager: Environmental Chemistry: Air and Water Pollution
2. A. K. De: Environmental Chemistry
3. W. A. Andrews, D. K. Moore and A. C. Le Roy: Environnemental Pollution
4. Roger N. Reeve: Environmental Analysis
5. Colin Baird: Environmental Chemistry
6. S. E. Manahan: Environmental Chemistry (6th Ed.)
7. D. Tyagi and M. Mehra: A Textbook of Environmental Chemistry

Course: Chem 201LF
Chemistry Practical–II
Examination: 36 hours (6 days)
Full Marks: 150 (1.50 units, 6 credits)

The relevant teacher(s) of the section shall evaluate continuously the Lab classes out of 15 marks and submit the average marks of Lab evaluation in sealed envelope to the Chairman of the relevant Examination Committee within three weeks from the last Lab class held. The average final marks shall be computed by the Examination Committee.

The total marks for the practical course shall be obtained by adding the two marks (i) **Experiment** and (ii) **Continuous Lab Assessment**. The **examination committee** shall send a copy of the consolidated marks to the **controller of examinations**.

Section–A
Physical Chemistry Practical–II
Examination: 12 hours (Two days)
Full Marks: 50
(i) Experiment: 35, (ii) Continuous Lab Assessment: 15

<u>Intended Learning Outcomes (ILO)</u>

This course concerns with some basic experiments in applied thermodynamics and electrochemistry. At the end of this course, students will be able to calculate the combined uncertainty in measured data, to represent data in table and graph and to get insight into some physical and chemical processes through experimental data. The achieved knowledge will help the students to predict the quality of reported data and analyze unknown samples.

Experiments in Physical Chemistry

1. Determination of the molecular weight of a solute by depression of freezing point method.
2. Determination of the molecular weight of a solute by elevation of boiling point method.
3. Determination of the composition of a liquid mixture by viscometric method.
4. Determination of viscosity coefficient of a liquid at two different temperatures and finding out the temperature coefficient for the given liquid.
5. Determination of the solubility product of sparingly soluble salts viz.
   (a) $Ca(OH)_2$, (b) Cu(II) iodate, (c) Hydrogen 2,3-dihydroxy butanedioate by titration method.
6. Determination of partition coefficient of
   (a) Iodine between methylene chloride and water,
   (b) Succinic acid between ether and water,
   (c) Salicylic acid between water and chloroform,
   (d) Acetic acid betwen water and n-hexane/cyclohexane, and
   (e) Benzoic acid between toluene and water.
7. Determination of heat of solution by solubility method.
8. Measurement of the specific rotation of an organic compound and determination of the unknown concentration of the compound by polarimetric method.

9. Determination of the equilibrium constant of the reactions :
   (a) Ester + water $\rightleftharpoons$ alcohol + acid.
   (b) I_2 + KI $\rightleftharpoons$ KI_3.
10. Determination of Λ_0 of acetic acid applying law of independent migration of ions.
11. Conductometric titration of a mixture of HCl and acetic acid and finding out their concentration.
12. Standardization of acids / bases by conductometric titration.
13. Determination of transport number by Hittorf's method.

NB: A few more experiments, relevant to the theoretical courses may be done, subject to the availability of the Lab facilities.

Recommended Books

1. D. P. Shoemaker et al: Experiment in Physical Chemistry
2. G. S. Weiss et al: Experiments in General Chemistry
3. Findlay: Practical Physical Chemistry
4. R. C. Das: Experimental Physical Chemistry
5. J. N. Gurtu: Advanced Experimental Chemistry
6. K. K. Sharma: An Introduction of Practical Chemistry
7. J. C. Muhler et al: Introduction to Experimental Chemistry
8. J. Rose: A Textbook of Practical Physical Chemistry
9. J. B. Yadav: Advanced Practical Physical Chemistry
10. Newcomb, wilson et al: Experiments in Physical Chemistry
11. Daniels et al: Practical Physical Chemistry
12. Brennan et al: Experiments in Physical Chemistry
13. S. R. Palit: Practical Physical Chemistry
14. Hodgman et al: Handbook of Chemistry and Physics
15. R. C. West et al: CRC Handbook of Physics and Chemistry
16. L. A. Lange: Handbook of Chemistry

Section–B
Organic Chemistry Practical–II
Examination: 12 hours (Two days)
Full Marks: 50
(i) Experiment: 35, (ii) Continuous Lab Assessment: 15

Intended Learning Outcomes (ILO)

This course shall help students to learn how to synthesize and purify organic compounds. This will be a first hand training on organic synthesis for the students.

Experiments in Organic Chemistry

i) Simple techniques used in organic laboratory, viz. crystallization, distillation, sublimation etc.

ii) Organic preparations involving typical reactions, e.g., Perkin reaction, Grignard reaction, Friedel-Crafts reactions, permanganate and chromic acid oxidation, esterification etc.

iii) Preparation of (i) acetanilide, (ii) benzoic acid, (iii) nitrobenzene, (iv) p-nitroacetanilide, (v) p-nitroaniline (vi) aspirin, (vii) cyclohexanone from cyclohexanol (viii) 3-aminoacetophenone from reduction of 3-nitroacetophenone with Sn/HCI (ix) dibenzalacetones (x) p-bromacetanilide.

Recommended Books

1. A.I. Vogel : Elementary Practical Organic Chemistry, Part-I, Small Scale Preparation; Part-II, Qualitative Organic Analysis Part-III Quantitative Organic Analysis
2. A. I. Vogel : A Textbook of Practical Organic Chemistry
3. Shriner, Fusion and Curtin : The Systematic Identification of Organic Compounds
4. H. T. Clarke and B. Haynes : A Hand Book of Organic Analysis

Section–C
Inorganic Chemistry Practical–II
Examination: 12 hours (Two days)
Full Marks: 50
(i) Experiment: 35, (ii) Continuous Lab Assessment: 15

Intended Learning Outcomes (ILO)

The students will learn to prepare standard solution and standardize the solutions of acid, base, oxidizing and reducing agent. They will also learn to estimate the metal ions (such as Fe^{2+}/Fe^{3+} and Cu^{2+} ions) via redox titrations.

Experiments in Inorganic Chemistry

1. Inorganic Quantitative Analyses (Volumetric)
   a. Application of the knowledge of significant figures and brief idea about the evaluation of analytical data
   b. Calibration of volumetric apparatus
   c. Acid-base titrations:
      i) Preparation of decinormal sulphuric acid and hydrochloric acid and their standardization with sodium carbonate
      ii) Standardization of sodium hydroxide solution by potassium hydrogen phthalate/oxalic acid
      iii) Determination of equivalent weight of a weak acid
      iv) Analysis of commercial caustic soda and soda ash
      v) Determination of acid content in vinegar
   d. Oxidation-reduction titrations:
      i) Standardisation of potassium permanganate solution by sodium oxalate
      ii) Estimation of iron (ferrous and ferric) in solution/ore/oxide by titration with $KMnO_4$/$K_2Cr_2O_7$/Ce(IV) solutions
      iii) Standardisation of thiosulphate solution against $K_2Cr_2O_7$/ KIO_3/ $KMnO_4$ solution
      iv) Estimation of copper in solution/brass/ore iodometrically
      v) Determination of calcium in limestone by $KMnO_4$
      vi) Estimation of available chlorine in bleaching powder / solution iodometrically.

2. Inorganic Syntheses

i) Potassium dichromate, $K_2Cr_2O_7$

ii) Potassium permanganate, $KMnO_4$

iii) Hexamminecobalt(III) chloride, $[Co(NH)_6]Cl_3$

iv) Tetramminecopper(II) sulfate, $[Cu(NH_3)_4]SO_4$

Recommended Books

1. Vogel: A Textbook of Inorganic Quantitative Analysis
2. Alexeve: Qunatitative Chemical Analysis
3. D. A. Skoog and D. M. West and F. J. Holler: Fundamentals of Analytical Chemistry (6th Edn)
4. Jugal Kishore Agarwal: Practicals in Engineering Chemistry
5. R .K. Das: Industrial Chemistry, part II

Course: Phys 241F
Heat, Radiation and Optics
Full marks: 100 (1.0 unit, 4 credits)
Final examination: 80 marks, 4 hours
Class assessment: 15 marks; Attendance: 5 marks

Intended Learning Outcomes (ILO)

This course emphasizes on fundamental concepts of heat, radiation and optics. After finishing the course, students will accumulate their knowledge on the nature of thermal energy and electromagnetic radiation, emergence of quantum mechanics, basic optics and optical properties of material. The outcomes will help them for understanding quantum chemistry and predicting the thermal and optical properties of matter.

1. **Heat**
   (a) **Thermometry:** Gas thermometers and their corrections, measurement of law and high temperatures, platinum resistance thermometers, thermocouple.
   (b) **Liquefaction of Gases:** Different methods of liquefaction, liquefaction of air and nitrogen, refrigeration.
   (c) **Thermal Conduction:** Thermal conductivity, Fourier's equation of heat flow, thermal conductivities of good and bad conductors.
2. **Radiation:** Radiation pressure**,** Kirchhoff's law, black-body radiation, Stefan-Boltzmann's law: Wein's law, Rayleigh-Jean's law, Planck's quantum law.
3. **Optics**
   (a) Introduction, nature, propagation and properties of light, waves theories and Huygen's principles of light.

(b) **Geometrical optics**: Fermats principle, theory of equivalent lenses; defect of images; optical instruments; dispersion; rainbow.
(c) **Interference**: Young's experiment; biprism; colour of thin films Newton's rings; Michelson and Fabry-peret interferometers.
(d) **Diffraction**: Fraunhoffer and Fresnel diffraction, diffraction by single slit, double slit and diffraction gratings, dispersive and resolving powers of gratings.
(e) **Polarization**: Plane, elleiptic and circular polarization; double refraction; rotatory polarization; Nicol prism; polarimeter.

Recommended Books

1. Bhuiyan and Rahman: A Textbook of Heat, Thermodynamics and Radiation.
2. Halliday and Resnick: Physics (I and II)
3. Haque: Principles of Heat, Thermodynamics and Radiation
4. Hossain: Textbook of Heat
5. Ishaque, et. al.: Textbook of Heat, Thermodynamics and Radiation.
6. Lee and Sears: Thermodynamics
7. Uddin and Kalam: Heat and Thermodynamics
8. Zemansky: Heat and Thermodynamics
9. K. Din: Textbook of Optics
10. Jenkin and White: Fundamentals of Optics
11. Matheu: Principle of Optics
12. M. N. Saha and B. N. Srivastava: A treatise on heat
13. N. Subrahmanyam and Brijlal: A textbook of Optics

Course: Phys 242LH
Physics Practical
Examination: 12 hours (Two days)
Full Marks: 50 (0.5 unit, 2 credits)
Experiment: 35, Laboratory assessment: 10, Class record: 5

Intended Learning Outcomes (ILO)

This course focuses on some basic experiments in physics. At the end of the course, students will be able to learn the way for determining material properties and verifying laws and principles in physics. The achievements will help the students to realize the laws, principles and properties through the experimental results.

Experiments in Physics

1. Determination of moment of inertia of a flywheel.
2. Determination of g by a compound pendulum.
3. Determination of Young’s Modulus by the method of bending.

4. Determination of rigidity modulus by dynamical method.
5. Determination of rigidity modulus by statical method.
6. Determination of the surface tension of mercury by Quincke's method.
7. Determination of viscosity of water by capillary flow method.
8. Determination of the surface tension of water by capillary rise method.
9. Determination of specific heat of a liquid by the method of cooling.
10. Determination of the ratio of the specific heats of a gas by Clement and Desorme's apparatus.
11. Determination of the figure of merit of a galvanometer.
12. Measurement of low resistance by the method of fall of potential.
13. Determination of galvanometer resistance.
14. Measurement of high resistance.
15. Determination of end-corrections of a meter bridge wire.
16. Determination of specific resistance of the material of a wire.
17. Measurement of resistance per unit length of a meter bridge wire.
18. Calibration of a meter bridge wire.
19. Determination of J by an electrical method.
20. Determination of refractive index of a prism by using a spectrometer.
21. Determination of wavelength of light by Newton's ring.

Course: Math 251F
Differential Equations
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course focuses on theory and solution strategy of problems related to differential equations. At the end of this course, students will be able to learn the theories, analytical and numerical solutions of differential equations for problems relevant to physical and chemical sciences. The achievement will help the students to understand the theories in quantum chemistry and structure of atoms and molecules.

1. **Ordinary Differential Equations**. Differential equations of first order and first degree, linear first order differential equations, homogeneous linear differential equations with constant coefficients, nonhomogeneous linear differential equations with constant coefficients, some other types of higher order differential equations, systems of first order differential equations, two invaluable resources for solutions to differential equations

2. **Series Solutions of Differential Equations**. The power series method, ordinary points and singular points of differential equations, series solutions near an ordinary point: Legendre's equation, solutions near regular singular points, Bessel's equation, Bessel functions.
3. **Fourier Series**. Fourier series as eigenfunction expansions, sine and cosine series, convergence of Fourier series, Fourier series and ordinary differential equations.
4. **Partial Differential Equations**. Some examples of partial differential equations, Laplace's equation, one-dimensional wave equation, two-dimensional wave equation, heat equation, Schrödinger equation, classification of partial differential equations.
5. **Integral Transforms**. Laplace transform, inversion of Laplace transforms, Laplace transforms and ordinary differential equations, Laplace transforms and partial differential equations, Fourier transforms, Fourier transforms and partial differential equations, inversion formula for Laplace transforms.
6. **Numerical Solutions of Differential Equations.** Solution by Taylor's series, Picard's method of successive approximation, Euler's method, predictor-corrector method, cubic splines method, boundary value problems, finite-difference approximation to derivative, solution of Laplace's equation by several methods.

Recommended Books

1. Jeremy Dunning-Davies: Mathematical Methods for Mathematicians, Physical Scientists and Engineers
2. David Z. Goodson: Mathematical Methods for Physical and Analytical Chemistry
3. D. A. McQuarrie: Mathematics for Physical Chemistry
4. S. S. Sastry: Introductory Methods of Numerical Analysis

Course: Math 252F
Analytical Geometry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course concerns with theories and applications of two and three-dimensional analytical geometry. Upon completion of this course, students will learn theories and application of straight line, circles, parabola, ellipse, planes, cones and spheres. The achievement will help the students to understand the coordinate systems used in quantum chemistry, draw and represent the molecular structures.

1. Change of axes. General equation of second degree and Pair of straight lines.

2. The circle and the system of circles.
3. The parabola and the ellipse.
4. Direction cosines and the plane.
5. The straight line.
6. The sphere and the cone.

Recommended Books

1. H. H. Askwith: Analytic Geometry of Conic Sections
2. C. Smith: Analytic Geometry of Conic Sections
3. M. L. Khanna: Coordinate Geometry
4. J. T. Bell: A Treatise of Three Dimensional Geometry
5. C. Smith: Elementary Treatise on Solid-Geometry
6. Vashishtha and Agarwal: Analytical Solid Geometry

Course: Stat 261F
Statistical Methods of Data Analysis
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course concerns with theories and applications of statistics in data analysis and modelling. Upon completion of this course, students will learn basic statistics, data handling, manipulation, presentation, fitting and modelling. The achievement will help the students to predict the quality of data and derive mathematical model of chemical and physical processes.

1. **Descriptive Statistics**: Preliminary of statistics and its scope in chemistry; collection and presentation of data: method of data collection, graphical representation, scales of measurement, data editing, qualitative classification, frequency distribution and its shape. Measure of location: mean, median, mode. Measure of dispersion: absolute and relative measure; checks for outliers by using quartiles.

2. **Probability and Distribution**: Concepts of probability, joint, marginal, and conditional probability, additional and multiplicative law of probability, Bayes theorem; random variable: types of random variable, expectation of random

variable; several types of distribution: binomial, Poisson, normal, lognormal, exponential, gamma distribution.

3. **Estimation**: Types, techniques and principles of estimation, central limit theorem, simulation, point estimation of population mean and proportion, confidence interval of single population mean and proportion, confidence interval of two population mean and proportion, confidence intervals with paired data; prediction and tolerance intervals; confidence intervals simulation.

4. **Significance Tests**: **N**ormal test, chi-square test, F-test; t-test; tests for single population mean and proportion, tests for difference between two population means and proportions, tests with paired data; test of population variances, distribution-free tests, fixed-level testing; multiple tests; outlier tests; simulation to perform hypothesis tests.

5. **Analysis of Variance**: One-way ANOVA, two-way ANOVA, multiple comparisons in ANOVA test, test of population means; experimental design and its application, completely randomized design (CRD), randomized block design (RBD).

6. **Curve Fitting**: Principles of least-squares fits, linearization of functions, point and confidence intervals of regression parameters, ANOVA for regression, effect of outliers and leverage points on regression, polynomial regression, multiple regression, weighted regression, non-linear regression, goodness of fit and model selection, idea of some statistical software for curve fitting.

Recommended Books

1. K. C. Bhuyan: Methods of Statistics, Sahityaprokashani, Dhaka
2. Manindra Kumar Roy and Jiban Chandra Paul: Business Statistics
3. Jeremy Dunning-Davies: Mathematical Methods for Mathematicians, Physical Scientists and Engineers
4. David Z. Goodson: Mathematical Methods for Physical and Analytical Chemistry
5. D. A. McQuarrie: Mathematics for Physical Chemistry

B. Sc. Honours Part–III Examination, 2020
Session: 2019–2020

The courses and distribution of marks are as follows

Courses	Course Titles	Units	Credits	Marks
Chem 311F	Quantum Chemistry	1.00	4	100
Chem 312F	Chemical Kinetics	0.75	3	75
Chem 313F	Colloids and Surface Chemistry	0.75	3	75
Chem 321F	Reaction Mechanism and Stereochemistry–I	1.00	4	100
Chem 322F	Natural Products and Medicinal Chemistry	0.75	3	75
Chem 323F	Industrial Chemistry–I	0.75	3	75
Chem 331F	Quantum Mechanics and Coordination Chemistry	1.00	4	100
Chem 332F	Nuclear Chemistry	0.75	3	75
Chem 333 F	Analytical Chemistry	0.75	3	75
Chem 301VF	Viva-voce in Chemistry–III	0.75	3	75
Chem 301LF	Chemistry Practical–III	2.25	9	225
	Total	**10.5**	**42**	**1050**

N.B. Minimum 60 and 45 lectures should be delivered for each 4 and 3 credit theory course, respectively.

All theory courses include 80% final examination and 20% in-course. The **Final examination** of 80% of each 100 marks (1.0 unit, 4 credits) and each 75 marks (0.75 unit, 3 credits) theory full course shall be of 4 (four) hours duration. In-course comprises of 15% tutorial or terminal and 5% class attendance. The class **teachers** of each course shall submit the average marks of in-courses in a sealed envelope to the **chairman** of the relevant **examination committee** within three weeks from the last class held. The relevant **examination committee** shall prepare the result by adding the average marks of each in-course to the average marks obtained in the final examination of respective course, and send a copy of the average marks of each in-course to the controller of examinations.

All practical courses include 70% practical examination and 30% continuous Lab assessment. The practical examination of 70% of 225 marks (2.25 units, 9 credits) practical course shall be of 36 (thirty six) hours duration (6 days). The students are required to submit a report after each practical class to the class teacher(s) for evaluation. After evaluation the report shall be returned to the students. The class **teacher(s)** shall submit the average marks of all Lab evaluation in a sealed envelope to the **chairman** of the relevant **examination committee** within three weeks from the last Lab class held. The examination committee shall send a copy of each of the consolidated **practical** and **Lab evaluation** marks to the **controller** of examinations.

Viva-voce examination (**Chem 301VF**) includes the assessment of the students through oral examination (of all the courses) by the **members** of the relevant examination committee. The **examination committee** shall send a copy of the marks to the **controller** of examinations.

N.B. Students having less than 60% class attendance shall not be allowed to sit for the examination.

Course: Chem 311F

Quantum Chemistry
Full marks: 100 (1.0 unit, 4 credits)
Final examination: 80 marks, 4 hours
Class assessment: 15 marks; Attendance: 5 marks

Intended Learning Outcomes (ILO)
This course focuses on principles and applications of quantum chemistry. Upon completion of the course, students will be able to explain microscopic behaviors of substances. They will be able to design novel compounds and predict their properties.

1. **Wave Mechanics** (8 lectures): Nature of electromagnetic radiation, principle of superposition of waves, diffraction and interference, standing waves; ***particle properties of waves***: blackbody radiation spectrum, failure of classical theory to explain the spectrum, success of Plank's radiation formula, Einstein's theory of the photoelectric effect, quantum theory of light; ***wave properties of particles***: de Broglie matter waves and Bohr theory, velocity of the particle and its associated wave, wave groups and wave packets, experimental verification of particle waves (Davisson and Germer), wave packet and uncertainty principle.

2. **Basic Postulates and Principles of Quantum Mechanics** (8 lectures): Postulate I: wavefunction; postulate II: Born interpretation of wavefunction, normalization of wavefunction; postulate III: quantum mechanical operators, time-independent Schrödinger equation, conditions of acceptable wavefunctions, correspondence between observables and operators, construction of operators for observables; postulate IV: eigenvalues and eigenfunctions, hermiticity of operators; postulate V: superposition and expectation values; complementary observables.

3. **Linear and Vibrational Motions of Particle** (10 lectures): Eigenvalue problems of a free particle, and particle in one, two and three dimensional boxes,

interpretation of solutions, energy, degeneracy, positions, momentum, uncertainty relations; particle with potential barrier: one and two finite potential barrier, potential barrier with definite thickness, quantum mechanical tunneling; harmonic oscillator: classical and quantum mechanical treatment, interpretations of solutions, comparing classical and quantum mechanical results.

4. **Rotational Motion and Structure of Hydrogenic Atoms** (12 lectures): Eigenvalue problems of particle on a ring and sphere, solutions, spherical harmonics; angular momentum: operators and their properties, eigenvalues, vector model; eigenvalue problem of rigid rotator, solutions and interpretation; eigenvalue problem of hydrogenic atom: separation of variables, radial solutions, energy levels, ionization energies, shells and subshells, atomic orbitals; spectrum of atomic hydrogen: energies of the transitions, selection rules, orbital and spin magnetic moments, spin-orbit coupling, fine-structure of the spectra, term symbols and spectral details.

5. **Structure and Spectra of Many Electron Atoms** (12 lectures): Need for approximate solutions; variation and perturbation theory with application to ground and excited states of helium atom, coulomb and exchange integrals; spectrum of helium; Pauli principle and Pauli exclusion principle; spin orbitals and Slater determinant; penetration and shielding; self-consistent field calculations; term symbols and transitions of many-electron atoms; Hund's rules and relative energies of terms; configuration interaction; normal and anomalous Zeeman effects; Stark effect.

6. **Electronic Structure of Molecules** (10 lectures): Born-Oppenheimer approximation, formulations and application to hydrogen molecule-ion; molecular orbital theory: linear combinations of atomic orbitals, hydrogen molecule, configuration interaction, homonuclear and heteronuclear diatomic molecules; molecular orbital theory of polyatomic molecules: symmetry-adapted linear combinations, conjugated π-systems.

Recommended Books

1. R. B. Singh: Introduction to Modern Physics
2. Wolfgang Demtröder: Atoms, Molecules and Photons– An Introduction to Atomic, Molecular and Quantum Physics
3. Arthur Beiser: Concepts of Modern Physics
4. R. K. Prasad: Quantum Chemistry (4^{th} edition)

5. P. Atkins, R. Friedman: Molecular Quantum mechanics
6. P. Atkins, J. de Paula, R. Friedman: Quanta, Matter, and Change– A Molecular Approach to Physical Chemistry
7. D. A. MacQuarie: Quantum Chemistry
8. Ira N. Levine: Quantum Chemistry

Course: Chem 312F
Chemical Kinetics
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course emphasizes on principles and applications of chemical kinetics. Upon completion of the course, students will acquire basic concepts of chemical kinetics and factors affecting the rate of chemical processes. Ultimately, they will be capable of designing new chemical processes and establishing reaction mechanism.

1 **Elementary Reactions** (8 lectures)**:** The rates of reactions; rate laws and rate constants, order and molecularity of reactions, determination of order of reactions. Integrated rate laws and half-lives, the temperature and concentration dependence of reaction rates, Arrhenius parameters and consecutive elementary reactions: rate determining step, steady state approximation, third order reactions, temperature effect on reaction rate: derivation of Arrhenius equation; experimental determination of energy of activation and Arrhenius factor.

2 **Theories of Reaction Rate** (12 lectures): Potential energy surface; significance of energy of activation. Equilibrium and rate of reaction, collision theory: collision frequency; energy factor; orientation factor; rate of reaction; weakness of the collision theory. Transition state theory: thermodynamic approach; comparison with Arrhenius equation and collision theory, unimolecular reactions and the collision theory: Lindemann's mechanism; Hinshelwood treatment; Rice-Ramsperger-Kassel (RRK) treatment; Marcus treatment; RRKM theory, kinetic and thermodynamic control, Hammond's postulate, probing of the transition state.

3 **Photochemical and Polymerization Reactions** (10 lectures): *Photochemical reactions*: Grotthuss-Draper law; Einstein law of photochemical equivalence; primary process in photochemical reactions; H_2-Br_2 reaction; H_2 and Cl_2 reaction, chain reactions: rate determination; reaction between H_2 and Br_2; chain length; chain transfer reactions; branching chain explosions; kinetics of branching chain explosion; free radical chains; chain length and activation energy in chain

reactions. *Polymerization reactions*: step growth polymerization, polycondensation reactions, acid catalyzed polycondensation reaction, chain growth polymerization, free radical polymerization, anionic and cationic polymerization, co-polymerization.

4 **Catalyzed Reactions** (8 lectures): Catalysis: positive catalysis; negative catalysis; autocatalysis; induced catalysis; promoters; poisons, theories of catalysis: intermediate compound formation theory; adsorption theory, characteristics of catalytic reactions, mechanism of catalysis, activation energies of catalyzed reactions, acid base catalysis, enzyme catalysis, influence of pH, heterogeneous, catalysis, micellar catalysis, models for micellar catalysis, phase transfer catalysis: general mechanism; difference between micellar and phase transfer catalyzed reactions, kinetics of inhibition: chain reactions, enzyme catalyzed reactions, inhibition in surface reactions.

5 **Reactions in Solutions** (7 lectures): Theory of absolute reaction rate, influence of internal pressure, influence of solvation, reactions between ions, entropy change, influence of ionic strength (salt effect), secondary salt effect, reactions between the dipoles, kinetic isotope effect, solvent isotope effect, Hemmett equation, linear free energy relationship, Taft equation, compensation effect.

Recommended Books

1. K. J. Laidler: Chemical Kinetics
2. Santosh K. Upadhyay: Chemical Kinetics and Reaction Dynamics
3. Margaret Robson Wright: An Introduction to Chemical Kinetics
4. Peter W. Atkins and Julio de Paula: Atkins' Physical Chemistry (10^{th} edition).
5. S. R. Logman: Fundamentals of Chemical Kinetics

Course: Chem 313F

Colloids and Surface Chemistry

Full marks: 75 (0.75 unit, 3 credits)

Final examination: 60 marks, 4 hours

Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course focuses on preparation and properties of colloids, and surface activities of materials. Upon completion of the course, students will get insight into the preparation, types and nature of colloidal systems along with the surface properties and processes occur on the surface. Eventually, they will be able to explore their achievements in the relevant fields like pharmaceuticals, paint, catalysis, nanoscience, etc.

1. **Chemistry of Colloids** (8 lectures): Colloids and crystalloids, classification, shape and size of colloidal particles, preparation and purification of colloids, properties of colloids: general, optical, electric and kinetic properties, coagulation, peptization and protection of colloids, stability of colloids. Origin of charge, electrokinetic phenomena, structure of double layer, zeta potential, elctrocapillary phenomena, Donnan membrane equilibrium, determination of size of colloids. Gels, emulsions and foams and their properties, colloidal electrolytes, importance and applications of colloids.
2. **Association Colloids** (10 lectures): Self-assembly and association colloids, importance of association colloids, surfactants in solution; micellization, structures of micelles, molecular architecture of surfactants: optimal head group area; volume and critical chain length of hydrocarbon tail; packing consideration and shapes of aggregates, critical micelle concentration and thermodynamics of micellization: mass action model; phase equilibrium approach; entropy change during micellization and hydrophobic effect, solubilization: location of solubilizate; extent of solubilization; thermodynamics of solubilization; micellar phase diagram; liquid-crystalline phases, catalysis by micelle; electrolyte inhibition in micellar catalysis; reverse micelle: surfactant aggregation in nonaqueous media; some uses of reverse micelles, emulsions and microemulsions: microemulsions; swollen micelles; phase diagram of microemulsion, some useful applications of microemulsions: tertiary oil recovery; polymer synthesis, biological membranes.
3. **Adsorption from Solution and Monolayer Formation** (10 lectures): Langmuir and Gibbs layers and Langmuir-Blodgett films, importance of monolayers and multilayers, spread or insoluble monolayers, properties of spread monolayers, structural aspects of monolayers, surface pressure versus area isotherms, Langmuir film balance, results of film balance studies, microstructural phases in monolayers, van der Waals equation of state for monolayers, monolayers as two-dimensional binary solutions, liquid-expanded phase, intermediate liquid phase, liquid-condensed and the solid phases, applications of monolayers and monolayer concepts: retardation of evaporation, damping of waves, stabilization of emulsions and foams, preparation of Langmuir-Blodgett films, adsorption from solution: Gibbs equation, location of the surface and the meaning of surface excess properties, relation between surface tension and surface excess concentration, Gibbs equation: experimental results, measuring surface excess concentrations, applications of adsorption from solution.

4. **Surface Tension and Wetting Phenomena** (9 lectures): Surface and interfacial tensions, curved interfaces: bubbles, cavities, and droplets, Laplace and Kelvin relations, nucleation. Variation of surface tension with temperature, measurements of surface and interfacial tensions, c**ontact angle and wetting:** spreading wetting, adhesional wetting, immersional wetting, measurement of contact angles, factors influencing contact angles and wetting, wetting agents, water repellency, ore floatation. Detergency: mechanism of detergency, wetting, dirt removal, redeposition of dirt, detergent additives. Adsorption from solutions: solution adsorption isotherms, isotherm equations, surface areas.

5. **Adsorption and Heterogeneous Catalysis** (8 lectures): Thermodynamics of adsorption: Gibbs adsorption equation and its verification. The extent of adsorption: physisorption and chemisorption, adsorption isotherms: Langmuir isotherm, BET and other (Temkin and Freundlich) isotherms. Rates of surface processes: rates of adsorption and desorption, mobility on surfaces. Catalytic activity at surfaces: adsorption and catalysis – Eley-Riedel mechanism, Langmuir-Hinshelwood mechanism, molecular beam studies. Examples of catalysis: hydrogenation, oxidation, cracking and reforming.

Recommended Books

1. Paul C. Hiemenz and Raj Rajagopalan: Principles of Colloids and Surface Chemistry
2. Peter W. Atkins and Julio de Paula: Atkins' Physical Chemistry (10th edition).
3. N. Kundu and S. K. Jain: Physical Chemistry
4. H. J. Butt, K. Graf, M. Kappl: Physics and Chemistry of Interfaces
5. Duncan J. Shaw: Introduction to Colloid and Surface Chemistry

Course: Chem 321F
Reaction Mechanism and Stereochemistry–I
Full marks: 100 (1.0 unit, 4 credits)
Final examination: 80 marks, 4 hours
Class assessment: 15 marks; Attendance: 5 marks

Intended Learning Outcomes (ILO)

This course confers advanced idea on mechanism and stereochemistry. These overall ideas will provide the students knowledge about how to frame molecular structure and how to discriminate the enantioselectivities in chemical reactions.

1. **Nucleophilic Aliphatic Substitution** (10 lectures): S_N1 and S_N2 mechanisms, stereochemistry, comparison, simple kinetics of S_N1 and S_N2 reactions, role of solvents, S_N1 *vs* S_N2, effects of structure, attacking reagents, neighboring group

participation and leaving group on S_N reaction, S_Ni reaction, enchiomeric and stereo-chemical effects.

2. **Elimination Reaction** (10 lectures): Classification, E1 and E2 mechanisms, kinetics, stereochemistry, selectivity of products (Saytzeff and Hofmann rule), evidence for the E2 mechanism (absence of rearrangement, absence of hydrogen exchange and the element effect), orientation and reactivity, elimination *vs* substitution, E2 *vs.* E1.

3. **Addition Reactions** (12 lectures)**:** Addition reactions to C=C bond and C≡C bond; addition of water (acid catalyzed, oxymercuration-demercuration, hydroboration-oxidation, mechanism, orientation, reactivity and stereochemistry), Br_2 (mechanism and stereochemistry), hydroxylation (syn- and anti-), and HBr, effects of substituents in alkene to HBr addition, selectivity on products. Epoxidations; Sharpless Jacobson's and Shi-epoxidation to double bonds, ozonolysis in triple bonds.

4. **Mechanism of Some Important Reactions** (10 lectures): Important organic reactions with their mechanism and synthetic applications; benzoin condensation, Aldol and crossed Aldol condensation, Claisen and Crossed Claisen condensation, Perkin condensation, Reformatsky, Reimer-Tiemann and Arndt-Eistert, Cannizzaro, Michael addition, Mannich, Hunsdiecker, Sandmeyer and Diels-Alder reactions.

5. **Rearrangement Reactions** (8 lectures): Definition and classification, Hofmann, Lossen, Schmidt, Pinacol-Pinacolone, Claisen, Wittig, Beckmann, Wagner-Meerwein, Wolf, Bayer-Villiger, Fries and Curtius rearrangement.

6. **Stereochemistry** (10 lectures):

   (a) Stereoisomerism, optical antipodes, optical purity and enantiomeric excess, CIP rules for R, S-nomenclature (only for C-chirals), racemic modifications and resolutions, asymmetric synthesis.

   (b) Geometrical isomerism for oximes and cyclic compounds, cis-trans, syn-anti conformation and E, Z-nomenclature, methods of interconversion between two geometrical isomers and determination of cis-trans relationship.

Recommended Books

1. I. L. Finar: Organic Chemistry Vol. I and II
2. J. B. Hendrickson, D. J. Cram and G. J. Hammond: Organic Chemistry
3. E. L. Elliel: Stereochemistry of Carbon Compounds
4. P. S. Kalsi: Stereochemistry Conformation and mechanism

5. P. Sykes: A Guide Book to Mechanism in Organic Chemistry
6. R. T. Morrison and R. N. Boyd: Organic Chemistry
7. E. S. Gould: Mechanism and Structure in Organic Chemistry
8. J. March: Advanced Organic Chemistry : Reactions, Mechanisms and Structure
9. Seyhan Edge: Organic Chemistry

Course: Chem 322F
Natural Products and Medicinal Chemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course briefly touched the idea on sources, preparation, structure elucidation and importance of natural products like carbohydrates, alkaloids, drugs, and some other medicinal compounds.

1. **Natural Products and Pharmacology** (8 lectures)**:** Definition, occurrence, importance of natural products, definition and explanation of the following terms: pharmacology, pharmacy, pharmaceuticals, drug and its nature, drug-body interaction, drug expiration date, half life of a drug, drug dose, medication and toxicology.
2. **Carbohydrates** (10 lectures)**:** Definition, classification, structure and configuration of aldoses and ketoses, nomenclature of aldose derivatives, lengthening and shortening the carbon chain of aldoses, projection formulae and conformations, reactions of monosaccharide, mutarotation, anomerization, epimerization, and determination of ring size, formation of glucosides, conformation of aldohexoses, molecular rotation and Hudson's rule; disaccharides and their glycosidic linkages, amino sugars, anhydro sugar.
3. **Alkaloids and Uses of NMR Spectroscopy** (10 lecture)**:**
   a. Occurrence, classification, extraction and isolation, physiological activities and uses of alkaloids, general methods of determining structure; chemistry of ephedrine, nicotine, atropine and morphine.
   b. **^{1}H and ^{13}C NMR Spectroscopy** (10 lectures): Basic principle of proton and ^{13}C NMR spectroscopy, nuclear magnetic moments, energy states and magnetogyric ratio, mechanism of absorption of energy, resonance, chemical

shift, shielding and deshielding effects, shifting of chemical shift values, magnetic anisotropy, n+1 rule, Pascal's triangle, coupling constant, peak height and number of protons.

4. **Purines, Nucleic acids** and **Terpenes** (9 lectures)**:**

   a. Purine and Uric acid Derivatives: Adenine, hypoxanthine, xanthine, guanine, caffeine, theobromine and theophylline, nucleosides, nucleotides, DNA, RNA, replication of DNA.

   b. The essential oils, classification of terpenes, isoprene rule, occurrence, extraction and isolation, general methods of determining structures of terpenes, detailed studies of some monoterpenes: (i) acyclic terpenes (citral) and (ii) bicyclic monoterpenes (α-pinene).

5. **Synthesis of Drugs, Classification and their Mode of Action** (8 lectures):

   (a) *Sulpha-drugs***:** Sulphanilamide, sulphapyridine, sulphathiazole, sulphadiazine, sulphamezathine, sulphaguanidine, prontosil, chloramine-T.

   (b) *Antimalarials:* Pamaquine, mepacrine, proguanil, chloroquine, camoquine, daraprim, paludrine.

   (c) *Antipyretic and Analgesics:* Paracetamol, aspirin, phenacetin, cinchopen, phenylbutazone, mefenamic.

   (d) *Arsenical Drugs:* Arsphenamine, atoxyl and tryparsamide.

Recommended Books

1. I. L. Finar: Organic Chemistry Vol. I and II
2. W. Pigman: Carbohydrates
3. S. W. Fox and J. F. Foster: Protein Chemistry
4. O. P Agarwal: Chemistry of Natural products Vol. I and II
5. G. Chatwal: Organic Chemistry of Natural Products Vol. I and II
6. Y. R. Sharma: Elementary Organic Spectroscopy; Principles and Chemical Applications
7. D. L. Pavia, G. M. Lampman, G. S. Kriz and J. A. Vyvyan: Introduction to Spectroscopy

Course: Chem 323F
Industrial Chemistry–I
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course gives students brief idea on some common chemical industries like fertilizer, toiletries, ceramics, sugar and alkali. This will help students to understand engineering and technological aspects associated with different steps in a chemical process industry.

1. **Unit Operations and Unit Processes** (4 lectures)**:** Introduction, evaporation, distillation, crystallization, and their applications in common industries, introduction of evaporators and their classification, operating principles of single and multiple effect evaporators, distillation; simple and fractional distillation, construction of fractionating column.
2. **Pulp and Paper** (4 lectures): Sources and classification of raw materials, production of pulps; sulfate, sulfite and soda processes, physical and chemical processes involved in it, characterization of papers and their evaluations, outlines for the utilization of wastes and used paper.
3. **Petroleum** (4 lectures): General idea of formation, composition and evaluation.
   a. **Separation Operation**: Distillation, adsorption, filtration, crystallization, extraction and treating process.
   b. **Conversion Process**: Cracking, polymerization, alkylation, hydrogenation, hydrocracking, isomerization, reforming or aromatization, esterification and hydrolysis, motor and aviation fuel, their characteristics and evaluation.
4. **Natural Gas** (3 lectures): Origin, composition and purification, production of hydrogen, nitrogen and carbon dioxide, production of urea and the physico-chemical processes associated with its production.
5. **Soap and Detergents** (4 lectures)**:**
   a. General idea of soap and principles of its cleansing action, production of soaps; raw materials, characterization of fats, oils and waxes, manufacturing procedure.
   b. Definition of detergents, detergency principles, classification of detergents and their quality comparison with soaps, production of detergents and physico-chemical operations.

6. **Cosmetics and Toiletries** (5 lectures): Raw materials, separation, purification and preservation of their ingredients, synthesis of various fragrant: esters, alcohols, ionones, nitro musks, aldehydes and diphenyl compounds and chemistry associated with them; production of natural perfumes: flower perfumes; jasmine, lily, orange bloosome, and rose, fruit flavors; apple, banana, grape and pineapple components, artificial flavors, talcum powders, medicated creams and lotions.

7. **Chlor-alkali Industry** (4 lectures): General principles of electrolysis, electrolysis of sodium chloride at very dilute, concentrated and molten conditions, definition of brine, sources of sodium chloride, preparation and purification, production of caustic soda and chlorine by electrolytic method, principles of using diaphragm, diaphragm materials, general information of different types of electrolytic cells and their merits and demerits.

8. **Sugar Industry** (4 lectures): Raw materials, production, detail of the operations and processes, refining of sugar, utilization of by-products.

9. **Biotechnology and Related Industries** (4 lectures): Enzymes and microorganisms, microbial activity, fermentation unit processes and control, recovery of fermentation waste products and waste treatment, manufacture of industrial alcohol, absolute alcohol, beers, wines and liquors, butyl alcohol and acetone, vinegar and acetic acid, citric acid, lactic acid.

10. **Refractory and allied materials** (4 lectures): Definition and classification, utilization of cement, glass and ceramics, raw materials, chemistry involved in the preparation of cement, glass and ceramics, setting and hardening process in cement and testing of cement.

11. **Ecological Problems of Chemical Technology** (5 lectures): The problem of sustenance of the chemical industry, biosphere and its protection, basic trends in biosphere protection for industrial wastes, purification of industrial flue gases, purification of gases from aerosols, purification of gases from vapor and gas impurities, effluents of industrial units and their purification, solid industrial wastes, removal of H_2S from gas streams.

Recommended Books

1. R. N. Shreve: The Chemical Process Industries
2. A. Roger: Roger's Industrial Chemistry, A Manual for the Students and Manufacture, Vol. I and II
3. W. L. Nelson: Petroleum Refinery Engineering
4. R. K. Das: Industrial Chemistry, Part I and II
5. B. K. Sharma: Industrial Chemistry

Course: Chem 331F
Quantum Mechanics and Coordination Chemistry
Full marks: 100 (1.0 unit, 4 credits)
Final examination: 80 marks, 4 hours
Class assessment: 15 marks; Attendance: 5 marks

Intended Learning Outcomes (ILO)

The course is designed to introduce the fundamental knowledge on wave mechanics, atomic spectra of multielectron system, transition metals and their important properties and basic idea of coordination compounds. The course will cover an overview of different theories pertaining to magnetic properties and structural features of coordination compounds, thermodynamic stability and electronic spectra of coordination compounds.

1. **Wave Mechanics** (10 lectures): The Schrödinger wave equation, Born interpretation of the wave function, physical significance of ψ, principle of superposition, particle in one dimensional box, particle in three dimensional box, solution of Schrödinger's wave equation for H-atom, atomic and molecular orbitals.
2. **Atomic Spectra** (6 lectures): Spectroscopic levels in multielectronic system, term multiplicities, Russel-Saunder's coupling, spectra of higher elements, fine structure of spectral lines.
3. **Transition Elements (d Block Elements)** (8 lectures): Definition, classification, position in periodic table, electronic configuration, basic properties. Comparison between 1st, 2nd and 3rd series of transition elements.
4. **Basic Idea of Coordination Compounds** (10 lectures): Introduction, nomenclature, structures, coordination number and coordination geometries, coordination number 2–6, EAN rule, types of ligands, isomerization in coordination compounds, Werner's coordination theory.
5. **Theories of Coordination Compounds** (13 lectures): Valence bond theory and crystal field theory, splitting of *d* orbitals in octahedral, tetrahedral and square planar complexes, crystal field stabilization energy (CFSE) and its calculation, factors affecting CFSE, high spin and low spin complexes, spectrochemical series, magnetic properties and structure determination of complexes, Jahn-Teller distortion, molecular orbital theory and its application to simple coordination compounds, uses of complexation in analysis.
6. **Stability and Electronic Spectra of Complex Compounds** (13 lectures): Definition and thermodynamics of stability constant, factors affecting stability of complexes, methods for the determination of stability constant of complexes in solution, uses of stability constant data in chemical analysis. Ground state term symbol, Racah parameters, nephelauxetic effect; correlation diagram, Tanabe-Sugano diagram and splitting in octahedral cases. Types of electronic spectra (i) d-

d transition, (ii) L→M charge transfer band, (iii) M→L charge transfer band, (iv) intraligand transition.

Recommended Books

1. R. C. Day and J. Selbin: Theoretical Inorganic Chemistry
2. J. E. Huheey: Inorganic Chemistry: Principles of Structures and Reactivity
3. D. K. Sabera: Electronic Structure and Chemical Bonding
4. F. A. Cotton and G. Wilkinson: Advanced Inorganic Chemistry
5. K. F. Purcell and J. C. Kotz: Inorganic Chemistry
6. W. U. Malik, G. D. Tuli and R. D. Madan: Selected Topics in Inorganic Chemistry
7. B. R. Puri and L. R. Sharma: Principles of Inorganic Chemistry
8. G. S. Manku: Theoretical Principles of Inorganic Chemistry

Course: Chem 332F
Nuclear Chemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

After studying the course the students will be able to explain the characteristics of nuclear forces, different models of nuclear structure, different types of nuclear reactions and their mechanisms, interactions of radiation with matter, radiation detection and measurements. The students will also achieve the knowledge about acceleration of charged particles, principles of nuclear reactors and uses of radioisotopes in chemistry.

1. **Nuclear Forces and Nuclear Structure** (7 lectures):
   (a) **Nuclear forces**: Nucleon, nuclear forces, characteristics of nuclear forces, meson field theory.
   (b) **Nuclear structure**: Liquid-drop model, shell model, collective model.
2. **Nuclear Reactions** (8 lectures): Definition, energetics, nuclear cross section, compound nucleus theory, direct interaction, different types of nuclear reactions, nuclear fission theory, nuclear fusion.

3. **Interaction of Radiations with Matters** (5 lectures): Energy loss per ion pair, range, stopping power, velocity and energy of α-particles, loss of energy by β-particles, Bremsstrahlung, gamma ray interaction with matter– photoelectric effect, Compton effect, pair production and annihilation.

4. **Radiation Detection and Measurements** (6 lectures): Specific ionization, behaviour of ion-pairs in electric fields, ionization chambers, proportional counters, Geiger-Müller counters, scintillation counters, semiconductor detectors.

5. **Acceleration of Charged Particles** (5 lectures): The Cockcroft-Walton (voltage multiplier) accelerator, Van de Graaff generator, linear accelerator, cyclotron.

6. **Nuclear Reactors** (8 lectures): Basic principles of chain-reacting systems, general aspects of reactor design, thermal, fast and intermediate reactors, reactor fuel, moderators, reflectors, coolants and control materials, critical size of a reactor.

7. **Radiochemical Applications** (6 lectures): Tracer technique, reaction kinetics and mechanisms, radiometric analysis, isotope dilution, neutron activation analysis, hot-atom chemistry (Szilard-Chalmers process), radiocarbon dating.

Recommended Books

1 S. Glasstone: Source Book on Atomic Energy

2 G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller: Nuclear and Radiochemistry

3 G. R. Choppin: Nuclear and Radioactivity

4 H. J. Arnikar: Essentials of Nuclear Chemistry

5 B. G. Harvey: Nuclear Chemistry

Course: Chem 333F
Analytical Chemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

The course is aimed to teach the students some fundamental topics of analytical chemistry. The topics include the errors in chemical analysis, tests of data, sampling methods, solvent extraction and ion-exchange methods, principles of complexometric titrations. Coverage is also given to UV-visible absorption spectroscopy and its applications in quantitation analysis, molecular spectrofluorometry– its applications and instrumentation.

1. **Evaluation of Analytical Data** (8 lectures): Definition of terms: mean, median, precision, accuracy, determinate errors and their correction, indeterminate errors, normal error curve and its properties, standard deviation, confidence level, tests of significance (t and F tests), rejection of data (Q-test), sensitivity, detection limit, least square analysis of data.

2. **Preliminary Steps of Analysis** (8 lectures): Sampling and sampling methods, decomposing and dissolving samples, separation of impurities from sample solution: precipitation, solvent extraction and ion-exchange methods, and selection of a method for analysis.

3. **Complexometric titration** (9 lectures): Complexometric titrations with (i) inorganic complexing agents, e.g., Cl^-, SCN^-, CN^- and (ii) aminocarboxylic acids, e.g., EDTA; EDTA titrations: effect of pH, titration curves, effect of the auxiliary complexing agents, indicators, titration methods, applications: water hardness, analysis of complex mixtures of metal ions.

4. **Molecular UV-Vis Absorption Spectroscopy** (10 lectures): Origin of spectra, absorbing species containing σ, π and n electrons, transitions of *d* and *f* electrons, charge transfer transitions, selection rules for electronic transitions, quantitative aspect of absorbing UV-Vis radiation by a molecule (Beer's law), limitations to Beer's law, measurement, applications: quantitative analysis of environmental, clinical, industrial and forensic samples; kinetic study, stoichiometry of metal ligand complexes, determination of equilibrium constants.

   Spectrophotometer: basic components of an optical instrument and their functions, single and double beam instruments.

5. **Molecular Photoluminescence (Spectrofluorometry)** (10 lectures): Theory of photoluminescent spectroscopy, energy-level diagrams for photoluminescent molecules: fluorescence and phosphorescence; molecular structures and photoluminescence, relationship between absorption and fluorescence spectra, effect of concentration on fluorescence intensity, quantum efficiency and quantum yield, fluorescence quenching, applications: fluorometric analysis of some inorganic, organic and biological species, instrumentation for fluorescence and phosphorescence processes, theory of chemiluminescence and bioluminescence.

Recommended Books

1. D. A. Skoog, D. M. West and F. J. Holler: Fundamentals of Analytical Chemistry (9th Ed.)
2. G. D. Christian: Analytical Chemistry (6th Ed.)
3. D. A. Skoog, F. J. Holler and S. R. Crouch: Principles of Instrumental Analysis (6th Ed.)

4. Pavia, Lampman and Kriz: Introduction to Spectroscopy (4th Ed.)
5. H. A. Laitinen and W. E. Harris: Chemical Analysis
6. Bassett, Danney, Joffery and Mendhams: Vogel's Textbook of Quantitative Inorganic Analysis
7. H. H. Willard, L. L. Merritt, J. A. Dean and F. A. Settle: Instrumental Methods of Analysis (6th Ed.)

Course: Chem 301LF
Chemistry Practical–III
Full Marks: 225 (2 units, 9 credits)
Examination: 36 hours (6 days)

The relevant teacher(s) of the section shall evaluate continuously the Lab classes out of 23 marks and submit the average marks of Lab evaluation in sealed envelope to the Chairman of the relevant Examination Committee within three weeks from the last Lab class held. The average final marks shall be computed by the Examination Committee.

The total marks for the practical course shall be obtained by adding the two marks (i) **Experiment** and (ii) **Continuous Lab Assessment**. The **examination committee** shall send a copy of the consolidated marks to the **controller of examinations**.

Section–A
Physical Chemistry Practical–III
Examination: 12 hours (Two days)
Full Marks: 75
(i) Experiment: 52, (ii) Continuous Lab Assessment: 23

Intended Learning Outcomes (ILO)

This course includes some basic experiments on volumetry, viscometry, titrimetry, potemtiometry, conductometry and thermometry. Upon completion of the course, students will be familiar with such experimental techniques, and ways of collecting, handling, statistical manipulation by least-square linear fitting and systematic reporting of data. They will also be able to design new experiments based on the above mentioned techniques.

Experiments in Physical Chemistry

1. Measurement and control of temperature, setting of water thermostat at certain temperature with the help of toluene-mercury regulator, preparation of reference electrodes.

2. Determination of viscosity coefficient of the (a) water-alcohol and (b) nitric acid-chloroform mixtures and comments on the structure of the solutions.
3. Construction of adsorption isotherm of a suitable acid from aqueous solution by charcoal.
4. Determination of the rate constant of acid-catalysed hydrolysis of an ester by titrimetric method at different hydrogen ion concentration.
5. Determination of the rate constant of acid-catalysed hydrolysis of sucrose by polarimetric method.
6. Kinetic studies of reduction of hydrogen peroxide.
7. Determination of the partial molar volume of alcohol in alcohol+water mixture by slope method.
8. Determination of cell constant, equivalent conductance at infinite dilution and verification of D-H-O equation conductometrically.
9. Determination of cooling corves of binary solid system.
10. Boiling temperature vs composition diagram of completely miscible binary liquid pairs.
11. Construction of Daniel cell and determination of the (a) e.m.f. of the cell, (b) standard electrode potential of quinhydrone, silver and silver-silver chloride electrodes.

NB: A few more experiments, relevant to the theoretical courses may be done, subject to the availability of the Lab. facilities.

Recommended Books

1 D. P. Shoemaker et al: Experiment in Physical Chemistry

2 G. S. Weiss et al: Experiments in General Chemistry

3 A. Findlay: Practical Physical Chemistry

4 R. C. Das: Experimental Physical Chemistry

5 J. N. Gurtu: Advanced Experimental Chemistry

6 K. K. Sharma: An Introduction of Practical Chemistry

7 J. C. Muhler et al: Introduction to Experimental Chemistry

8 J. Rose: A Textbook of Practical Physical Chemistry

9 J. B. Yadav: Advanced Practical Physical Chemistry

10 Newcomb, wilson et al: Experiments in Physical Chemistry

11 Daniels et al: Practical Physical Chemistry

12 Brennan et al: Experiments in Physical Chemistry

13 S.R. Palit: Practical Physical Chemistry

14 C. D. Hodgman et al: Handbook of Chemistry and Physics

15 R. C. West et al: CRC Handbook of Physics and Chemistry

16 L. A. Lange: Handbook of Chemistry

Section–B
Organic Chemistry Practical–III
Examination: 12 hours (Two days)
Full Marks: 75
(i) Experiment: 52, (ii) Continuous Lab Assessment: 23

Intended Learning Outcomes (ILO)

The students shall gain knowledge on the separation and identification of organic compounds in a mixture. This course also gives fundamental idea on evaluating the product quality in cement, sugar and soap industries.

Experiments in Organic and Industrial Chemistry

1. Separation of a mixture of organic compounds using chemical and chromatographic (PTLC/CC) methods and their systematic identification (both solids and liquids) by chemical method.
2. Analysis of cement for (a) insoluble materials, (b) silica, (c) iron(III) oxide, and (d) calcium oxide etc.
3. Determination of iodine value, saponification value, acid value and R.M. value of oils and fats.
4. Analysis of molasses for (a) moisture, (b) total sugars and (c) reducing sugars.
5. Estimation of celluose, hemicellulose and lignin in a sample of jute fibre.

Recommended Books

1. A. I. Vogel: A Textbook of Practical Organic Chemistry
2. Shiriner, Fusion and Curtin: Systematic Organic Analysis
3. H. T. Clarke: Practical Organic Chemistry
4. A. I. Vogel: Elementary Practical Organic Chemistry–Part I, II and III
5. J. Bassett and others: Vogel's Textbook of Quantitative Inorganic Analysis
6. Skoog and West: Fundamentals of Analytical Chemistry
7. Schwarzenbach and Flaschka: Complexometric Titrations

Section–C
Inorganic Chemistry Practical–III
Examination: 12 hours (Two days)
Full Marks: 75
(i) Experiment: 52, (ii) Continuous Lab Assessment: 23

Intended Learning Outcomes (ILO)

The Inorganic Section of this laboratory course enables the students to perform the gravimetric estimation of metal ions, separation technique and gravimetric estimation of the component of the mixtures.

Experiments in Inorganic Chemistry

1. Gravimetric estimation of the following :
   i) **Iron** as ferric oxide.
   ii) **Barium** as barium sulphate.
   iii) **Zinc** as zinc ammonium phosphate.
   iv) Maganese as manganese pyro-phosphate.
2. Quantitative separation and estimation of the components of the following mixtures :
   i) Iron and manganese, (ii) Copper and zinc, (iii) Copper and nickel.
3. Estimation of hydrochloric acid as silver chloride.
4. Analyses of alloys, ores and minerals.
5. Analysis of coal for (a) moisture, (b) volatile matter, (c) ash and (d) sulphur.

Recommended Books

1. A. I. Vogel: A Textbook of Inorganic Quantitative Analysis
2. Alexeve: Qunatitative Chemical Analysis
3. D. A. Skoog and D. M. West and F. J. Holler: Fundamentals of Analytical Chemistry (6th Edn)
4. Jugal Kishore Agarwal: Practicals in Engineering Chemistry
5. R. K. Das: Industrial Chemistry, part II

B. Sc. Honours Part–IV Examination, 2021
Session: 2020–2021

The courses and distribution of marks are as follows:

Courses	Course Titles	Units	Credits	Marks
Chem 411F	Principles of Chemical Spectroscopy	1.00	4	100
Chem 412F	Electrode Processes and Statistical Thermodynamics	0.75	3	75
Chem 413F	Chemistry of Solids and Nanomaterials	0.75	3	75
Chem 421F	Reaction Mechanism and Stereochemistry–II	1.00	4	100
Chem 422F	Natural Products Chemistry	0.75	3	75
Chem 423F	Industrial Chemistry–II	0.75	3	75
Chem 431F	Organometallics, Metal Clusters and Solvents	1.00	4	100
Chem 432F	Heavy Transition Metals, Magnetochemistry and Group Theory	0.75	3	75
Chem 433F	Separation and Electroanalytical Techniques	0.75	3	75
Chem 401VF	Viva-voce in Chemistry–IV	0.75	3	75
Chem 401LF	Chemistry Practical–IV	2.25	9	225
	Total	**10.5**	**42**	**1050**

N.B. Minimum 60 and 45 lectures should be delivered for each 4 and 3 credit theory course, respectively.

All theory courses include 80% final examination and 20% in-course. The **Final examination** of 80% of each 100 marks (1.0 unit, 4 credits) and each 75 marks (0.75 unit, 3 credits) theory full course shall be of 4 (four) hours duration. In-course comprises of 15% tutorial or terminal and 5% class attendance. The class **teachers** of each course shall submit the average marks of in-courses in a sealed envelope to the **chairman** of the relevant **examination committee** within three weeks from the last class held. The relevant **examination committee** shall prepare the result by adding the average marks of each in-course to the average marks obtained in the final examination of respective course, and send a copy of the average marks of each in-course to the controller of examinations.

All practical courses include 70% practical examination and 30% continuous Lab assessment. The practical examination of 70% of 225 marks (2.25 units, 9 credits) practical course shall be of 36 (thirty six) hours duration (6 days). The students are required to submit a report after each practical class to the class teacher(s) for evaluation. After evaluation the report shall be returned to the students. The class **teacher(s)** shall submit the average marks of all Lab evaluation in a sealed envelope to the **chairman** of the relevant **examination committee** within three weeks from the last Lab class held. The examination committee shall send a copy of each of the consolidated **practical** and **Lab evaluation** marks to the **controller** of examinations.

Viva-voce examination (**Chem 401VF**) includes the assessment of the students through oral examination (of all the courses) by the **members** of the relevant examination committee. The **examination committee** shall send a copy of the marks to the **controller** of examinations.

N.B. Students having less than 60% class attendance shall not be allowed to sit for the examination.

Course: Chem 411F
Principles of Chemical Spectroscopy
Full marks: 100 (1.0 unit, 4 credits)
Final examination: 80 marks, 4 hours
Class assessment: 15 marks; Attendance: 5 marks

Intended Learning Outcomes (ILO)

This course concerns with the underlying principles involved in the interactions of electromagnetic radiation with matter. It helps students to understand the generation of spectroscopic signals and spectra. As a consequence, they will be able to analyze molecular spectra and thereby establish molecular structure.

1. **Absorption and Emission of Radiation** (8 lectures**):** The time dependent Schrodinger equation; induced quantum transitions; interaction of radiation with molecular system, comparison with experimental quantities; the basis of selection rules for spectroscopic transitions; the integrated absorption coefficient for a transition of a particle in a box; induced emission and induced absorption; the integrated absorption coefficient for a vibrational transition; the intensities of absorption bands due to electronic transitions.

2. **Rotational Spectroscopy** (8 lectures): The rotation of molecules– linear molecules; symmetric, spherical, and asymmetric tops. Rotational energy of diatomic molecules; rotational energy transitions and selection rules; intensities of spectral lines; effect of isotopic substitution. The non-rigid rotator and its spectrum, microwave spectra of polyatomic molecules. Techniques and instrumentation, Stark effect, qualitative and quantitative applications of microwave (rotational) spectroscopy.

3. **Infrared Spectroscopy** (14 lectures): Vibrational energies of diatomic molecules: the simple harmonic oscillator and the anharmonic oscillator models; selection rules for energy transition; the diatomic vibrating rotator and its spectrum, interaction of rotations and vibrations. Vibrations of polyatomic molecules–normal modes of vibration; overtones, combination and hot bands; influence of rotation on the spectra of polyatomic molecules; analysis by infrared techniques; techniques and instrumentation; Fourier transformed (FT) infrared spectroscopy.

4. **Raman Spectroscopy** (8 lectures): Theories of Raman effect; pure rotational Raman spectra; vibrational Raman spectra, rotational fine structure of Raman spectra, polarization of light and the Raman effect; structure determination from Raman and infrared spectroscopy; techniques and instrumentation.

5. **UV-Visible Spectroscopy** (12 lectures): Electronic spectra of diatomic molecules: the vibrational structure of electronic bands and the Franck-Condon principle; rotational structure of electronic bands. Electron orbitals in diatomic molecules; electronic states in diatomic molecules; potential energy curves for electronic states of diatomic molecules. Electronic spectra of polyatomic molecules: electronic states of localized groups; electronic transitions of conjugated systems–the free electron model; electronic states and transitions in aromatic systems; electronic transitions of coordination compounds. Emission and decay processes: nonradiative processes, fluorescence, and phosphorescence.

6. **Nuclear Magnetic Resonance (NMR) Spectroscopy** (10 lectures): The nuclear spin; interaction between nuclear spin and a magnetic field: the nuclear Zeeman effect; nuclear spin states and absorption of energy; population of nuclear spin states; the Larmor precession, chemical shift and shielding, factors affecting chemical shift, concepts and origin of spin-spin splitting, first and second order NMR spectra; macroscopic magnetization; the Bloch equations for free precessions and under perturbations; the rotating frame of reference and Bloch equations; relaxation processes (T_1 and T_2) and their mechanisms; free induction decay (FID), Fourier transformation of the FID and NMR signal.

Recommended Books

1. Gordon M. Barrow : Introduction to molecular spectroscopy
2. C.N. Banwell and E.M. McCash: Fundamentals of Molecular Spectroscopy (4^{th} edn.)
3. Peter F. Bernath: Spectra of Atoms and Molecules
4. J.K.M. Sanders and B.K. Hunter: Modern NMR Spectroscopy: A Guide for Chemists

Course: Chem 412F
Electrode Processes and Statistical Thermodynamics
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course emphasizes on the underlying principles of electrochemical processes and calculation of thermodynamic properties from microstates. It helps students to understand the surface structure of electrodes, mechanism of electrode processes as well as microscopic and macroscopic nature of substances. The outcome of this course leads the students to design new electrochemical processes with establishing mechanism and find out the bulk properties of substances from quantum properties.

1. **Theories of Electric Double Layers** (10 lectures): Formation of double layer at electrode-electrolyte interface; parallel plate condenser theory (Helmholtz theory); diffuse layer theory (Gouy-Chapmann theory); adsorption theory (Stern's treatment); recent developments in double layer theory; potential of zero charge and its significance. Adsorption at electrode surface: nature and behavior of adsorbed ions and molecules at electrodes (Langmuir isotherm); Temkin isotherm and heterogeneity of interaction effects.
2. **Kinetics of Electrode Processes** (10 lectures): Faradaic and non-Faradaic processes, electrode polarization and classification of polarization phenomena, concept and theory of over potential, rate of electrochemical reactions; mechanism of overall electrochemical reactions. Activation controlled relations: Butler-Volmer model; standard rate constant, symmetry factor; net current and exchange current; Tafel plot; Marcus theory of charge transfer reactions; double layer effects on electrode reaction rates. Mass transfer controlled reactions: modes of mass transfer, concept of diffusion layer; thickness of Nernst's diffusion layer; mass transfer coefficient; mass transfer limiting currents; reversible reactions; irreversible reactions; quasi-reversible reactions.
3. **Some Selected Electrode Processes** (10 lectures): Hydrogen evolution reaction, oxygen evolution reaction, batteries and fuel cells: general considerations; maximum energy density of batteries; types of batteries; design requirements and characteristics of batteries; primary batteries; secondary batteries; fuel cells; porous gas-diffusion electrodes; the polarity of batteries, corrosion and passivity: phenomenology; pH-potential diagrams; current-potential diagrams for corrosion; potentiostatic behavior; inhibition of corrosion; kinetic origin of passivation effects, electroplating: general observations; macro throwing power; micro throwing power; plating from nonaqueous solutions, ionic redox reactions: energetics; kinetic aspects.

4. **Concepts of Statistical Thermodynamics** (8 lectures): Configurations and weights, instantaneous configuration, dominating configuration, Boltzmann distribution, molecular partition function: interpretation of the partition function; approximations and factorizations, internal energy and entropy: internal energy; statistical entropy, canonical partition function: canonical ensemble; concept of ensemble; fluctuations from most probable distribution, thermodynamic information in the partition function: internal energy; entropy, independent molecules: distinguishable and indistinguishable molecules; entropy of a monatomic gas (Sakur-Tetrode equation).
5. **Applications of Statistical Thermodynamics** (7 lectures): Thermodynamic functions: Helmholtz energy; pressure; enthalpy; Gibbs energy, molecular partition function: translational contribution; rotational contribution; vibrational contribution; electronic contribution; overall partition function, mean energies: mean translational energy; mean rotational energy; mean vibrational energy, residual entropies, equilibrium constants, activated complex theory and explanation for steric factor in terms of partition function, reactions between polyatomic molecules.

Recommended Books

1. Allen J. Bard and Larry R. Faulkner: Electrochemical Methods– Fundamentals and Applications
2. Christopher Brett and Ana Brett: Electrochemistry – Principles, Methods and Applications
3. K. J. Vetter: Electrochemical Kinetics
4. B. E. Conway: Electrode Processes
5. Eliezer Gileadi: Electrode Kinetics
6. Peter W. Atkins and Julio de Paula: Atkins' Physical Chemistry (10^{th} edition)
7. Gurdeep Raj: Physical Chemistry

Course: Chem 413F
Chemistry of Solids and Nanomaterials
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course emphasizes on synthesis, structure and properties of solids and nanomaterials. It will help students to understand the crystallographic structure, preparation protocol and novel properties of bulk and nanoscale materials. The outcome of this course leads the students to design smart materials, determine crystal structure and elucidate unique physical properties.

1. **Crystal Structure** (15 lectures): Classification of solid; characteristic properties of solids: isomorphism, polymorphism, allotropy and anisotropy. The growth of crystals; classifications and properties of crystals; unit cell; crystal lattice; Bravis lattice; Miller indices; symmetry operations and symmetry elements; point groups; close pack structure– cubic and hexagonal; some important structure type: sodium chloride, zinc blend, diamond, wurtzite, pervoskite and spinal structure; perfect and imperfect crystals; type of crystal defects, thermodynamic and equilibrium concentration of intrinsic defect; creation and color centers; influence of defects on physical properties of solids; non-stoichiometry; solid solution; solid electrolytes and their applications; liquid crystals: classifications, theory and their applications.

2. **Diffraction Techniques** (7 lectures): X-ray diffraction; nature and production of X-rays; Bragg's law; the powder method: theory, principle, and applications. Single crystal X-ray diffraction: theory, principle, and applications. Principle of neutron and electron diffractions.

3. **Properties of Solids** (7 lectures): Band theory of solids; band structures of metal, semiconductor and insulator. Types of semiconductors; Hall-effect; applications of semiconductors: p-n junction, photoconductor and superconductor. Magnetic properties of metals; optical properties: luminescence, laser, photocopying process.

4. **Properties of Nanomaterials** (10 lectures): Introduction, consequences of the nanoscale: nanoparticle morphology; electronic structure; optical properties; magnetic properties; mechanical properties; melting, one-dimensional nanomaterials, two-dimensional nanomaterials, three-dimensional nanomaterials, manipulating atoms and molecules: scanning tunnelling microscopy; atomic force microscopy; nanostencils; optical tweezers; molecular lithography; data storage.

5. **Reactivity of Solids** (6 lectures): Nature of solid state reactions; reactions involving single solid phase; solid-gas, solid-liquid, solid-solid reactions; kinetics of thermal decomposition reactions, photographic process.

Recommended Books

1. A. R. West**:** Solid state chemistry and its applications
2. C.N.R. Rao and J. Gopalakrishnan: New Directions in Solid State Chemistry
3. A. K. Galway**:** Chemistry of solids
4. L. E. Smart and E. A. Moore: Solid State Chemistry-An Introduction
5. W. J. Moore**:** Physical Chemistry (5th edition)
6. D. K. Chakrabarty**:** Solid state Chemistry
7. P. Atkins and J. Paula**:** Atkin's Physical Chemistry (9th edition)

Course: Chem 421F
Reaction Mechanism and Stereochemistry–II
Full marks: 100 (1.0 unit, 4 credits)
Final examination: 80 marks, 4 hours
Class assessment: 15 marks; Attendance: 5 marks

Intended Learning Outcomes (ILO)

This course addresses kinetics, reaction mechanisms and stereochemistry. The objectives of this course are to provide an increased knowledge of measurement and analyses of chemical reaction rates, theoretical conjecture and prediction what takes place at each stage of an overall chemical reaction and structural information respectively.

1. **Kinetics, Energetic and Organic Reaction Mechanism** (10 lectures): Kinetics and energetics; reaction rate, reversible reactions, mechanistic implications from rate law, transition state theory, energy of activation and entropy of activation, investigation of reaction mechanism, identification of products, study of intermediates, trapping of intermediates, crossover experiment, kinetic, isotopic and stereo-chemical studies.
2. **Mechanism of Esterification and Hydrolysis** (8 lectures): ($A_{AC}1$, $A_{AC}2$, $A_{AL}1$, $A_{AL}2$, $B_{AC}1$, $B_{AC}2$, $B_{AL}1$ and $B_{AL}2$) mechanisms, stereochemistry, weakness and deviations, transesterification and its uses in synthesis.
3. **Stereochemistry** (9 lectures): Stereochemistry of allenes and biphenyl derivatives, atropisomerism, buttressing effects, R,S-nomenclature of allenes and biphenyls, enantiotopic faces, diastereotopic and homotopic faces, stereo convergence, stereospecificity, diastereoselectivity and chemoselectivity in reactions with examples, substrate and reagent control stereoselectivity.
4. **Conformational Analyses** (9 lectures): Relative stability of cyclic and acylic conformers, conformers of ethylene glycol, acetaldehydes, propanaldehydes and acetone, conformation of haloalkanes, halohydrins and alkenes, conformational stability of cis-trans 1,2- 1,3- 1,4-dimethylcyclohexane, 2-alkyl ketone, 3-alkyl ketone and haloketone effects in cyclohexane.
5. **Pericyclic Reactions** (8 lectures): Orbital symmetry, electrocyclic and cycloaddition both in thermal and photochemical aspects, stereochemistry and mechanisms, Woodward-Hofmann rule, sigmatropic changes (both carbon and H-shift), Cope, oxy-Cope, anionic oxy-Cope and Claisen Claisen-Cope and McLafferty rearrangements with stereochemistry.

6. **Free Radical Reaction** (8 lectures): Definitions, generation of long and short lived free radicals, detection, configuration, types, stability of free radicals, auto-oxidations, radical initiators and radical scavengers, free radical mechanisms in general; substitution mechanism, mechanism at aromatic substrate, neighboring-group assistance in free radical reactions, reactivity for aliphatic substrates, reactivity at a bridgehead position, reactivity in aromatic substrates, reactivity in the attacking radical, effect of solvent on reactivity, free radical reactions: (i) hydrogen as leaving group (ii) allylic halogenations (iii) halogenations of aldehydes (iv) substitution by oxygen (v) hydroxylation at an aromatic carbon and other free radical substitution affected by oxygen.

7. **Photochemistry** (8 lectures): Light absorption, Jablonsky diagram, fluorescence and phosphorescence, singlet and triplet states, photosensitization reactions and example of photochemical reactions: (i) photorearrangement, (ii) photoaddition, (iii) photosubstitution, (iv) photooxidation / reduction, photocyclization, (v) photoelimination, Norrish I and II type reactions and (vi) photochemistry of aromatic compounds.

Recommended Books

1. E. S. Gould : Mechanism and Structure in Organic Chemistry
2. E. R. Alexander : Principles of Ionic Organic Reactions
3. P. Sykes : A Guidebook to Mechanism in Organic Chemistry
4. E. L. Eliel: Stereochemistry of Carbon Compounds
5. E. L. Eliel *et al* : Conformational Analysis
6. I. L. Finar : Organic Chemistry, Vol. I and II
7. J. B. Hendrickson, D. J. Cram and G. S. Hammond : Organic Chemistry
8. R.T. Morrison and R.N. Boyd : Organic Chemistry
9. J. March: Advanced Organic Chemistry

Course: Chem 422F
Natural Products Chemistry
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This course offers idea on various natural products with their synthesis, structural identification, separation and purification. Students would be able to gain fundamental knowledge on structure and structure-activity relationships and quality aspects of medicine.

1. **Antibiotics** (5 lectures): Definition, classification of antibiotics, physiological actions. Chemistry and importance of penicillins, streptomycin and chloromycetin, mechanism of the mode of action against pathogenic microorganisms.

2. **Bioorthogonal Chemistry** (7 Lectures): Uses of bioorthogonality, mechanism, limitations, Cu-free click chemistry, toxicity of copper, resioselectivity, development of cyclooctynes, its reactivity, nitro-dipole cycloaddition, norbornene cycloaddition, tetrazine ligation, tetrazole photo-click chemistry, quadricyclane ligation, Staudinger ligation.

3. **Vitamins** (5 lectures): Vitamins and nutrients, vitamers, provitamins. Chemistry and importance of vitamins A, B_2, C, D and E.

4. **Colouring Matters** (5 lectures): A general knowledge of occurrence, isolation, purification, properties and structure of anthocyanins, flavonoids and carotenoids.

5. **Steroids andHormones** (10 lectures):

   a. Diels hydrocarbon, chemistry and stereochemistry of cholesterol and ergosterol, biosynthesis of steroids.

   b. Definition and classification of hormones, chemistry of testosterone, oestrone and progesterone, biosynthesis of hormones.

6. **Amino acids, Dipeptides and Proteins** (5 lectures): Defination of α-amino acids, classification, peptide formation, helical structures of proteins, denaturation, renaturation and annealing, biosynthesis of proteins, molecular weight determination, assay of amino acids and sequence analysis of peptides and proteins.

7. **Chromatography and Mass Spectroscopy to Natural Products Detection** (8 lectures)**:** Basic principle of TLC and column chromatography, principle of mass spectroscopy– basic rules of fragmentation patterns, identification and analysis of organic compounds and drugs.

Recommended Books

1. A. Burger: Medicinal Chemistry and Drug Discovery (vol. I and II)
2. S. F. Dyke: The Chemistry of Vitamins
3. Karrer and Karrer: Caroteniods

4. I. L. Finar: Organic Chemistry (Vol-2)
5. S. W. Fox and J. F. Foster: Introduction to Protein Chemistry
6. Ward W. Pigman : Carbohydrates
7. D. A. Skoog, F. J. Holler and S. R. Crouch : Principle of Instrumental Analysis
8. H. C. Hill : Introduction to Mass Spectroscopy
9. D. L. Pavia, G. M. Lampman, G. S. Kriz and J. A. Vyvyan : Introduction to Spectroscopy

Course: Chem 423F
Industrial Chemistry–II
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

Students shall be able to understand the application of chemistry in industrial processes and additionally can address safety issues associated with process and unit operations. This course shall also enable students to understand polymers and nano-materials.

1. **Polymers** (5 lectures): Polymers and their classification, addition and condensation polymerisations and their kinetics, molecular weight and degree of polymerisation, polydispersity and molecular weight distribution, general idea of polymer structure, glass transition temperature and the factors influencing it, crystallinity in polymers, solubility and nature of polymers in solution.

2. **Polymer Processing Industries** (5 lectures): Introduction, elastomerics; preparation, properties and applications, synthetic fibres: polyamides, rayon, dacron, orlon and teflon, plastics; properties, common plastics, compounding and processing techniques.

3. **Leather Technology** (5 lectures): Definition of leather, hides and skins and their classifications, preparation of hides and skins, pre-tannage processes, tanning processes: chrome tanning, vegetable tanning and alum tanning, finishing of leather.

4. **Textile Dyeing Technology** (5 lectures): Dyes and their properties, relationship between color and constitution, classification of dyes, chemistry associated with the dyeing of fibres, composition of jute, cotton, silk and wool, preparation of fibres for dyeing, methods of dyeing.

5. **Coating Technology** (5 lectures) :

   (a) Resin: Definition, classification and applications of resins, alkyd resin: classification, raw materials and chemistry associated with preparation, phenol-formaldehyde resin and important synthetic resins.

   (b) Paints and Varnishes: Definitions, classification, constituents, purpose of coating, compounding, methods of applications, cure and paint failure, enamels and lacquers.

6. **Nano-materials, Fabrication and Applications** (6 lectures): General introduction to nanoscience and commonly used terms explained in it, diffusion, colloid stability: lyophobic sols, DLVO theory, flocculation and coagulation, electrokinetic phenomena, synthesis of uniform particles: general principles and examples, methods of synthesis and characterization of organic, inorganic and multilayered-hybrid nanoparticles, particle size analysis, carbon chemistry; fullerenes and nanotubes, history of fullerence discovery, methods of synthesis, characterisation, properties and applications in nanotechnology, carbon nanotube synthesis, structure and characterisation method, properties and applications of carbon nanotubes, nanofabrication, ion beam techniques, bio-nano-link, nanoparticle toxicology.

7. **Fertilizers** (4 lectures): Classification of fertilizers and their importance as plant nutrient, production of phosphate fertilizers like normal superphosphate, triple superphosphate and ammonium phosphate.

8. **Agrochemicals and Pesticides** (5 lectures): Pesticides and their classifications, preparation of some common organo-chlorinated and organo phosphorous insecticides: BHC, DDT, parathion, methyl parathion, paraoxon and malathion, herbicides: trichlorophenoxy compounds, properties, uses and mode of action.

9. **Food and Food By-product Processing Industries** (5 lectures): Types of food processing, its instrumentation and methods, by-products of food and their uses, food additive, milk processing, meat processing, gelatin and additives.

Recommended Books:

1. V. R. Gowariker, N. V. Fiswanathan and J. Sreedhar: Polymer Science
2. R. N. Shreve: The Chemical Process Industries
3. Vincent Sauchelli: Fertilizer Nitrogen, its Chemistry and Technology
4. R. K. Das: Industrial Chemistry, Part I and II
5. Linda Williams and Dr. Wade Adams : Nanotechnology
6. B. K. Sharma: Industrial Chemistry

Course: Chem 431F
Organometallics, Metal Clusters and Solvents
Full marks: 100 (1.0 unit, 4 credits)
Final examination: 80 marks, 4 hours
Class assessment: 15 marks; Attendance: 5 marks

Intended Learning Outcomes (ILO)

The course provides the students with the knowledge of organometallic compounds (including metal carbonyls and metal nitrosyls) and their reactions, the metal carbonyl and metal atom clusters. The course also provides the knowledge of solvents, non-aqueous solvents and the reactions involved therein, and modern theories of acids and bases.

1. **Organometallic Compounds** (12 lectures): Definition, nomenclature, 18-electron rule, π-acceptor ligands, methods of preparation, properties, structure and bonding of metal carbonyls and nitrosyls. Organometallic compound of η^1–η^8 systems: preparation, properties and structure; cyclopentadienyl complexes and metallocene; ferrocene: structure, reactivity and reactions.
2. **Types of Organometallic Reactions** (6 Lectures): Reactions involving gain or loss of ligands, oxidative additions, reductive eliminations, insertion reactions, and intermolecular nucleophilic additions to unsaturated ligands.
3. **Metal-to-Metal Bonds and Metal Atom Clusters** (12 lectures): Introduction, metal carbonyl clusters: low-nuclearity carbonyl clusters (LNCCs), isoelectronic and isolobal relationship, high-nuclearity carbonyl clusters (HNCCs), hetero atoms in metal atom clusters, electron counting schemes for HNCCs (the Capping and Wade's rule). Metal-metal bonds in non-carbonyl compounds: octahedral metal halide and Re_3^- clusters. Compounds with M-M multiple bonds: major

structural types, quadruple bonds, triple bonds, other bond orders in the tetragonal context, relation of clusters to multiple bonds, one dimensional solids.

4. **Solvents** (10 lectures): Solubilities of compounds, effect of temperature on solubility, role of water as a solvent, chemical structure and solubility, solubility from chemical reactions, energy change in solution formation, the effect of hydration and lattice energies, Born's equation for solubilities of salts.

5. **Nonaqueous Solvents** (10 lectures): Classification of solvents, role of solvents in chemical reactions, chemical reactions in liquid NH_3, SO_2, H_2SO_4 and HF media.

6. **Modern Theories of Acids and Bases** (10 lectures): Development of the concepts of acids and bases, class a and b acid-base theory, Pearson's concept of hard and soft acids and bases (HSAB), application of HSAB concept, symbiosis, measurement of acid-base strength, Drago and Waylands E and C parameter, periodic trends in Bronsted acidity, super acids.

Recommended Books

1. D. Shriver, M. Weller, T. Overton, J. Rourke and F. Armstrong: Inorganic Chemistry (6th Ed.)
2. M. Halka and B. Nordstorm: Periodic Table of the Elements–Lanthanides and Actinides
3. C.E. Housecroft and A.G. Sharpe: Inorganic Chemistry
4. G.S. Manku: Theoretical Principles of Inorganic Chemistry
5. G.L. Miessler, P.J. Fischer and D.A. Tarr: Inorganic Chemistry
6. J. E. Huheey: Inorganic Chemistry: Principles of Structures and Reactivity
7. F. A. Cotton and G. Wilkinson: Advanced Inorganic Chemistry (5th Ed.)
8. S. Z. Haider: Selected Topics in Inorganic Chemistry
9. N. C. Day and J. Selbin: Theoretical Inorganic Chemistry
10. Purcell and Kotz: Inorganic Chemistry
11. J. P. Collman and L. S. Hegedus: Principles and Applications of Organotransition Metal Chemistry
12. W. U. Malik, G. D. Tuli and R. D. Madan: Selected Topics in Inorganic Chemistry
13. H. H. Sisler: Chemistry in Nonaqueous Solvents

Course: Chem 432F
Heavy Transition Metals, Magnetochemistry and Group Theory
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

Upon completion of this course the students will learn about the characteristics of lanthanides and actinides, chemistry of some heavy metals and magnetochemistry. They will have the fundamental ideas about inorganic polymers and inorganic free radicals. The course also includes molecular symmetry, group theory and its application to molecular geometry.

1. **Chemistry of Lanthanides and Actinides** (8 lectures): Periodicity, general characteristics of lanthanides, comparison of transition metal ions and lanthanide ions, lanthanide chelates, uses of lanthanides and their compounds, occurrence and separation of lanthanides; general characteristic of actinides and their comparison with lanthanides, separation of actinide elements.

2. **Chemistry of Some Heavy Metals** (6 lectures):

   (a) **Molybdenum and tungsten**: The elements, oxides, sulphides, simple oxo and sulphides anions; isopoly and heteropoly acids and salts; aqua and oxo-complexes.

   (b) **Platinum group metals**: General remarks on the chemistry of platinum metals, binary compounds– oxides, sulphides, phosphides, hallides.

   (c) **Palladium and platinum**: General remarks, stereochemistry, the II state, d^8, complexes of Pd(II) and Pt(II), complexes in low oxidation state.

3. **Magnetochemistry** (12 lectures): Some definitions– magnetic lines of forces, field strength, magnetic moment, magnetic permeability, intensity of magnetisation, magnetic induction, magnetic susceptibility; Coulomb's law, causes of dia- and paramagnetism; Langevin's theories of dia-and paramagnetism; Curie's law, Curie-Weiss law, general theory for the measurement of magnetic susceptibility; different methods for the measurement of magnetic susceptibility; ferromagnetism and antiferromagnetism: definitions, special properties and theories, hysteresis loop; application of magnetic measurements to chemical problems: diamagnetic correction, Pascal's constants, determination of the geometrical structure of coordination compounds.

4. **Inorganic Polymers** (7 lectures): Introduction, classification of polymers, polymerisation processes for the preparation of polymeric substances, condensation polymerisations, addition polymerisation with special reference to phosphagenes (phosphonitrilic halides) and inorganic benzene, polymerisation involving both addition and condensation, sulfur clusters and selenium clusters.

5. **Inorganic Free Radicals** (4 lectures): Methods of generation of free radicals, techniques of study of free radicals, reactions and properties of free radicals.

6. **Molecular Symmetry and Group Theory** (8 lectures): Molecular symmetry, symmetry elements and operations, reducible and irreducible representation of groups, character table, group theory and its application to various types of molecules, determination of number of IR and Raman active bands and geometry of the molecule.

Recommended Books

1. F. A. Cotton and G. Wilkinson: Advanced Inorganic Chemistry (4th and 5th Ed.)
2. W. U. Malik, G. D. Tuli and R. D. Madan: Selected Topics in Inorganic Chemistry
3. S. Z. Haider: Selected Topics in Inorganic Chemistry
4. J. E. Huheey: Inorganic Chemistry: Principles of Structure and Reactivity
5. Purcell and Kotz: Inorganic Chemistry
6. Gurdeep Raj: Advanced Inorganic Chemistry (Vol. I)
7. P. W. Selwood: Magnetochemistry
8. Earnshaw: An Introducatiuon to Magnetochemistry
9. F. A. Cotton: Chemical Application of Group Theory

Course: Chem 433F
Separation and Electroanalytical Techniques
Full marks: 75 (0.75 unit, 3 credits)
Final examination: 60 marks, 4 hours
Class assessment: 11 marks; Attendance: 4 marks

Intended Learning Outcomes (ILO)

This advanced analytical chemistry course describes the separation techniques emphasizing on different kinds of chromatography. The separation techniques include capillary electrophoresis and its application in chemical analysis. The course also covers electroanalytical techniques including potentiometric methods, voltammetry and polargraphy.

1. **Introduction to Chromatography** (5 lectures): General description, classification of chromatographic methods, chromatograms, migration rates of solutes, retention time, retention factor, selectivity factor, rate theory, kinetic variables affecting column efficiency, theory of band broadening, optimization of column performance.

2. **Liquid Chromatography (LC)**:

   (a) **Partition and adsorption in liquid chromatography** (3 lectures): Column for bonded phase, normal phase and reverse phase packing, effect of mobile phase on selectivities, applications of partition chromatography; theory, column packing and applications of adsorption chromatography.

   (b) **High performance liquid chromatography** (HPLC) (5 lectures): Scope, LC instrumentation, pumping systems, injection systems, columns for HPLC, detectors.

   (c) **Other liquid chromatography** (4 lectures): Ion-exchange equilibria, ion-exchange packing, inorganic ion chromatography (IC) and single column IC. Affinity chromatography, ion pair and chiral chromatography.

3. **Gas Chromatography (GC)** (5 lectures): Principles of gas-liquid chromatography (GLC) and gas-solid chromatography (GSC), instruments for GLC, detectors and applications.

4. **SEC, SFC, TLC and PC** (4 lectures): Theory, column packing, characteristics of mobile phases and applications of size exclusion chromatography (SEC) and supercritical fluid chromatography (SFC). Scopes, principles, preparation and characteristics of plates and papers; performance and identification methods of thin layer chromatography (TLC) and paper chromatography (PC).

5. **Capillary Electrophoresis** (4 lectures): Theory of electrophoretic migration, electroosmosis flow (EOF), instrumentation and common separation modes, e.g., CZE, MEKC; factors influencing the separation performance, applications in qualitative and quantitative analysis.

6. **Potentiometric Methods** (8 lectures): Indicator electrodes, membrane indicator electrodes; glass electrode for pH measurements, liquid membrane electrodes, solid state and precipitate electrodes, pH meters, errors affecting pH measurements with glass electrodes, direct potentiometric measurements, calibration for direct potentiometry, standard addition method, potentiometric titrations, end point determination.

7. **Voltammetry and Polarography (**8 lectures**)**: Theory of hydrodynamic voltammetry and classical polarography; measurement and applications.

Recommended Books

1. D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch: Fundamentals of Analytical Chemistry (9th Ed.)
2. D. A. Skoog, F. J. Holler and S. R. Crouch: Principles of Instrumental Analysis (6th Ed.)
3. Willard, Merritt, Dean and Settle: Instrumental Methods of Analysis (6th Ed.)

4. R. Kuhn and Hoffsterrer-Kuhn: Capillary Electrophoresis: Principles and Practice
5. David Harvey: Modern Analytical Chemistry (1st Ed.)
6. Daniel C. Harris: Quantitative Chemical Analysis (8th Ed.)
7. Allen J. Bard and Larry R. Faulkner: Electrochemical Methods: Fundamentals and Applications
8. Andr´e M. Striegel, Wallace W. Yau, Joseph J. Kirkl and Donald D. Bly: Modern Size-Exclusion Liquid Chromatography: Practice of Gel Permeation and Gel Filtration Chromatography (2nd Ed.)
9. GE Healthcare: Affinity Chromatography: Principles and Methods
10. Heinz Engelhardt: High Performance Liquid Chromatography
11. Veronika R. Meyer: Practical High-Performance Liquid Chromatography (2nd Ed.)

Course: Chem 401 LF
Chemistry Practical–IV
Full Marks: 225 (2 units, 9 credits)
Examination: 36 hours (6 days)

The relevant teacher(s) of the section shall evaluate continuously the Lab classes and submit the average marks of Lab evaluation in sealed envelope to the Chairman of the relevant Examination Committee within three weeks from the last Lab class held. The average final marks shall be computed by the Examination Committee.

The total marks for the practical course shall be obtained by adding the two marks (i) **Experiment** and (ii) **Continuous Lab Assessment**. The **examination committee** shall send a copy of the consolidated marks to the **controller of examinations**.

Section–A
Physical Chemistry Practical–IV
Examination: 12 hours (Two days)
Full Marks: 75
(i) Experiment: 52, (ii) Continuous Lab Assessment: 23

Intended Learning Outcomes (ILO)

This course includes some basic experiments on volumetry, viscometry, titrimetry, potemtiometry, conductometry and thermometry. Upon completion of the course, students will be familiar with such experimental techniques and ways of collecting, handling, statistical manipulations by linear and non-linear fitting, and systematic reporting of data. They will also be able to design new experiments based on the above-mentioned techniques.

Experiments in Physical Chemistry

1. Determination of the partial molar volume of NaCl in aqueous solution by apparent molar volume method.
2. Determination of viscosity coefficient of a liquid at different temperatures and estimation of the activation parameters of viscous flow.
3. Determination of radius of sucrose molecules from viscosity measurements.
4. Determination of the rate constant of hydrolysis of an ester catalysed by a base (NaOH).
5. Kinetic studies on iodine clock reaction.
6. Acid catalysed hydrolysis of methyl acetate at different temperatures and estimation of the activation energy for the reactions.
7. Determination of dissociation constant of acetic acid by conductometric method.

8. Construction of phase diagram of (a) phenol-toluene and (b) naphthalein-naphthol systems.
9. Verification of Beer-Lambert law and estimation of ions in a solution spectrophotometrically.
10. Determination of dissociation constant of acetic acid potentiometrically and verification of Henderson-Hasselbalch equation.
11. Setting up of a concentration cell and determination of liquid-junction potential.
12. Determination of solubility product constant of AgCl potentiometrically.
13. Determination of the solubility product constant of AgCl and $BaSO_4$ conductometrically

NB: A few more experiments, relevant to the theoretical courses shall be done, subject to the availability of the Lab. facilities.

Recommended Books

1. D. P. Shoemaker et al: Experiment in Physical Chemistry
2. G. S. Weiss et al: Experiments in General Chemistry
3. A. Findlay: Practical Physical Chemistry
4. R.C. Das: Experimental Physical Chemistry
5. J. N. Gurtu: Advanced Experimental Chemistry
6. K. K. Sharma: An Introduction of Practical Chemistry
7. J. C. Muhler et al: Introduction to Experimental Chemistry
8. J. Rose: A Textbook of Practical Physical Chemistry
9. J. B. Yadav: Advanced Practical Physical Chemistry
10. Newcomb, wilson et al: Experiments in Physical Chemistry
11. Daniels et al: Practical Physical Chemistry
12. Brennan et al: Experiments in Physical Chemistry
13. S. R. Palit: Practical Physical Chemistry
14. C. D. Hodgman et al: Handbook of Chemistry and Physics
15. R. C. West et al: CRC Handbook of Physics and Chemistry
16. L. A. Lange: Handbook of Chemistry

Section–B
Organic Chemistry Practical–IV
Examination: 12 hours (Two days)
Full Marks: 75
(i) Experiment: 52, (ii) Continuous Lab Assessment: 13,
(iii) Industrial Tour: 10

Intended Learning Outcomes (ILO)

This course would help students to become acquainted with multi-step organic syntheses and normal purification method of synthesized compound. This course would also guide students to understand the necessity of quality control in industrial processes.

Experiments in Organic and Industrial Chemistry

1. Quantitative estimation of functional groups: a) Hydroxy and phenolic groups, b) Amino groups, c) Ester groups, d) Carboxylic acid (monobasic and dibasic), e) Carbonyl groups and f) Formalin estimation.
2. Multistep organic synthesis: a) Synthesis of nitrophenols, paracetamol, b) Condensation of anthracene with maleic anhydride (preparation of Diels-Alder adduct), c) Preparation of sulphanilamide and other sulphur drugs. d) Preparation of acridone from anthranilic acids, e) Methyl orange and salicylic acid from aspirin, f) Estimation of Vit. C in tablets (some other synthesis may also be included if facilities are made available).
3. Analysis of soap (a) moisture, (b) total alkali, and (c) filling agent.
4. Analysis of industrial water effluents (total hardness, temporary and permanent hardness).
5. Analysis of soil for (a) clay, (b) silica, (c) bicarbonate, (d) different trace elements and (e) organic matters.
6. Emulsion and solution polymerization of vinyl acetate (VAc): (a) measurement of degree of polymerization (DP) by viscosity method (b) relationship of DP (only solution polymerization) and concentration of initiator.
7. Emulsion and solution polymerization of vinyl alcohol (VA): (a) measurement of DP by viscosity method (b) preparation of PVA threads (c) hot water resistance of PVA threads.
8. Ion exchange property of adsorbents like sand, charcoal etc.
9. Analysis of fertilizers (a) phosphate (b) nitrate and (c) sulphate.
10. Determination of cellulose content in the supplied pulp.
11. Determination of density, molar mass and radius of the given polymer sample.
12. Determination octane and cetane jumber of petroleum fuel.

Recommended Books

1. Shriner, Fusion and Curtin:Systematic Identification of Organic Compounds.
2. A. I. Vogel: Practical Organic Chemistry
3. Siggia: Quantitative Organic Analysis via Functional Groups
4. Fritz and Hammond: Quantitative Organic Analysis
5. K. L. Williamson: Macroscale and Microscale Organic Experiment
6. A. I. Vogel: Elementary Practical Organic Chemistry–Part I, II and III
7. J. Bassett and others: Vogel's Textbook of Quantitative Inorganic Analysis
8. Skoog and West: Fundamentals of Analytical Chemistry
9. Schwarzenbach and Flaschka: Complexometric Titrations

Section–C
Inorganic Chemistry Practical–IV
Examination: 12 hours (Two days)
Full Marks: 75
(i) Experiment: 52, (ii) Continuous Lab Assessment: 23

Intended Learning Outcomes (ILO)

The Inorganic Section of this laboratory course enables the learners to carry out the complexometric titration, experiments based on polarimetry, spectrophotometry and polarograpy, separation of metal ions by ion-exchange method, determination of stability constant of complexes and analysis of water.

Experiments in Inorganic Chemistry

1. Complexometric titrations: analysis of alloys and ores, preparation of complex salts and their complete analysis, ion exchange separation of inorganic ions containing not more than three radicals.
2. Polarimetry: Preparation of optically active inorganic compounds, measurement of their specific and molecular rotations, determination of concentration of an optically active compound.
3. Spectrophotometry: Determination of molar extinction coefficient of a complex ion, determination of concentration of metal ions in solution, study of complex formation kinetics.
4. Polarography: Determination of diffusion coefficients of ions in solution, quantitative determination of metal ions in a mixture.

5. Solvent extraction method: Separation of a) Fe^{3+} and Cu^{2+} and b) Sb^{3+} and Sb^{5+}.

6. Refractive index: Study of complex formation with compounds such as CdI_2 and KI, NaCl and KF, $FeCl_2$ and KCNS etc.

7. Determination of stability constants of the nickel(II) glycinate system.

8. Analysis of water for (a) total solids, (b) hardness: temporary-permanent, (c) chloride, (d) ammonia, (e) iron, (f) dissolved oxygen and (g) organic matter

Recommended Books

1. A.I. Vogel: A Textbook of Inorganic Quantitative Analysis
2. Alexeve: Qunatitative Chemical Analysis
3. D. A. Skoog and and F. J. Holler and D. M. West: Fundamentals of Analytical Chemistry (6th Edn)
4. Jugal Kishore Agarwal: Practicals in Engineering Chemistry
5. R. K. Das: Industrial Chemistry, part II
6. J. Bassett and others: Vogel's Textbook of Quantitative Inorganic Analysis
7. Schwarzenbach and Flaschka: Complexometric Titrations

<u>Marks Distribution for Class Attendance</u>

The Marks for Attendance shall be distributed on the basis of following table:

Attendance	Marks	Attendance	Marks	Attendance	Marks
95-100%	20%	90-<95%	18%	85-<90%	16%
80-<85%	14%	75-<80%	12%	70-<75%	10%
65-<70%	8%	60-<65%	6%	<60%	00%

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