# DEPARTMENT OF CHEMISTRY
## UNIVERSITY OF DHAKA
## DHAKA

# CURRICULUM FOR
# B.S. (HONOURS) IN CHEMISTRY

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## DEPARTMENT OF CHEMISTRY
## UNIVERSITY OF DHAKA

Under the act of 1920, the University of Dhaka opened its doors on the 1st day of July 1921. The Faculty of Science of Dhaka University initially started with only three Departments, namely Physics, Mathematics and **Chemistry**. Professor Sir J. C. Ghosh was appointed as the first Head of the Department of Chemistry in 1921.

### Vision

The Department of Chemistry aspires to be an internationally top ranking Centre of Excellence in teaching and research with a view to produce world class chemists and work force of the country with the help of innovative ideas and modern technology for ensuring highest level of confidence among chemistry graduates.

### Mission

The Department has the proactive approach to keep pace with the continuous development of chemistry, providing highest standard of teaching and introducing newer development of chemistry at regular intervals.

The Department will focus on the research facilitating access to books and journals, newer instrumental development and designing newer experiments in the field of chemistry. The graduates will have the global competitiveness with productive careers to engage in advanced studies and training at home and abroad.

Arrangements of effective industrial training of undergraduate students will be made by the Department for imparting knowledge of real application of chemistry so that they can play a leading role for the development of industry and friendly environment of the country.

### Objectives

The Department of Chemistry, University of Dhaka will attempt to achieve certain objectives.

Improvement of Teaching-Learning Objectives would be achieved by modernizing chemistry education by formulating a flexible and student-centered curricula design with interdisciplinary and multidisciplinary courses giving emphasis on the green chemistry. That would emphasize learning outcomes, competencies, facilitating lifelong learning and employability.

The academic infrastructure of the Department and quality of teaching and research will be continuously improved.

Qualified teachers of the Department of Chemistry will be encouraged to offer innovative and quality teaching and to motivate the junior teachers and students with the creation ofmodern facilities. Updating of academic programs would meet the demand of job market and increase employability of graduates.

Research activities at Graduate and Postgraduate levels will be further enhanced and Department - Industry interaction with respect to research to be established that may also create newer entrepreneurs.

For ensuring better laboratory working environment, safety and precautionary measures against health hazards, and waste disposal systems will be improved.

## B.S. (Honours) Program in Chemistry

The Guidelines for Letter Grading System for B.S. (Honours) Program in Chemistry for the Department of Chemistry under the Faculty of Science.

### 1. The B.S. (Honours) Degree Programin Chemistry

The B.S. (Honours) degree program in the Department of Chemistry under the faculty of Sciences, University of Dhaka is a 4-year program comprising of four academic sessions, each having duration of 12 calendar months to be distributed as follows:

| | |
|---|---|
| 30 weeks | For holding classes |
| 04 weeks | Preparation for examinations |
| 06 weeks | Annual examination and publications of results |
| 30 weeks | Vacation and holidays |

### 2. Definition of a Credit

The credit is defined as follows:

(i) For theoretical courses, 15 class hour of 50 minutes each = 1 credit
(ii) For practical courses, 30 hour lab work = 1 credit
(iii) The courses are offered as 4, 3 and 2 credits courses. The contact hours for the courses are as follows:

| | | |
|---|---|---|
| each 4 credits theory course | ≅ | 50-60 lectures (each 50 minutes) |
| each 3 credits theory course | ≅ | 38-45 lectures (each 50 minutes) |
| each 2 credits theory course | ≅ | 25-30 lectures (each 50 minutes) |
| each 4 credits laboratory course | ≅ | 120 hours laboratory work |
| each 2 credits laboratory course | ≅ | 60 hours laboratory work |

### 3. Credit Requirements for the 4 year B.S.(Honours) Degree in Chemistry

The total credits for the 4-year B.S. (Honours) degree in Chemistry and their distribution among theory and practical courses (Major & Minor) and assignments/oral presentations are given below;

| | | | |
|---|---|---|---|
| 80 | credits of | Chemistry theory courses | (major) |
| 30 | credits of | Chemistry laboratory courses | (major) |
| 08 | credits of | Oral /Seminar | (major) |
| 08 | credits of | Physics theory courses | (minor) |
| 02 | credits of | Physics laboratory courses | (minor) |
| 12 | credits of | Mathematics courses | (minor) |
| 140 | credits of | Major and Minor courses | |

The major courses (CH) and (CHL) will be given by the Department of Chemistry. Physics minor (PM) and Mathematics minor (MTM) courses will be given by the Departments of Physics and Mathematics respectively.

Students must participate in the co-curriculum programs in connection with gaining first-hand knowledge of industrial operations, environmental information and the like. This will be in the form of short training, visit to industrial concerns etc. as decided by Department.

**4. Grades and Grade Points**

Grades and grade points will be awarded on the basis of marks obtained in the written, oral and practical examinations according to the following scheme:

| Marks Obtained (%) | Grade | Grade Point |
|---|---|---|
| 80-100 | A+ | 4.00 |
| 75-79 | A | 3.75 |
| 70-74 | A- | 3.50 |
| 65-69 | B+ | 3.25 |
| 60-64 | B | 3.00 |
| 55-59 | B- | 2.75 |
| 50-54 | C+ | 2.50 |
| 45-49 | C | 2.25 |
| 40-44 | D | 2.00 |
| less than 40 | F | 0.00 |
| | I | Incomplete |
| | W | Withdrawn |

Only 'D' or higher grade will be counted as credits earned by a student.

**A student obtaining 'F' grade in any course (theory and practical) will not be awarded degree**. Student with **'F'** grade in any course shall be allowed to improve twice/two times only with the following batches.

**GPA:** Grade point average (GPA) is the weighted average of the grade points obtained by the students in all the courses completed by the student in a year. GPA will be calculated according to the following formula:

$$\text{GPA} = \frac{\sum(Grade\ points\ in\ a\ course \times Credits\ for\ the\ course)}{Total\ credits\ taken}$$

CGPA = Cumulative GPA for different years.

## 5. Assessment and Evaluation

The performance of a student in a given course will be evaluated in the following way:

(i) For a theory course the assessment will be made by in-course exams/assignments/performance evaluation in the class/final examinations.

(ii) The assessment of laboratory and/or field courses will be made by observing overall performance of the student at work, viva-voce, assignments and evaluation of practical reports.

At the beginning of each academic session, an examination committee is to be constituted for that session by the respective department. The examination committee will have a Chairman, two internal members and an external member. The Chairman of the Examination Committee will act as a course co-coordinator for that session.

(iii) **Third Examination:** Under double-examiner system and in case of difference of above 20% of marks, there will be a 3rd examiner. Marks of nearest two examiners (theory and thesis) will be average out as final marks.

## 6. The Distribution of Marks for a Course

It will be as follows:

**(a) Theory Course**

| | |
|---|---|
| Class attendance | 05% |
| In-course assessment | 25% |
| Course final examination | 70% |

**(b) Practical Course**

| | |
|---|---|
| Class assessment including class attendance | 40% |
| Course final examination | 60% |

**(c) Marks for Attendance**

| **Attendance (%)** | **Marks (%)** |
|---|---|
| 90 and above | 05 |
| 85 to 89 | 04 |
| 80 to 84 | 03 |
| 75 to 79 | 02 |
| 60 to 74 | 01 |
| Less than 60 | 00 |

**(d) In-course Assessment for Theory Courses**

(i) In-course assessment may be done by taking class test and/or by giving assignments.

(ii) The course teacher will announce the dates of in-course examinations at the beginning of the course. The in-course assessment will be of one hour duration and the teacher concerned will be responsible to assess the students sitting in his/her course. There will be 2 tests for 3 and 4 credit course and one for 2 credit course. For 3 and 4 credit courses average of the two should be considered to finalize the grade.

(iii) Maximum duration of in-course tests will be one class hour.

(iv) Questions for in-course tests may preferably be of multiple choice (MCQ) type. Students may also be evaluated by giving short questions as decided by the course teacher.

**Answer scripts must be shown to the students.**

(v) Course teachers must announce results in 4 weeks of holding the examination.

(vi) Marks for in-course assessment must be submitted by the course teacher to the Chairman of the Examination Committee and the Controller of Examinations before the final examination.

**(e) Course Final Examination (Theory and Practical Courses)**

(i) Students having 75% or more attendance on average (collegiate) are eligible to appear in the final examination.

(ii) Student having 60-74% attendance are considered to be non-collegiate and will be eligible to sit for the final examination on payment of fine Tk. 5,000/- (Five thousands).

(iii) Student having attendance less than 60% will not be allowed to sit for the final examination but may seek readmission in the program.

(iv) The year final examinations will be conducted centrally by the Controller of Examinations as per existing rules.

(v) The duration of theoretical course final examinations will be as follows:

| Credit | Duration of Examination |
|---|---|
| 4 credits course | 4 hours |
| 3 credits course | 3 hours |
| 2 credits course | 2.5 hours |

(vi) Duration of practical examinations will be between 4-6 hours irrespective of credit hours.

(vii) For theoretical course final examinations, there will be two examiners: course teacher will be the first examiner and the second examiner will be from within the department or from any other department of Dhaka University relevant to the subject. In case a suitable examiner is not found from Dhaka University, a teacher from outside Dhaka University may be appointed as second examiner with prior permission from the Vice-Chancellor. Evaluation will be made under the existing rules.

**7. Promotion to the Next Academic Year**

A student has to attend courses required for a particular year, appear at the annual examinations and score a minimum specified GPA/CGPA for promotion to the next year.

Promotion to the next year will be given if a student scores minimum GPA/CGPA as follows:

| | | | |
|---|---|---|---|
| 1st year to 2nd year | GPA | 2.00 | (D) |
| 2nd year to 3rd year | CGPA | 2.25 | (C) |
| 3rd year to 4th year | CGPA | 2.50 | (C) |

**8. Requirements for the Award of the B.S. (Honours) Degree**

They are as follows:

(i) Minimum number of required credits must be earned in the maximum period of six academic years starting from the date of 1st year of admission.

(ii) Must have CGPA of at least 2.5.

**9. Time Limits for Completion of Bachelor's Degree**

A student must complete the courses of his/her studies for a B.S. (Honours) degree in a maximum period of six academic years.

**10. Improvement**

(i) If a student obtains a grade C+ or lower in a course in any year, he/she will be allowed to repeat the term-final examination **only once** with the following batch for the purpose of grade improvement. A student failing to improve his/her grade in a course can retain the earlier grade.

(ii) Grade improvement will not be allowed in those courses in which a student obtains grade better than 'C+'.

(iii) A student will be allowed to repeat a maximum of 20 credits in his/her four years B.S. Program for grade improvement.

(iv) **Improvement in 4th year courses:** Students would be allowed to sit for improvement examination in the 4th year courses with the

following batch, provided they must do it before the publication of final result by the office of the Controller of Examinations or Issuance of Provisional Certificate by the Controller of Examinations.

**11. Readmission**

(i) A student can take readmission 2 (two) times throughout the program either in the same class or in different classes. In both cases, he/she must complete the degree by 6 (six) years from the time of original admission.

(ii) A student may seek readmission and continue studies as a regular student provided he/she has at least 30% attendance in the previous year.

(iii) On readmission, grades earned earlier by a student in the case of readmission shall, in general, cease to exist and the student has to retake all courses and examinations, but in case if they do not get the opportunity to repeat the courses due to late admission, marks of in-course assessment and laboratory performance/ assessments in the previous year may be retained by the students.

**12. Dean's Award**

As recognition of excellent performance the names of the students may be included in **Dean's Honor Award** or **Dean's Merit Award** in an academic year without appearing at any improvement examination.

There will be two categories of awards for graduate students:
(i) **Dean's Honor Award:** Students with **CGPA 3.85** and above.
(ii) **Dean's Merit Award:** Students with **CGPA 4.00**

**13. Departmental Award**

Financial supports are available in the form of scholarships/stipends based on the needs and academic performance.

**14. Other General Regulations**

For any matter not covered in the above guidelines, existing rules for Integrated Honours Course of Dhaka University will be applicable.

**Year-wise Distribution of Courses (Major and Minor)**

**First Year**

| Course Type | Course No. | Course Title | Credits |
|---|---|---|---|
| Major | CH 101 | Physical Chemistry I | 4 |
| | CH 121 | Organic Chemistry I | 4 |
| | CHL 122 | Organic Chemistry Laboratory I | 2 |
| | CH 141 | Principles of Inorganic Chemistry | 4 |
| | CHL 142 | Qualitative Inorganic Analysis, Inorganic Preparations and Elemental Crystal Chemistry | 4 |
| | CH 161 | Fundamental of Analytical Chemistry | 2 |
| | | Oral / Seminar | 2 |
| Major Total [Theory = 14, Lab = 6 and Oral =2] | | | 22 |
| Minor | MTM102 | Calculus I | 2 |
| | MTM103 | Analytic and Vector Geometry | 2 |
| | MTM104 | Linear Algebra | 2 |
| | PM 111 | Mechanics and Waves | 2 |
| | PM 122 | Electricity and Magnetism | 2 |
| Minor Total [Mathematics = 6 and Physics = 4] | | | 10 |
| **1st Year Total Credits [Major and Minor]** | | | **32** |

**Second Year**

| Course Type | Course No. | Course Title | Credits |
|---|---|---|---|
| Major | CH 201 | Chemical Thermodynamics | 3 |
| | CHL 202 | Physical Chemistry Laboratory I | 2 |
| | CH 203 | Electrochemistry | 3 |
| | CH 221 | Organic Chemistry II | 3 |
| | CH 222 | Stereochemistry | 3 |
| | CH 241 | Chemistry of the Representative Elements | 4 |
| | CHL 242 | Quantitative Inorganic Analysis | 4 |
| | | Oral / Seminar | 2 |
| Major Total [Theory = 16, Lab = 6 and Oral =2] | | | 24 |
| Minor | MTM203 | Ordinary Differential Equation | 2 |
| | MTM204 | Numerical Analysis | 2 |
| | MTM202* | Calculus II | 2 |
| | MTM205* | Mathematical Methods | 2 |
| | *Either MTM 202 or MTM 205 has to be taken | | |
| | PM 211 | Optics | 2 |
| | PM 223 | Electricity and Magnetism | 2 |
| | PML 204 | Physics Non-major Practical | 2 |
| Minor Total [Mathematics = 6 and Physics = 6] | | | **12** |
| **2nd Year Total Credits [Major = 24 and Minor 12]** | | | **36** |

**Third Year**

| Course Type | Course No. | Course Title | Credits |
|---|---|---|---|
| Major | CH 301 | Chemical Kinetics and Photochemistry | 3 |
| | CH 302 | Surface Chemistry, Colloid Science and Phase Equilibria | 2 |
| | CHL 303 | Physical Chemistry Laboratory II | 4 |
| | CH 321 | Organic Reaction Mechanism I | 2 |
| | CH 322 | Chemistry of Natural Products | 2 |
| | CH 323 | Bioorganic Chemistry | 2 |
| | CHL 324 | Organic Chemistry Laboratory II | 4 |
| | CH 341 | Advanced Concepts of Atomic Structure and Chemical bonding | 2 |
| | CH 342 | Transition Metals and Coordination Chemistry | 3 |
| | CHL 343 | Inorganic Synthesis and Characterization | 2 |
| | CH 361 | Instrumental Methods of Analysis | 3 |
| | CH 371 | Quantum Chemistry and Statistical Mechanics | 2 |
| | CH 381 | Chemical Spectroscopy I: Theory | 3 |
| | | Oral / Seminar | 2 |
| **3rd Year Total Credits [Theory = 24, Lab = 10 and Oral = 2]** | | | **36** |

**Fourth Year**

| Course Type | Course No. | Course Title | Credits |
|---|---|---|---|
| Major | CH 401 | Physical Properties of Polymers | 2 |
| | CH 402 | Chemistry of Solids | 2 |
| | CHL 403 | Physical Chemistry Laboratory III | 2 |
| | CH 421 | Organic Reaction Mechanism II | 4 |
| | CHL 423 | Organic Chemistry Laboratory III | 2 |
| | CH 441 | Selected Topics in Inorganic Chemistry | 3 |
| | CH 442 | Elements of Chemical Crystallography | 2 |
| | CHL 443 | Advanced Inorganic and Analytical Chemistry Laboratory | 2 |
| | CH451 | Chemical Spectroscopy II: Applications | 3 |
| | CH 461 | Organic Process Industries | 3 |
| | CH 462 | Inorganic Process Industries | 3 |
| | CHL 463 | Industrial Chemistry Laboratory | 2 |
| | CH 471 | Nuclear Chemistry | 2 |

| | | | |
|---|---|---|---|
| Major Optional Courses | *CH 481 | Environmental Chemistry | 2 |
| | *CH 482 | Applied Physical Chemistry | 2 |
| | *CH 483 | Synthetic Organic Polymers | 2 |
| | *CH 484 | Agricultural Chemistry | 2 |
| | *CH 485 | Medicinal Chemistry | 2 |
| | *CH486 | Bioinorganic Chemistry | 2 |
| | | Project (Optional)* | 2 |
| | | Oral / Seminar | 2 |
| **4th Year Total Credits [Theory = 26, Lab = 6/8, Project = 2/0, Oral = 2]** | | | **36** |

***Optional Courses:** Any one (1) of Courses CH 481 – CH 486 must be taken by the student.The student may take project (optional) in lieu of either CHL 403 or CHL423 or CHL 443.

**N.B.** : The learning objectives and learning outcomes of Mathematic minor courses (MTM 102, MTM 103, MTM 104, MTM 202, MTM 203, MTM 204 and MTM 205) are available in the parent Department.

**Detailed Syllabus for B.S. (Honours) in Chemistry**

**FIRST YEAR COURSES**

**CH 101 Physical Chemistry I (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart detailed knowledge on different states of matter and their physical properties.
(ii) Give knowledge on kinetic theory of gases and their application to ideal gases and also on deviation from ideal gas equation.
(iii) Know the properties of solution, concepts of acid, base, pH and pH scale.
(iv) Introduce concepts on chemical equilibrium, energetics in chemistry and thermochemistry.
(v) Give preliminary concepts on electrochemistry and chemical kinetics.

**Course Content**

1. **State and Properties of Matter:** Microscopic and macroscopic systems, physical properties and their classification, molar volume, refractive index and molar refraction, properties of molecules, optical activity and molecular structure, dipole moment and molecular structure, potential and kinetic energies of molecules, degrees of freedom of motion: translational, rotational and vibrational energy of systems, quantization of energy of particles, principle of equipartition of energy, intermolecular forces, states of aggregation of matter.

2. **Gaseous State:** Review of gas laws, ideal and real gases,equation of state: ideal gas equation, kinetic theory of gases: application to ideal gases, collision number, mean free path, Boltzman distribution of molecules, deviation from ideal behaviour: van der Waals equation, critical constants, principle of corresponding states.

3. **Properties of Liquids and Solutions:** Vapour pressure and its measurement, temperature variation, fractional distillation, steam distillation, surface tension of liquids, viscosity of liquids and molecular structure, solutions: Raoult's law, ideal and non-ideal solutions, temperature-composition diagram for pairs of miscible liquids, colligative properties of solutions, Nernst distribution law and its application.

4. **Energetics in Chemistry:** Observables in macroscopic systems, work and heat, internal energy, the first law of thermodynamics, state functions and exact differentials. Enthalpy, work of expansions: reversible and adiabatic expansions, Joule-Thomson effect, heat

capacities at constant pressure and constant volume, enthalpy changes in various chemical and physical processes, measurements of enthalpy changes,Hess's law and its applications, Born-Haber cycle.

5. **Chemical Equilibrium:** Equilibrium in chemical reactions and the equilibrium law, $K_p$, $K_x$ and $K_c$ and their determination, degree of dissociation, response of equilibrium to temperature, concentration and pressure changes, principle of Le Chatelier and Brown, applications, dissociation in solution, Ostwald dilution law, ionic equilibria, dissolution of solids, solubility product, common ion effect, pH, pOH and buffer solution.

6. **Electrochemical Cells:** Electrolytic and Galvanic cells, electrodes, half cell reaction, cell reaction, cell notation, reduction potentials, e.m.f. of cells, standard hydrogen electrode.

7. **Rates of Chemical Reaction:** Measurement of reaction rates, rate equation, order and rate constant, determination of order and rate constants, elementary and complex reactions, molecularity, effect of temperature on the rate of reaction, activation energy, collision theory of reaction rates, catalysis.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Distinguish among the different states of matter in terms of intermolecular force of attraction, intermolecular space and other physical properties.

(ii) Demonstrate ideal gas equation and its deviation and different units of solution and their inter-conversion.

(iii) Explain pH scale, buffer system and functioning of different types of indicators.

(iv) Describe different types of forces acting in the liquid system and reason of hydrogen bonding.

(v) Achieve fundamental concepts on electrochemistry and chemical kinetics.

**Books Recommended**


1. Physical Chemistry, P. Atkins and J. D. Paula.
2. General Chemistry, D. D. Ebbing.
3. Chemistry, S. S. Zumdahl.
4. Physical Chemistry, G. W. Castellan.
5. A Textbook of Physical Chemistry, S. Glasstone.
6. Principles of Physical Chemistry, S. H. Maron and C. F. Pruton.
7. A-level Chemistry, E.N. Ramsden.
8. Principles of Physical Chemistry, M. M. Huque and M. A. Nawab.

**CH 121 Organic Chemistry I (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart preliminary knowledge on the atomic structure, electronic configuration, bond formation of molecules, and shapes of the molecules.

(ii) Give knowledge on the energetics involved in bond formation, transition states, factors governing the rate of reactions and types of reaction.

(iii) Understand different class of organic compounds, their synthesis, nomenclature, physical and chemical properties, and their applications.

(iv) Impart knowledge on the mechanism of different types of addition, substitution, elimination reactions including their stereochemical changes.

(v) Give preliminary knowledge on detection of organic compounds by chemical test and characterization by spectroscopic techniques.

**Course Content**

1. **Basic Principles of Organic Chemistry:** Atomic structure and chemical bonding, atomic orbital, molecular orbital, shapes of molecules with reference to alkanes, alkanes, alkynes and arenes, bond angle, bond length and bond energy.

2. **Alkanes:** Structure and reactivity of aliphatic hydrocarbons, chain reaction of methane and its mechanism, carbon-carbon single bond compounds, conformation of ethane and butane, optical activity of asymmetric carbon compounds, natural gas, petroleum, gasoline, petrochemicals and petroleum fraction, octane number, antiknocking agent-TEL etc.

3. **Alkenes:** Structure and synthesis, electrophilic addition to alkenes, hydrogenation, bromination, hydrohalogenation and ozonolysis, homolytic and heterolytic addition of hydrogen halides to unsymmetrical alkenes (Markovnikov and anti Markovnikov rules) and their mechanism, reaction of alkenes with $KMnO_4$, $OsO_4^-$, peracids etc., polymers of ethane, isoprene (rubber and gutta percha), styrene, tetrafluoro ethene, vinyl chloride etc., geometrical isomerism: cis-trans, E/Z-system, determination of configuration of geometrical isomers.

4. **Dienes:** Synthesis, orbital picture of 1, 3-butadiene and cumene, isomerism of 1, 3-butadine-s-cis and s-trans, addition of halogen and hydrogen halides to, 1, 3-butadiene; 1,2 and 1, 4-addition.

5. **Alkynes:** Structure and synthesis, acidic properties of alkynes, comparison among alkanes, alkenes and alkynes.

6. **Alicyclic Compounds:** Small and normal-size rings, their formation, conformation on stability and reactions, Baeyer's strain theory, cis-trans isomerism in alicyclic system.

7. **Aromatic Hydrocarbons Arenes:** Structure and resonance of benzene, aromaticity of benzene, Huckel 4n+2 rule, source of benzene, electrophilic substitution in aromatic system-nitration, sulphonation halogenation, alkylation and acylation, aromaticity of some common heterocyclic compounds.

8. **Polyaromatic Compounds:** Nomenclature, numbering in the rings and their resonance.

9. **Halogeno Compounds:** Chemistry of alkyl-, aryl-, allyl- and vinyl halides, their synthesis and reactions, reactions of halogeno alkanes with alkali-substitution vs elimination, reactions with metals-Grignard and Wurtz reaction, halocarbons-DDT, gammexane, their uses and residual effect in the environment.

10. **Hydroxyl Compounds:** Alcohols and phenols, their synthesis and reactions, hybridization of oxygen in alcohols and phenols, hydrogen bonding, resonance, acidity and reactivity of phenols, comparison between alcohols and phenols.

11. **Ethers and Epoxides:** A brief description of synthesis and reaction of ethers and epoxides.

12. **Carbonyl Compounds:** Synthesis and reactions of aldehydes and ketones, orbital picture, hybridization of carbonyl carbon and carbonyl oxygen, nucleophilic reactions, oxidation and reduction, relative reactivity of carbonyl compounds.

13. **Carboxylic Acids:** Orbital picture, hydrogen bonging, synthesis and manufacture of methanoic, ethanoic, ethanedioic and butane-1,4-, dioic acids, preparation of acid halides, acid anhydrides and amides, relative reactivity of carboxylic acid derivatives.

14. **Spectroscopic Methods:** A very brief treatment of spectroscopic methods- UV, IR NMR and Mass spectroscopy, their application in organic chemistry with reference to identification of organic compounds.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand the knowledge on bonding, shapes of organic molecules and their reactivity.

(ii) Demonstrate on different class of organic compounds, their synthesis, systematic naming, physical chemical properties and their applications.

(iii) Explain on the mechanism of different types of addition, substitution, elimination reactions including their stereochemical changes.
(iv) Detect different class of organic compounds by chemical test and their characterization by spectroscopic techniques.

**Book Recommended**

1. Organic Chemistry, T. Morrison and R. N. Boyd; Problems and their Solution in Organic Chemistry.
2. Organic Chemistry, S. H. Pine,J. B. Hendrickson, D. J. Cram and G. S. Hammond.
3. Organic Chemistry (Vol. 1 and 2), I. L. Finar; Problems and Their Solution in Organic Chemistry.
4. Fundamentals of Organic Chemistry, T. W. G. Solomons.
5. Introduction to Organic Chemistry, A. Jr. Streitwieser and C. H. Heathcock.
6. Advanced Organic Chemistry (Bengali), M. U. Ahmed.

**CH141 Principle of Inorganic Chemistry (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to
(i) Provide fundamental knowledge on development of different theories of atomic structures over time period, electronic configurations and related principle and rules.
(ii) Give knowledge on periodic classification and variation of different properties of elements along the periods and down the groups.
(iii) Impart knowledge on different types and theories of bonding, Born-Haber cycle, Fajan's rule and different shapes of molecules.
(iv) Acquaint with the basic rules of nomenclature of inorganic compounds, types of solids and different types of chemical reactions.
(v) Give fundamental concepts on different terms, theories and definitions for enabling learners to understand inorganic chemistry on advanced level.

**Course Content**

**1. Atomic Structure:** Atomic nucleus, fundamental particles, nuclear forces, nuclear binding energy, nuclear stability, radioactivity, isotopes, mass spectrometry, cathode rays, mass and charge of an electron, $\alpha$-particle scattering, Rutherford atom model, Planck's quantum theory, Bohr's theory for hydrogen atom, electromagnetic radiation, absorption and emission spectra, ionization energy from absorption spectrum, emission spectrometer, emission spectrum of atomic hydrogen, dual behaviour of electron, de Broglie equation, Heisenberg's uncertainty principle, quantum mechanics, Schrödinger wave equation for

hydrogen atom, wave function and its significance, quantum numbers, atomic orbitals and their energies, shapes and orientation, Pauli exclusion principle, Aufbau principle, Hund's rule, electronic configurations.

2. **Periodic Classification:** Periodic law, periodic table, prediction of elements, elements in groups, periods and blocks, naming of all elements, electronic configuration of groups and periods, metals, nonmetals and metalloids, diagonal relationship, periodicity of atomic and molecular properties e.g. ionization energy, electron affinity, electronegativity, atomic/ionic radii, metallic character, melting and boiling points, lattice energy etc., properties of main group elements, usefulness and limitation of periodic table.

3. **Chemical Bonds:** Chemical bond, types of chemical bonds, ionic bond: energetics of ionic bond formation, properties of ionic compounds, factors influencing the formation of ionic bond, radius ratio rule, Born-Haber cycle, Fajan's rule; covalent bond: sigma and pi bond, properties associated with covalent compounds, limitation of covalency, polar covalent bond, Lewis formulation, formal charge, valence shell electron pair repulsion (VSEPR) theory and molecular geometry, valence bond theory, energy change during formation of molecules, hybridization of bond orbitals, molecular orbital theory, bonding and antibonding orbitals and their significance, bond order, stability of molecules, MO diagram of simple diatomic $H_2$ to $Ne_2$ molecules, coordination bond, metallic bond, hydrogen bond, van der Waal's forces.

4. **Inorganic Nomenclature:** Prefixes and affixes used in inorganic nomenclature, use of enclosing marks, numbers, letters, and italic letters, names for cations, anions, radicals and heteropolyanions, names of acids, salts, and salt like compounds.

5. **Solids:** Types of solids, characteristics of crystalline and amorphous solids, unit cell, crystal lattice, seven crystal systems, crystal defects, description of NaCl, CsCl, graphite, diamond and ice structures.

6. **Acids and Bases:** Various concepts on acids and bases, conjugate acids and bases, neutralization reactions, acid - base strength, hard and soft acids and bases, hard and soft acids and bases in qualitative analysis, acid - base properties of oxides, hydroxides and salts, effect of structures on acid - base properties.

7. **Types of Reactions:** Oxidation - reduction reactions, oxidizing and reducing agents, assigning oxidation states to bounded atoms, redox half reactions, rules for balancing redox reactions, Ellingham diagram, Latimer diagram, and Frost diagram, standard reduction potential, the electrochemical series, disproportionate reactions, double

decomposition reactions, Metathetic or precipitation reactions and solubility product principle, common ion effect, acid - base reactions, substitution reactions, condensation reactions, addition reaction, elimination reactions, isomerization reaction, polymerization reactions, nuclear reactions, nuclear disintegration.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand the nuclear and extra-nuclear structure of atom and their periodic classification.
(ii) Describe the nature of the bonding in molecular compounds and how the shapes of molecules and polyatomic ions are determined.
(iii) Identify different types of chemical reactions, e.g. acid/base reactions, redox reactions, precipitation reactions, etc.
(iv) Explore the properties of crystalline and amorphous solids, defect solids, etc.
(v) Learn how to apply different concepts and principles of inorganic chemistry to other branch of chemistry.

**Books Recommended**


1. General Chemistry, D. D. Ebbing and S. D. Gammon.
2. Introduction to Modern Inorganic Chemistry, S. Z. Haider.
3. Inorganic Chemistry, D. F. Shriver and P. W. Atkins.
4. General Chemistry, P. W. Atkins and J. A. Beran.
5. Chemistry – The Molecular Nature of Matter and Change, M. Silberberg.
6. Chemistry, S. S. Zumdahl.
7. Chemistry, J. McMurry and R. A. Pribush.
8. General Chemistry, J. B. Russel.
9. Basic Inorganic Chemistry, F. A. Cotton, G. Wilkinson and P. L. Gaus.
10. Inorganic Chemistry, A. G. Sharp.
11. Introduction to Inorganic Chemistry, G. I. Brown.
12. Principles of Descriptive Inorganic Chemistry, G. Wulfsberg.
13. Inorganic Chemistry, G. L. Miessler and D. A. Tarr.


**CH161 Fundamentals of Analytical Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart classical and modern concepts of analytical detection, separation and quantification mainly based on the sensitivity and selectivity of different chemical reactions.

(ii) Impart knowledge on sampling and dealing with the sample for analysis, data presentation, significant figure convention and errors in the quantitative analysis.
(iii) Deal with the knowledge of chemical separation and their application for quantitative determination by both gravimetric and solvent extraction methods.
(iv) Understand the knowledge of application of different types of reactions such as acid-base reaction, redox reaction, complexation reaction for the quantitative estimation of various species.
(v) Give knowledge on a simple spectrophotometer and its use for quantitative determination.

**Course Content**

1. **Basic Concepts in Analytical Chemistry:** Classical and modern concepts of analytical detection and quantification, sensitivity, selectivity, specificity, concentration limit, dilution limit etc. of chemical reactions, sample containers, sample preservation, sampling, sample dissolution, wet ashing and dry ashing, reagents and reactions, group separation, elemental analysis, and analysis of insoluble materials, precision and accuracy, mean and median, types of errors, significant figure convention.

2. **Acid-Base Reactions:** Acid-base equilibria and buffers in analytical chemistry, indicators, titrations of acid-base, titration in non-aqueous solvents - solvent choice and advantages.

3. **Redox Reactions:** Oxidation-reduction equilibria in chemical analysis, redox titration curve, indicators for oxidation-reduction titrations, $KMnO_4$ as a standard oxidants, titrations with $K_2Cr_2O_7$ and cerium (IV), redox titrations involving iodine, iodometric and iodimetric methods.

4. **Complexation in Quantitative Analysis:** Complexation of metal ions, complexation equilibria, influence of $[H^+]$ on complexation, metal chelate stability, titration with chelating agent such as EDTA, NTA etc., metallochromic indicators, colour transition with metallochromic indicators, masking and demasking, uses of EDTA titrations.

5. **Solvent Extraction in Analytical Chemistry:** Separation processes, liquid-liquid extraction, distribution of solute between solvent pair, effect of number of extractions, batch and continuous extractions, some examples of liquid-liquid extraction.

6. **Gravimetric Methods of Analysis:** Principle of gravimetric method, properties of precipitates and precipitating agents, coagulation and peptization of precipitates, treatment of colloidal precipitates, co-

precipitation and post precipitation, drying and ignition of precipitates, results and calculation.

7. **Spectrophotometric Analysis:** Ultraviolet and visible radiation, absorbance, transmittance, absorptivity, the Beer-Lambert's law, limitations of Beer-Lambert's law, wavelength selection, basic components of a spectrophotometer, qualitative and quantitative analysis, stoichiometric determination of metal-ligand complexes, derivative spectrophotometry.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Collect representative sample and preserve for analysis.
(ii) Represent analytical data as per convention.
(iii) Choose proper method for the quantitative estimation by applying straight forward classical titrimetric methods or eliminating the interferences either by separation or suppressing.
(iv) Analyze various chemical and environmental samples either by using classical chemical methods or by spectrophotometric method.

**Books Recommended**


1. Quantitative Chemical Analysis, S. E. Manahan.
2. Modern Methods of Chemical Analysis, R. L. Pecsok, L. D. Shields, T. Cairns and L. G. McWilliam.
3. Fundamentals of Analytical Chemistry, D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch.
4. Analytical Chemistry, G. D. Christian.
5. Modern Analytical Chemistry, D. Harvey.
6. Analytical Chemistry Principles, J. H. Kennedy.
7. A Textbook of Macro and Semimicro Qualitative Inorganic Analysis, A. I. Vogel.
8. Instrumental Analysis, H. H. Bauer, G. D. Christian and J. E. O'Reilly.


**CHL122Organic Chemistry Laboratory I (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart fundamental knowledge on dealing with the organic compounds such as purification by different techniques, drying, preservation etc.
(ii) Acquaint with the practical knowledge of recording melting point, mixed melting point, boiling point etc.
(iii) Understand the preparation of different organic compounds or conversion of one compound to the other by adopting different reactions.

(iv) Give knowledge on separation and purification by solvent extraction and fractional distillation.

**Course Content**

**Simple laboratory techniques and their uses in synthesis**

**1.** Drying and storage of organic compounds.

**2.** Determination of melting temperature and mixed melting temperature melting temperature curve.

**3.** Purification of organic compounds by recrystallization.

**4.** Determination of boiling temperature.

**5.** Purification by distillation. Azeotropic distillation of mixtures of alcohol and water.

**6.** Separation of organic compounds by solvent extraction.

**7.** Preparation of alkene: Cyclohexene from cyclohexanol.

**8.** Preparation of alkyl halide: t-Butyl chloride from t-butyl alcohol.

**9.** Preparation of alcohol: t-Butyl alcohol from t-butyl chloride.

**10.** Oxidation of hydrocarbons: Benzoic acid from toluene.

**11.** Oxidation of alkene: Adipic acid from cyclohexene.

**12.** Oxidation of alcohol: Cyclohexanone from cyclohexanol.

**13.** Acetylation: Acetylation of aniline and salicylic acid.

**14.** Bromination of phenylamine/phenol, isolation and purification of bromo derivatives.

**15.** Addition reactions to carbon-carbon double bonds: halogenation of cinnamaldehyde/cinnamic acids.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Handle simple glass apparatus and instrument safely.

(ii) Separate and purify organic compounds by recrystallization, solvent extraction or fractional distillation and properly preserve them.

(iii) Preparedifferent organic compounds or convert one compound to the other by adopting different reaction routes.

(iv) Verify purity of the compounds by recording melting or boiling temperature.

**Books Recommended**


1. Unitized Experiments in Organic Chemistry, R. Q. Brewster, C. A. Vanderwerf and W. E. McEwen.
2. A Textbook of Practical Organic Chemistry, A. I. Vogel.
3. A Handbook of Organic Analysis, H. T. Clarke.
4. The Systematic Identification of Organic Compounds, R. L. Shriner, C. K. F. Hermann, T. C. Morrill, D. Y. Curtin and R. C. Fuson.


**CHL142Qualitative Inorganic Analysis, Inorganic Preparations and Elemental Crystal Chemistry (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Discuss about safety rules and safety in the laboratory.

(ii) Demonstrate an understanding on handling solids, handling liquids, carrying out stoichiometric calculations, and performing standard laboratory procedures like weighing, qualitative and quantitative liquid transfer, gravity filtration, recrystallization, volume reduction, and the determination of melting point/decomposition temperature.

(iii) Give knowledge on simple inorganic preparation, purification and identification.

(iv) Provide students with the knowledge of seven crystal system.

(v) Identification of different cations and anions in inorganic salt by systematic semi-micro qualitative inorganic analysis.

**Course Content**

1. **Safety:** The twelve rules of safety, safety in the laboratory.

2. **Preparation and Purification of Inorganic Compounds:**
   (i) Purification of commercial NaCl by recrystallization and salting out processes.
   (ii) Preparation of ferrous sulphate $FeSO_4.7H_2O$, Mohr's salt $[FeSO_4.(NH_4)_2SO_4.6H_2O]$, potash alum $[K_2SO_4.Al_2(SO_4)_3.24H_2O]$, chrome alum $[K_2SO_4.Cr_2(SO_4)_3.24H_2O]$, sodium carbonate $Na_2CO_3$, sodium cobaltinitrite $Na_3[Co(NO_2)_6]$.

3. **Model Making:** Seven crystal systems model.

4. **Systematic Semimicro Qualitative Analysis of Inorganic Salts:** Qualitative analysis of known and unknown admixtures of inorganic salts consisting of up to five different radicals. This analysis includes: preparation of salt solution,techniques of dry tests of radicals, group separation and confirmation of radicals, removal of interfering radicals, use of solubility product principle and salting effect in analysis, treatment of insoluble substances, etc.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Realize the importance of laboratory safety and be thoughtful about setting up the safety expectations.
(ii) Acquire and/or improve skills in planning for an effective laboratory session.
(iii) Prepare common inorganic compounds and identify their basic constituents.
(iv) Learn to make models on seven crystal systems.
(v) Know how to apply the qualitative semi-micro analysis to identify the cations and anions present in a mixture of inorganic salts.

**Books Recommended**

1. A Textbook of Macro and Semimicro Qualitative Inorganic Analysis, A. I. Vogel.
2. Semimicro Qualitative Analysis, F. J. Welcher and R. B. Hahn.
3. Qualitative Analysis, V. Alexeyev.

**PM 111 Mechanics and Waves (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Make the students to understand the basic addition, subtraction and multiplication rules of vectors.
(ii) Give knowledge on the physical significance of advanced vector analysis along with their applications.
(iii) Prepare the students for solving different problems related to Newton's laws of motion and conservation of energy.
(iv) Inform about different phenomenon of simple harmonic motion.
(v) Impart knowledge related to rotational motion.

**Course Content**

**1.** **Vectors:** Addition and Subtraction. Unit Vectors. Scalar and Vector Products.Scalar Triple Product. Vector Triple Product. Scalar and VectorFields. Gradient, Divergence and Curl. Greens theorem, Gauss andStoke's Theorems. Curvilinear coordinates.

**2.** **Particle Dynamics:** Motion in One Dimension, Motion in Two and Three Dimension, Application of Newton's Law, Conservation of Linear Momentum, Work and Energy. Conservation Laws. Conservative Force.

3. **Simple Harmonic Motion:** Definition. Combination of Two SHM's. Lissajou's Figures. Damped SHM. Forced Oscillation. Resonance. Power and Intensity of Wave Motion, Principle of Superpositoin.

4. **Wave in Elastic Media:** Longitudinal vibration. Vibration of Strings. Beats. Doppler Effect.

5. **Rotational Motion:** Toque, Neowton's Law of Rotation, Moment of Intertiaof Various Soid Bodies, Parallel Axis Theorem Radius of Gyration. Angular Momentum, Kater's Pendulum.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Apply different vector rules in calculating problems and learn about the physical significance and application of vector related theorems.
(ii) Explain harmonic motion and mechanism of developing Lissajou's figure changing phase difference between two waves.
(iii) Set up differential equations for damped SHM, forced oscillation and find out their solutions with graphical interpretations with clear idea about underdamp, critically damp, overdamp and resonance.
(iv) Deduce expressions for power and intensity of wave motion.
(v) Understand how the resonance produced in a stretched vibrating string and the mechanism of producing beats and Doppler effect.

**Books Recommended**


1. Physics, R. Resnick and D. Halliday.
2. Gases, Liquids and Solids, D. Tabor.
3. The Mechanical Properties of Matter, M.T. Sprackling.
4. The General Properties of Matter, F.W. Newman and V.H. L. Searle.
5. Properties of Matter, S. Ahmed and A.K. Nath.


**PM 122 Electricity and Magnetism (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Make students to understand electric field produced by a static change as well as by an electric dipole and to understand the Gauss's law for static charge in vacuum and as well as in dielectric medium.
(ii) Inform the need of electric images and Gauss's law for magnetism and magnetic energy.
(iii) Give knowledge on electromotive force - electrical circuital laws,the magnetic field produced by direct current and the laws related to direct current carrying wire and their applications.
(iv) Acquaint with the electromagnetic induction and its applications.

(v) Explain the mechanism of producing alternating current and its related properties and applications.

**Course Content**

1. **Electrostatics:** Electric Intensity and Potential. Gauss's Law. Electric Dipole. Density of Charge in a Polarized Dielectric. Gauss's Law for charges in a Dielectric. Capacitance Co-efficient of Potential, Capacitance and Induction Energy of Charged Systems. Electrical Images.
2. **Magnetostatics:**Gauss's Law. Magnetic Dipole. Energy in a Magnetic Field.
3. **Direct Current:** Current and Electromotive Force. Ohm's Law. Combination of Resistances and Kirchhoff's Law's Wheatstone Bridge.
4. **Magnetic Field of a Current and Ampere's Law:** Biot-Savart Law. Magnetic Fields of Simple Circuits. Galvanometers. Lorents Force. CRT.
5. **Electromagnetic Induction:** Faraday's Law. Self-Inductance. Mutual Inductance.
6. **Alternating Current:** Generation of AC. RMS Value. Power Factor. CR and LR Circuits. Gain, Decible.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Calculate the electric field intensity and potential produced by a point charge and by an electric dipole and also enable to apply the Gauss's law for static electricity in different situations in vacuum as well as in dielectric medium.
(ii) Understand the Gauss's Law for magnetism and the concept of non-existence of magnetic monopole and acquire knowledge about the energy in magnetic field.
(iii) Solve different problems related to Ohm's law and Kirchhoff's circuital laws and understand the balance condition of Wheatstone bridge and problems related to the magnetic field produced by a current and its role in making galvanometer and function of a CRT.
(iv) Understand how induced current is produced by changing magnetic field in a circuit.
(v) Understand the self and mutual induction in coils and can explain the operation of motor and generator and calculate the RMS value and power factor of alternating current.

**Books Recommended**

1. Physics, R. Resnick and D. Halliday.
2. Principles of Electricity, L. Page and N. L. Adams.
3. Electricity and Magnetism, S. G. Starling.
4. Electromagnetic Fields and Waves, P. Lorrain and D. Corson.
5. Bidyat O Chumbak, A. M. Harun ar Rashid.
6. Fundations of Electromagnetic Theory, J. R. Reitz, F. J. Milford and R.W. Christy.
7. Concepts of Electricity and Magnetism, M. S. Huq, A.K. Rafiqullah and A.K.Roy.

**MTM 102 Calculus I(2 Credits)**

**Course Content**

**A. Differential Calculus**

**1.** Functions and their graphs (polynomial and rational functions, logarithmic and exponential functions, trigonometric functions and their inverses, hyperbolic functions and their inverses, combination of such functions). Limits of Functions: definition. Basic limit theorems (without proofs). Limit at infinity and infinite limits. Continuous functions. Properties Continuous functions on closed and boundary intervals (no proofs required).

**2.** **Differentiation:** Tangent lines and rates of change. Definition of derivative. One-sided derivatives. Rules of differentiation (with applications). Linear approximations and differentials. Successive differentiation. Leibnitz theorem. Rolle's Theorem: Lagrange's mean value theorems. Extrema of functions, problems involving maxima and minima.

**B. Integral Calculus**

**1.** **Integrals:** Antiderivatives and indefinite integrals. Techniques of integration. Definite integration using antiderivatives.

**2.** Definite integral as a limit of a sum. The fundamental theorem of calculus. Integration by reduction.

**3.** **Application of Integration:** Plane areas. Solids of revolution. Volumes by cylindrical shells. Volumes by cross-sections. Arc length and surface of revolution.

**Books Recommended**

1. Calculus with Analytic Geometry, H. Anton.

2. Calculus with Analytic Geometry,E.W. Swokowski.
3. Calculus, L. Bers and P. Karal.
4. A First Course in Calculus, S. Lang.

**MTM 103 Analytic and Vector Geometry (2 Credits)**

**Course Content**

***Two Dimensional Geometry***

**1.** Coordinates in two dimensions. Transformations of coordinates.

**2.** Reduction of second degree equations to standard forms. Pairs of straight lines. Identifications of conics. Equations of conics in polar coordinates.

***Three-Dimensional Geometry***

**3.** Coordinates in three dimensions. Direction cosines, and direction ratios.

**4.** Planes, straight lines and conicoids (basic definitions and properties only).

***Vector Geometry***

**5.** Vectors in plane and space. Algebra of vectors. Scalar and vector products. Triple scalar products. Applications to Geometry.

**Books Recommended**

1. Analytic Geometry and Vector Analysis,A.F.M. Abdur Rahman and P.K. Bhattacharjee.
2. Analytic Geometry and Vector Analysis, K. Mohammad.
3. Vector Geometry,J. A. Hummel.

**MTM 104 Linear Algebra (2 Credits)**

**Course Content**

**1.** **Matrices and Determinants:**Notion of matrix. Types of matrices. Matrix operations, laws of matrix Algebra. Determinant function. Properties of determinants. Minors, Cofactors, expansion and evaluation of determinants. Elementary row and column operations and row-reduced echelon matrices. Invertible matrices. Block matrices.

**2.** **System of Linear Equations:**Linear equations. System of linear equations (homogeneous and non-homogeneous)and their solutions. Application of matrices and determinants for solving system of linear equations.

3. **Vector Spaces:**Vectors in $R^n$ and $C^n$ -Review of geometric vectors in $R^2$ and $R^3$ space. Vectors in $R^n$ and $C^n$. Inner product. Norm and distance in $R^n$ and $C^n$. Abstract vector space over R and C. Subspace. Sum and direct sum of sub spaces. Linear independence of vectors; basis and dimension of vector spaces. Row and column space of a matrix; rank of matrices. Solution spaces of systems of linear equation.

4. Linear transformations. Kernel and image of a linear transformation and their properties. Matrix representation of linear transformations. Change of bases.

5. Eigenvalues and eigenvectors. Diagonalization. Cayley Hamiton theorem. Applications.

**Books Recommended**


1. Linear Algebra with Applications,H. Anton and C.Rorres, 7th edition.
2. Linear Algebra, S. Lipshutz, Schaum's Outline Series.
3. Linear Algebra,W. Greub.


## SECOND YEAR COURSES

### CH 201 Chemical Thermodynamics (3 Credits)

**Learning Objectives**

The learning objectives of this course are to

(i) Impart knowledge on laws of thermodynamics, criteria and extent of conversion of heat into work and vice versa.
(ii) Acquaint with the thermodynamic functions, such as enthalpy, entropy, Helmholtz work function, Gibb's free energy etc.
(iii) Give knowledge on the derivation of thermodynamic equations involving colligative properties.
(iv) Introduce preliminary concepts on the phase rule and phase equilibria.

**Course Content**

1. **Thermodynamics:** Review of the first law of thermodynamics, temperature dependence of enthalpy, the concept of the second law of thermodynamics,the direction of spontaneous change, dispersal of energy, heat engines, Carnot cycle, search for a state function, entropy, Clausius inequality, changes in U, H, and S with T and P, criterion for equilibrium in closed systems, Helmholtz and Gibbs functions, heat engines, refrigerator and heat pumps, properties of exact differentials, chain rule, Maxwell's relations: reversible, irreversible, adiabatic and isothermal process, general expression for Cp-Cv, Joule-Thomson expansion: inversion temperature, thermodynamic derivation,

experimental determination of Joule-Thomson coefficient, internal pressure, temperature and pressure dependence of Gibb's function, chemical potential and fugacity, Euler's theorem, partial molar quantities and their determinations, Gibb's-Duhem equation, thermodynamics of mixing, chemical potential in mixtures.

2. **Third Law of Thermodynamics:** Nernst heat theorem, statement of the third law, absolute entropy, applications and limitations of third law.

3. **Phase Equilibrium:** Phase, component and degrees of freedom, phase Rule, thermodynamic interpretation of phase diagram of water, thermodynamics of phase change, Clapeyron and Clausius-Clapeyron equations, thermodynamic derivation of colligative properties: depression of freezing point, elevation of boiling point and osmotic pressure.

4. **Chemical Equilibrium:** Extent of reaction, reactions and the Gibb's function, the equilibrium law, thermodynamic equilibrium constant, equilibrium constant from thermal data, exergonic and endergonic reactions, coupled reactions, feasibility of reactions, Ellingham's diagram, thermodynamics of ATP, biological energy conversion-synthesis of proteins and the oxidation of glucose.

5. **Applications of Thermodynamic Principles:** Energy conversion, efficiencies of power plants: possibilities and limitations of the heat engine, energy balance in a closed system, energy balance in a reacting system, fuels and combustion, adiabatic flame temperature, ignition, flash point.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Explain the successes and limitations of laws of thermodynamics.
(ii) Demonstrate the significance of thermodynamic parameters and their sign and magnitude.
(iii) Find out the criteria of conversion of energy into work and the extent of conversion.
(iv) Predict the feasibility of physical and chemical changes in terms of thermodynamic functions.
(v) Determine thermodynamic parameters of physical or chemical changes applying thermodynamic principles.

**Books Recommended**

1. Physical Chemistry, P. Atkins and J. de Paula.
2. Physical Chemistry, G. W. Castellan.

3. Chemical Thermodynamics:Basic Concepts and Methods, R. M. Rosenberg and I. M. Klotz.
4. Thermodynamics for the Chemists, S. Glasstone.
5. Physical Chemistry, G. M. Barrow.
6. Physical Chemistry, R. A. Alberty.
7. Elementary Principles of Chemical Processes, R. M. Felder and R.W. Rousseau.
8. Physical Chemistry, R. J. Silbey, R. A. Alberty and M. G. Bawendi.

**CH 203 Electrochemistry (3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Provide basic concept of electrolytes, conductance in detail and conductance behavior of weak and strong electrolytes.
(ii) Give concepts on acid base equilibria, buffer preparation, and theories of indicators.
(iii) Acquaint with the advanced idea on galvanic cells, cell reactions, electrode processes and electrical double layer.
(iv) Provide idea on the analytical applications of galvanic cells and industrial applications of electrochemical processes.

**Course Content**

1. **Conductance:** Concept of weak and strong electrolytes. Specific conductance ($\kappa$) and molar conductance ($\lambda$) and their measurements, variation of $\kappa$ and $\lambda$ with the concentration of weak and strong electrolytes, Kohlrausch's law of independent ion migration and its application, transport number and its determination, factors affecting transport number, applications of conductance in kinetic measurements, acid-base titrations, precipitation titration, determination of the solubility of sparingly soluble salts, water quality index, etc., impact of conductance on biochemistry, ion channels and ion pumps.

2. **Acid-base Equilibria:** pH of weak acid and weak base solutions, Henderson-Hasselbalch equation, indicators, $pK_a$ of an indicator, pH range of an indicator, theories of acid-base indicator, buffer mechanism, buffer capacity, salt hydrolysis.

3. **Theories of Electrolytes:** Theories of strong electrolytes: Debye-Hückel limiting law and its test, determination of activity co-efficient, Debye-Hückel-Onsagar equation: limitations and applications.

4. **Galvanic Cells:** Galvanic cells, half cells, electrode potentials, e.m.f. of cells, Nernst equation, different types of electrodes: standard hydrogen electrode, secondary reference electrodes, concentration

cells, measurement of e.m.f. of a cell: compensation method: use of high impedance voltmeters, measurements of electrode potentials, cell reactions, half cell reactions, thermodynamic functions from e.m.f. measurements: standard free energy changes, equilibrium constants, activities, quinhydrone and hydrogen ion selective electrodes.

5. **Applications of Galvanic Cells:** Analytical applications: e. m. f. measurements: feasibility of a reaction, potentiometric titration, ion selective electrodes for analytical purposes, pH titration, electro-gravimetry, rechargeable battery: dry cell and fuel cell, solar cells, photoelectrochemical generation of hydrogen from water.

6. **Electrode Processes:** Polarization: concentration polarization, activation polarization and Ohmic polarization. Polarography and voltammetry.

7. **Industrial Applications of Electrochemistry:** Chloro-alkali industries, electrometallurgy,electrochemical treatment of industrial effluents.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Describe the behavior of weak and strong electrolytes, conductance related various terms, Kohlrausch's law of independent ionic migration and its applications.

(ii) Achieve knowledge on acid base equilibria, pH, pKa, pKb, pKw, pH range of an indicator, theories of acid base indicators, buffer solutions and their functions.

(iii) Demonstrate knowledge on different types of cells and their reactions, different types of electrodes and Nernst equation.

(iv) Explain theories of electrolytes, activity, activity coefficients, Debye-Huckel limiting law and its test, Debye-Huckel-Onsagar equation: limitations and applications

(v) Measure the e.m.f. of a cell and thermodynamic functions and use of ion selective electrodes.

**Books Recommended**

1. Physical Chemistry, P. Atkins and J. D. Paula.
2. Physical Chemistry, G. W. Castellan.
3. Physical Chemistry, G. M. Barrow.
4. Physical Chemistry, R. A. Alberty.
8. An Introduction to Electrochemistry, S. Glasstone.

**CH 221Organic Chemistry II (3 Credits)**

**Learning Objectives**

The learning objectives of the course are to

(i) Give fundamental idea about organic compounds containing carbon-nitrogen bond, their preparations and properties.
(ii) Provide knowledge on organo-sulphur and organo-phosphrous compounds.
(iii) Acquaint with the basic idea about preparation, properties and applications of organometallic and heterocyclic compounds.
(iv) Impart knowledge on the various classes of dyes.

**Course Content**

1. **Nitro and Nitroso Compounds:** Synthesis, resonance, reactivity and reactions of aliphatic and aromatic nitro and nitroso compounds. Reduction of nitro compounds.

2. **Amino Compounds:** Synthesis, physical and chemical properties of amino compounds, basicity of amines, reactions of amino compounds, diazonium, azo and hydrazo compounds, uses with special emphasis on synthetic utility of diazonium compounds, separations of primary, secondary and tertiary aliphatic amines, quaternary compounds and N-oxides, oxidation of amines, optical activity of quaternary nitrogen containing compounds, azides, enamines.

3. **Other Compounds Containing Carbon-Nitrogen Bond:** Structure, shape, synthesis, physical and chemical properties of nitriles, isonitriles, thiocyanates, carbamates and ureas, imines and oximes and related compounds.

4. **Organo-Sulphur and Organo-Phosphorus Compounds:**Structure, shape, synthesis, physical and chemical properties of thiols, alkyl-, dialkyl-, alkylaryl phosphines and sulphides, phosphonium salts, alkyl and aryl thioacids, alkyl and aryl sulphonic acids, sulphonates and sulphamic acid, optical activity of phosphorus and sulphur compounds.

5. **Organometallic Compounds and Their Uses in Organic Synthesis:** Synthesis of organometallic compounds containing lithium, magnesium, copper, cadmium, zinc and their synthetic utility.

6. **Heterocyclic Compounds:** Synthesis, structure, physical and chemical properties of heterocyclic compounds: pyridine, pyrrole, furan, thiophane, quinoline and isoquinoline, heterocyclic systems containing both N and S and both N and O: a few examples and their chemistry.

7. **Dyes:** Theory of colour and constitution, classification of dyes and synthesis of some typical dyes: methyl orange, Congo red, Malachite

green, crystal violet, indigo, Rosaline, phenolphthalein, rhodamine B, alizarin and thymol Blue.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand and comprehend the preparation, properties and applications of nitrogen, sulphur and phosphorous containing organic compounds.
(ii) Demonstrate the synthesis of various organometallic compounds and their different applications.
(iii) Explain synthesis, structure, physical and chemical properties of heterocyclic compounds.
(iv) Understand the theory of colour and constitution of different classes of dyes and will be able to outline their synthesis.

**Books Recommended**

1. Organic Chemistry, T. W. G. Solomons, C. B. Fryhle and S. A. Snyder.
2. Principles of Organic Synthesis, R. O. C. Norman.
3. Organic Chemistry,I. L. Finar,Vol. 2.

**CH 222 Stereochemistry (3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Give fundamental knowledge on organic compounds having identical functional groups but with different three dimensional arrangements of atoms i.e. stereoisomers and stereo-chemical representation of their structures by different conventions or projection rules.
(ii) Impart knowledge on optical activity, origin of optical activity,optical isomerism and related terms.
(iii) Demonstrate the existence of geometrical isomers in different double bond containing systems and cyclic compounds and their representation by cis-*trans*, *syn-anti*, *E/Z* system and also their variation in physical properties.
(iv) Give knowledge on conformation, conformational analysis, configurations and their correlation.
(v) Impart knowledge on the stereochemistry of the fused-ring and bicyclic systems.

**Course Content**

1. **Fundamentals of Stereochemistry:** Stereochemistry and stereoisomerism, stereochemical representation of structures (Fischer projection, Newman, Sawhorse, conversion among these forms).

2. **Optical Activity and Optical Isomerism:** Cause of optical activity, chirality (asymmetry and dissymmetry), symmetry elements, optical isomerism, diastereoisomers, enantiomers, epimers, anomers, meso- and racemic compounds, racemic modifications and their resolution, atropisomerism: biphenyls, allenes and spirans.

3. **Geometrical Isomerism:** Conditions, configurations of geometrical isomers- *cis-trans*, *syn-anti*, *E/Z* system, physical properties and configurational assignments of geometrical isomers, interconversion of geometrical isomers, geometrical isomerism of polyenes, carbon-nitrogen, nitrogen-nitrogen double bonds and cyclic compounds (*cis-trans* isomerism in substituted cyclohexane).

4. **Conformation and Conformational Analysis:** Conformations and conformers, conformations of ethane, propane, n-butane and butane-2,3-diol, cyclohexane, methyl- and dimethylcyclohexanes, conformations of cyclobutane, cyclopentane and cyclohexane and their stability, conformation of mono and disubstituted cyclohexanes (1,3-diaxial interaction, butane-gauche interaction).

5. **Configuration:** D and L, *threo and erythro*, R and S absolute configurations, determination of the configurations of simple organic compounds, absolute and relative configurations and their correlation.

6. **Stereochemistry of the Fused-Ring System and Bicyclic System:** Stereochemistry of decalines, fused- and bicyclic bridges-ring systems,Bredt's rule and its exception in flexible ring systems.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Differentiate chiral and achiral molecules.
(ii) Recognize and draw structural isomers (constitutional isomers), stereoisomers including enantiomers and diastereomers,racemic mixture, and meso compounds.
(iii) Predict the energetically preferred conformation for straight-chain and branched alkanes, and for substituted cycloalkanes.
(iv) Determine R and S configurations for chiral molecules and distinguish between enantiomers, diastereomers, meso compounds, and conformational isomers.
(v) Realize the fundamentals of stereochemistry of the fused-ring and bicyclic organic compounds.

**Books Recommended**

1. Stereochemistry of Carbon Compounds, E. L. Eliel.
2. Organic Chemistry, T. W. G. Solomons and C. B. Fryhle.
3. Organic Chemistry,I. L. Finar, Volume 2.
4. Organic Stereochemistry, G. Hallas.

**CH 241 Chemistry of the Representative Elements (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Demonstrate an understanding on basics of s- and p-block elements.

(ii) Discuss the characteristics features of alkali and alkaline earth metals, preparations and usesof alkali and alkaline earth metal compoundsand the biological significance of sodium, potassium, magnesium and calcium.

(iii) Explain large scale preparation and properties of some industrially important compounds viz. cement, plaster of Paris, sodium hydroxide, sodium carbonate and sodium bicarbonate, etc.

(iv) Present the principles of p-block element chemistry with an emphasis on synthesis, structure, bonding and reaction mechanisms.

(v) Describe the properties and uses of inert gases and underlying principles of making their compounds.

**Course Content**

**1. Hydrogen:** Isotopes and heavy water, water gas: water gas shift reaction, reducing action, ortho and para hydrogen, binary hydrides and their classification, the hydrogen bond, structure of ice, hydrates and water clathrates, hydrogen: the prospective future fuel.

**2. The Alkali Metals:** Occurrence and extraction, comparative properties, ionization energies, alkali metal solutions in liquid ammonia and other solvents, cation sizes and bond polarization, hydration radii and solubilities of salts, diagonal relation between Li and Mg, binary compounds: oxides, hydroxides, salts, complexation of alkali ions, organometallic compounds and crown ethers.

**3. The Alkaline Earth Metals:** Occurrence and extraction, comparative properties of the elements, ionization energies, cation sizes and polarization, stability of ionic compounds, diagonal relation between Be and Al, compounds of beryllium and calcium, compounds of other metals, organometallic and complex compounds, minerals of nuclear materials.

**4. The Boron Family:** Occurrence and extraction, borates and boric acid, Lewis acid character of $BX_3$ compounds and their elimination reactions, stability of $BX_4^-$ anions, chemistry of the boron hydrides, electron deficient bonds, polyhedral boranes and carboranes, aqua ions, oxo salts, aqueous chemistry of Al to Tl, stability of Tl(I) state.

5. **Carbon and Its Congeners:** Allotropes of carbon, lamellar compounds of graphite, catenation, carbanion, carbonium ion, carbene intermediate, carbides. oxides of carbon and carbonic acid, reduction potentials of species having C-O linkage, C-N bond and related compounds, C-S bond, multiple bonding in carbon and silicon, silica, structure of silicates and aluminosilicates, inert pair effect and stability of 2+ oxidation state in the latter elements.

6. **The Nitrogen Family:** The elements, electronic structure and oxidation states, compounds of nitrogen, strong triple bond, stability of $N_2$,nitrogen fixation, nitrides, nitrogen hydrides and their derivatives, $NH_3$ as a non-aqueous solvent, salts of ammonium ion, hydrazine as a rocket fuel, hydroxylamine, azides, oxides and oxoacids of nitrogen and phosphorus, reduction potentials of species having N-O and P-O linkages, occurrence and allotropes of phosphorus, comparing the valency of N and P, P-N polymers, major uses of phosphorus.

7. **The Chalcogens:** General properties, electronic structure, and oxidation states, isotopes, and allotropes of oxygen, oxygen factories of nature, octet and oxygen compounds, $SO_2$ as non-aqueous solvent, ionic and covalent oxides, mono-,di-, and tri-coordinated oxygen species, ozone: its production and importance in atmosphere, CFCs and destruction of ozone layer, peroxidic and superoxidic compounds, dioxygen as ligand, hemoglobin and dioxygen,occurrence and allotropes of sulfur, oxides and oxoacids, sulfurdioxide as ligand, S-N polymers.

8. **The Halogens:** Comparative properties, MO diagrams, colours and physical states of dihalogens, trends in bond dissociation energies, solid form and metallic luster of iodine, occurrence, electrolytic production of $F_2$and $Cl_2$, their uses, recent chemistry of fluorine, pseudohalogens, polyhalogens, interhalogen compounds: classification, structures, physical and chemical properties, polyhalides, oxides and oxoacids, reduction potentials of species having Cl-O linkage.

9. **The Inert Gases:** Discovery of argon, occurrence, recovery and uses, chemistry of noble gases, xenon compound: fluorides, oxides, oxyfluorides, and oxo-acids and their structures, complexes of xenon, krypton compounds, chemistry of radon, clathrate compounds of noble gases.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Recognize s and p block elements and their characteristics.

(ii) Describe physical and chemical properties of group I-VII elements in the periodic table.

(iii) Compare trends in reactivity found in groups I-VII and use atomic structures to explain the variation of reactivity within a group.
(iv) Explain the chemistry of inert gases and their compounds, uses of inert gases.

**Books Recommended**


1. Chemistry of the Elements, N. N. Greenwood and A. Earnshaw.
2. Introduction to Modern Inorganic Chemistry, S. Z. Haider.
3. Basic Inorganic Chemistry, F. A. Cotton, G. Wilkinson and P. L. Gaus.
4. Advanced Inorganic Chemistry, F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann.
5. Inorganic Chemistry, T. Moeller.
6. Inorganic Chemistry, D. F. Shriver, P. W. Atkins and C. H. Langford.
7. Principles of Descriptive Inorganic Chemistry, G. Wulfsberg.
8. Concepts and Problems in Inorganic Chemistry, M. S. Sethi and P. S. Raghavan.


**CHL 202: Physical Chemistry Laboratory I (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to
(i) Impart basic knowledge on the development of different theories of physical chemistry based on the experimental data.
(ii) Carry out some simple physical experiments such as on kinetics, thermochemistry, chemical equilibrium, colligative properties etc. for solid foundation on theories.
(iii) Promote physical chemistry learning and writing skills through the presentation of reports on the experiments.

**Course Content**

1. **Determination of Molecular Weights:** Volatile liquids and non-volatile solids.

2. **Experiments Involving Equilibrium**
   (a) Determination of partition coefficient.
   (b) Determination of equilibrium constant of a reaction.
   (c) Determination of molecular association and dissociation.
   (d) Determination of solubility of a solute at different temperatures.

3. **Thermochemical Measurements**
   (a) Determination of heat of neutralization of a strong base by a strong acid.
   (b) Experiments involving the application of Hess's law.

**4. Electrochemical Measurements**

(a) Measurement of cell constant of a conductance cell.
(b) Measurement of specific and molar conductance.
(c) Conductometric titration.
(d) Measurement of e.m.f. and standard electrode potential.
(e) e.m.f. titration.
(f) pH-titration.

**5. Study of Molecular Structure by Measurements of Some Physical Properties viz.**

(a) Viscosity and density.
(b) Surface tension.
(c) Vapour pressure.

**6. Measurement of the Colligative Properties of Solutions**

(a) Depression of freezing point of water.
(b) Elevation of the boiling point of a liquid.

**7. Experiments Involving Kinetics**

(a) Kinetic study of a clock reaction.
(b) Effect of temperature on reaction rates.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Follow kinetics of a reaction and the effect of temperature on reaction rates.
(ii) Explain partition co-efficient and distribution of a solute in two immiscible solvents and determination of equilibrium constant of a chemical equilibrium.
(iii) Gain knowledge on viscosity and calculating the molecular diameter of a solute by using viscosity measurement of its solutions.
(iv) Explain the conducting behavior of strong and weak electrolytes and demonstrate conductometric and pH-metric titration of acids and bases.
(v) Demonstrate the applicability of Hess's law and the energetic of solubility equilibria.

**Books Recommended**

1. Practical Physical Chemistry, A. Findlay.
2. Experimental Physical Chemistry,G. P. Matthews.
3. Experiments in Physical Chemistry, F. Daniels, J. H. Matthews, P. Bender and R. A. Alberty.
4. Experiments in Physical Chemistry, J. M. Wilson, R. J. Newcomb, A. R. Denoro and R. M. W. Rickett.
5. Findlay's Practical Physical Chemistry, B. P. Levitt edited.
6. Experiments in Physical Chemistry, D. P. Shoemker and C. W. Garland.

7. Chemistry Experiments for Instrumental Methods, D. T. Sawer, W. R. Heinman and J. M. Beebe.
(The books recommended for theoretical courses are also imperative).

**CHL242 Quantitative Inorganic Analysis (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Discuss the difference between qualitative and quantitative chemical analysis.
(ii) Become familiar with different volumetric and gravimetric measurements used for quantification in the inorganic laboratory.
(iii) Gain an understanding of the underlying physical and chemical principles in both volumetric and gravimetric analysis of different chemicals.
(iv) Make capable of recording and reporting findings from these experimental processes to a basic, scientific standard.

**Course Content**

1. **Data Collection and Processing:** Introduction to analytical balance, volumetric glassware, reagents and standard solutions, calibration of weights and glassware, uncertainty in measurements, accuracy and precision, standard deviation, systematic error, random error, probable error, propagation of error, rounding off, significant figures, primary and secondary standard substances.

2. **Volumetric Analysis:** The principle of volumetric analysis, preparation of standard solutions, classifications of methods of volumetric analysis,

   (i) Neutralization Method: Standardization of sodium hydroxide solution using oxalic acid solution as a primary standard titrant, standardization of hydrochloric acid using standard sodium hydroxide solution, determination of acetic acid content in vinegar, determination of carbonate in washing soda, determination of bicarbonate in baking powder, determination of carbonate and bicarbonate in a mixture, determination of vitamin C in a vitamin C tablet, determination of acetylsalicylic acid in aspirin, determination of total acid and ascorbic acid in lemon juice.

   (ii) *Oxidation-Reduction Method:* Standardization potassium permanganate using standard oxalic acid solution, determination of Fe(II) using standard permanganate solution, determination of Fe(II) using potassium dichromate solution as primary standard

titrant, determination of Fe(III) using dichromate solution, determination of Fe(II) and Fe(III) in a Fe(II)-Fe(III) mixture.

(iii) *Iodometric Method:* Standardization of sodium thiosulphate solution using dichromate solution, iodometric determination of copper, iodometric determination of Fe(III) using $Cu_2I_2$ as catalyst, iodimetric determination of sulfite, determination of available chlorine in bleaching powder, determining the oxidizing capacity of a household cleanser.

(iv) *Precipitation Method:* Preparation of standard silver nitrate solution, standardization of ammonium or potassium thiocyanate solution, determination of chloride by Volhard's method.

(v) *Complexometric Method:* Preparation of standard EDTA solution, complexometric determination of copper using Fast sulphon Black as indicator, zinc and magnesium using Eriochrome Black T as indicator, nickel using murexide as indicator, determination of lead, zinc and copper in a mixture, determination of harness of water, determination of sulphate, determination of aluminium by back titration, determination of calcium by substitution titration, determination of Ca in egg shells.

3. **Gravimetric Analysis:** Determination of calcium as oxalate, aluminium as 8-hydroxyquinolate, sulfate as barium sulfate, phosphate as ammonium magnesium phosphate hexahydrate, chromium as barium chromate, sodium as sulfate, nitrate as nitron nitrate, cobalt as $K_3Co(NO_2)_6$.

4. **Analysis of Mixtures:** Separation and quantitative determination of copper and nickel, iron and manganese, copper and zinc, iron and calcium, chromium and nickel from the respective binary admixtures using suitable methods.

5. **Colorimetric Method of Analysis:** Determination of iron with 1,10-phenanthroline.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Select the appropriate glassware and equipment for quantitative tasks and be able to carry them out with precision and accuracy.
(ii) Apply statistical methods for the evaluation of laboratory data.
(iii) Work with others as part of a team to solve scientific problems.
(iv) Compose laboratory reports that summarize experimental procedures and the accurately present and interpret data.

**Books Recommended**

1. Vogel's Textbook of Quantitative Inorganic Analysis, $3^{rd}/4^{th}$ edition.

2. Elementary Quantitative Analysis - Theory and Practice, W. J. Blaedel and V. W. Meloche.
3. Quantitative Chemical Analysis, R. B. Fischer and D. G. Peters.
4. Fundamentals of Analytical Chemistry, D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch.
5. Analytical Chemistry, G. D. Christian.

**PM 211 Optics (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Discuss about the different kinds of aberration in Geometrical Optics and matrix analysis of lenses.
(ii) Impart knowledge about interference with some applications of interference.
(iii) Aware about the mechanism of diffraction and its applications.
(iv) Acquaint with different types of applications of interference phenomena.

**Course Content**

1. **Geometrical Optics:** Spherical Aberration. Chromatic Aberration. Astigmatism. Ray Matrices. Applications.
2. **Coherence:** First Order Coherence, Spatial and temporal coherence Higher Order Coherence.
3. **Interference of Waves:** Principle of Superposition. Phase Velocity and Group velocity: Huygens Principle. Young's Experiment. Biprism. Newton's Rings Michelson's Interferometer. Shapes and Positions of Fringes.
4. **Diffraction:** Diffraction. Fraunhofer Diffraction. Single, Double and Multiple, Slits. Diffraction grating. Spectrometer. Resolving power.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Learn the main cause of aberration in lenses and also the matrix method used in matrix geometry of lens.
(ii) Understand different types of aberrations are produced and different mechanisms of minimizing aberrations.
(iii) Realize the conditions for interference with special emphasis on temporal and spatial coherence.
(iv) Learn how interference was examined by Thomas Young and the conditions for occurring dark and bright fringes of interference pattern depending on the path difference between two coherent rays.

(v) Understand the conditions and types of diffraction and get familiar with the single slit, double slit and multiple slit diffraction phenomena: especially diffraction grating and its use by a spectrometer are made clear to the students.

**Books Recommended**


1. Optics, E. Hecht and A. Zajac.
2. Optics,B. B. Rossi.
3. Modern Optics,B. D. Guenther.
4. Fundamentals of Optics, F.A. Jenkins and H. E. White.
5. Vibrations and Waves, A. P. French.
6. Principles of Optics, M. Born and E. Wolf.


**PM 223 Electricity and Magnetism (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Aware with the main role of varying current in LCR Circuit.
(ii) Be familiar with the thermo electricity.
(iii) Impart knowledge about the magnetic materials and their behavior in a magnetic field.
(iv) Discuss the behavior of LCR series and parallel circuit when they are connected to an alternating voltage source.
(v) Acquaint with semiconductor as a start of semiconductor device technology and formation of P-N junction diode with its role as a rectifying element.

**Course Content**

1. **Varying Current:** Transients, Decay and Growth of Current. LCR Circuit.
2. **Thermo-electricity:** Seebeck, Peltier and Thomson effects. Thermo couple.
3. **Magnetic Properties of Materials:** Magnetization. B-H Curve.
4. **Alternating Current:** Use of Complex variable. LCR Circuits. Series and Parallel circuit. Q-Factor. Transformer.
5. **Semiconductors and Rectification:** Energy bands (Qualitative). Holes. Intrinsic and Extrinsic Semiconductors. p-n Junction. Depletion Layer. Diode Equation and Characteristics. Half Wave and Full-Wave rectification.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Learn how varying current is produced and how a capacitor is charged and discharged in LCR Circuit.

(ii) Understand the mechanism behind the production of thermo e.m.f in thermo couple and the application of thermo couple.

(iii) Recognize different types of magnetism specially para-, dia- and ferro-magnetism. Also know the change of magnetization of a ferromagnetic substance with the change of magnetic field with special emphasis on coercive force and remnant magnetization.

(iv) Understand the role of alternating voltage applied to LCR Series and parallel circuit.

(v) Acquire the basic idea of formation of pn-junction diode, how depletion layer in pn-junction diode is formed and deduction of diode equation and the characteristic curve of a pn-junction diode.

(vi) Get idea on the operation of half wave and full wave rectifiers with the derivation of their efficiency, ripple factor and form factor.

**Books Recommended**


1. Physics, R. Resnick and D. Halliday.
2. Principles of Electricity, L. Page and N. L. Adams.
3. Electricity and Magnetism, S. G. Starling.
4. Electromagnetic Fields and Waves, P. Lorrain and D. Corson.
5. Foundations of Electromagnetic Theory, J. R. Reitz, F. J. Milford and R. W. Christy.


**PML 204 Physics Non-Major Practical(2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Use basic concepts of electricity and optics in practical purpose.

(ii) Develop skills to verify the basic laws of electricity and optics using respective instruments.

(iii) Develop skill for application of knowledge of electricity and optics.

**Course Content**

**1.** Experiments with a post office box:
   (i) Determination of an unknown resistance
   (ii) Verification of the laws of combination resistances.

**2.** Determination of the galvanometer resistance by half-deflection method.

**3.** Determination of the galvanometer resistance by Kelvin's method.

**4.** Determination of low resistance by the method of fall of potential.

**5.** Measurement of high resistance by the method of deflection.

**6.** Comparison of e.m.f. of two cells.

**7.** Measurement of the angle of a prism using a spectrometer and determination of refractive index of the materials of the prism by minimum deviation method.

**8.** Determination of wavelength of sodium light by means of Newton's rings.

**9.** Determination of wavelength of sodium light by using a biprism.

**10.** Determination of wavelength of light using a plane diffraction grating.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) After completing the experiments of electricity, the students know how to determine the unknown resistance experimentally and to verify the laws of resistance. Students learn to determine the unknown high resistance and also learn to compare the e.m.f.s of two cells.

(ii) After completing the practical of optics, the students learn to use spectrometer to measure the angle of a prism and also learn to find out the refractive index of the material of the prism.

(iii) Students learn to determine the unknown wave length of light by using Newton's ring experiment, by using the experiment related to bi prison and also by diffraction grating experiment.

**Books Recommended**

1. Practical Physics, G. Ahmed and M. Sahabuddin.
2. Practical Physics, G. Kumar.

**MTM 203 Ordinary Differential Equation (2 Credits)**

**Course Content**

**1.** Ordinary differential equations and their solutions: Initial value problems. Boundary value problems. Basic existence and uniqueness theorems (statement and illustration only).

2. Solution of first order equations: Separable equations and equations reducible to this form. Linear equations, Exact equations, Special integrating factors, Substitutions and transformations.

3. Solution of higher order linear differential equations: Solution space of homogeneous linear equations. Fundamental solutions of homogeneous systems. Reduction of order. Homogeneous linear equations with constant coefficients. Non homogeneous equations.

4. Method of undetermined coefficients. variation of parameters. Euler-Cauchy differential equations.

5. Systems of differential equations, Linear system, Fundamental matix. Solutions of linear systems, with constant coefficient.

**Books Recommended**


1. Differential Equation,S. L. Ross.
2. A First Course in Differential Equations with Applications,D. G. Zill.
3. Differential Equations, F. Braner and J. A. Nohel.
4. An Elementary Treatise on Differential Equations,H.T.H. Piaggio.


**MTM204 Numerical Analysis (2 Credits)**

**Course Content**

1. **Solution of Equation in One Variable:** Bisection algorithm, Method of false position. Fixed point iteration, Newton-Raphson method, Error Analysis for iterative method, Acceleration of convergence.

2. **Interpolation and Polynomial Approximation:** Taylor polynomials, Interpolation and Lagrange polynomial, Iterated interpolation, Extrapolation.

3. **Differentiation and Integration:**Numerical differentiation, Richardson's extrapolation, Elements of Numerical Integration, Adaptive quadrature method, Romberg's integration, Gaussian quadrature.

4. **Solutions of Linear Systems:** Gaussian elimination and backward substitution, pivoting strategies, Matrix inversion; LU decomposition method.

**Books Recommended**


1. Numerical Analysis, R. L. Burden and J.D. Faires.
2. Numerical Methods for Differential Equations, M.A. Celia and W.G. Gray.
3. Numerical Analysis,L. W. Johson and R.D. Riess.

**MTM202Calculus II(2 Credits)**

**Course Content**

**A. Differential Calculus**

1. **Vector-valued Functions of a Single Variable:** Limits, derivatives and integrals of vector valued functions. Tangent lines to graphs of vector-valued functions. Curvature of plane and space curves.
2. **Partial Differentiation:** Functions of several variables. Limits and continuity. Partial derivatives. Differentiability, linearization and differentials. The Chain rule. Partial derivatives with constrained variables. Directional derivatives; gradient vectors and tangent planes.
3. Taylor's formula (in one and in several variables). Extrema of functions of several variables, Lagrange multiplier.

**B. Integral Calculus**

1. **Multiple Integrals:** Double and triple integrals; and iterated integrals. Area as a double integral. Double integrals in polar form. Volume as a triple integral. Triple integral in cylindrical and spherical polar coordinates.
2. General multiple integrals. Change of variables in multiple integrals. Jacobians.
3. Gradient, divergence, curl. Green's theorem, Gauss's theorem, Stoke's theorem.

**Books Recommended**


1. Calculus with Analytic Geometry, H. Anton.
2. Calculus with Analytic Geometry,E. Swokowski.
3. Calculus with Analytic Geometry, L. Bers and P. Karal.
4. Calculus of Several Variables,S. Lang.


**MTM205Mathematical Methods(2 Credits)**

**Course Content**

1. **Fourier Series:** Fourier Series, Fourier sine and cosine series. Properties of Fourier series. Operations on Fourier series. Complex form.
2. **Solution of Differential Equations in Infinite Series**. Equations of Legendre, Bessel, Hermite and Laguerre. Special functions:Legendre, Hermite and Laguerre polynomials; Bessel functions. Generating functiions and recurrenc relations.

3. **Beta and Gamma Functions**.

4. **Laplace Transforms:** Basic definitions and properties, Existence theorem.. Laplace transforms of periodic functions. Transforms of convolutions. Inverse transform. Use of Laplace transforms in solving initial value problems.

5. **Functions of a Complex Variable, Analytic Functions:** Complex integration; Cauchy's theorem and Cauchy's integral formula. Singularities and residues. Cauchy's residue theorem. Evaluation of real integrals using contour integration.

**Books Recommended**


1. Special Functions and their Applications, W. N. Lebedev and R.A. Silverman.
2. Advanced Engineering Mathematics,E. Kreuszig.
3. Laplace Transforms, M. R. Spiegel, Schaum's Outline Series.
4. Complex Variables and Applications,R. V. Churchill and J. W. Brown.


## THIRD YEAR COURSES

### CH 301 Chemical Kinetics and Photochemistry (3 Credits)

**Learning Objectives**

The learning objectives of this course are to

(i) Review the knowledge about the basics of reaction kinetics.
(ii) Provide knowledge about the theories of reaction rate in gas phase reactions.
(iii) Study the reaction kinetics of the reactions in solution and unimolecular reactions.
(iv) Give idea about different types of catalytic mechanisms.
(v) Acquaint with the preliminary concept of photochemistry and radiation chemistry.

**Course Content**

1. **Chemical Kinetics:** Review of elementary concepts: order, molecularity and rate constant, integration of rate equations for model reaction systems: zero, first and second order reactions, parallel, consecutive, successive and opposing reactions: methods for determination of order and rate constants, complex reactions, steady state approximation, kinetics of polymerization reactions, chain reactions, explosions.

2. **Techniques and Methods for Measuring Rates of Reactions:** Conventional chemical methods: conductance methods, polarimetry, spectrophotometry, methods based on gas pressure and volume measurements, techniques for measuring rates of fast reactions: production and measurement of free radicals, flash photolysis, flow methods, relaxation techniques, relative methods.

3. **Temperature Dependence of Reaction Rates and Theories:** The Arrhenius equation, bimolecular reactions: collision theory-its success and failures, transition state theory: elementary treatment, Eyring equation, thermodynamic formulation, reaction enthalpy and enthalpy diagrams.

4. **Reactions in Solution:** Diffusion and activation controlled reactions,theories of reaction rate in solutions, effect of dielectric constant and ionic strength on rates of reactions in solution.

5. **Theories of Unimolecular Reactions:** Unimolecular reactions: Lindemann theory, Hinshelwood treatment.

6. **Kinetics and Reaction Mechanism:** Principle of steady state approximation, iodinationof acetone, decomposition of nitrogen pentoxide, decomposition of ethane and acetaldehyde, hydrogen-chlorine, and hydrogen bromine reaction, hydrogenation of ethylene.

7. **Catalysis:** Homogeneous and heterogeneous catalysis, acid-base catalysis, Hinshelwood and Rideal mechanism, enzyme catalysis: Michael-Menten equation, autocatalysis, oscillatory reactions.

8. **Photochemistry and Photochemical Reaction:** Laws of photochemistry, quantum yield and its significance, light source, actinometer and its working principle, fates of photo excited species, photodissociation, photoionization, some typical photochemical reactions, photosensitization and photocatalysis, mechanism of photocatalytic reactions, formation and depletion of ozone in the stratosphere, ozone hole.

9. **Radiation Chemistry:**Types of radiation, deference between photochemistry and radiation chemistry, G-value and its significance.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Demonstrate different theories of rate of chemical reactions.
(ii) Correlate theoretical and experimental physical chemistry.
(iii) Apply various techniques to study the kinetics of bimolecular and unimolecular reactions.
(iv) Gain knowledge on catalytic and enzyme-controlled kinetic processes.

(v) Acquainted with the knowledge on photophysical, photochemical and radiation-controlled processes.

**Books Recommended**

1. Chemical Kinetics, K. J. Laidler.
2. Atkins' Physical Chemistry, P. Atkins and J. De Paula.
3. Kinetics of Chemical Change, C. N. Hinshelwood.
4. Reaction Kinetics, M. J. Pilling and P. W. Seakins.
5. Chemical Kinetics and Dynamics, J. I. Steinfield, Joseph S. Francisco and William L. Hase.
6. Chemical Kinetics, K. A. Connors.
7. Chemical Kinetics and Reaction Mechanism, J. H. Espenson.
8. Fundamentals of Photochemistry, K. K. Rohatgi-Mukherjee.
9. Principles and Applications of Photochemistry, R. P. Wayne.
10. Introduction to Molecular Photochemistry, C. H. J. Wells.

**CH 302 Surface Chemistry, Colloid Science and Phase Equilibria (2 Credits)**

**Learning objectives**

The learning objectives of this course are to

(i) Acquaint with the definitions, classification and properties of interfaces and adsorption process.
(ii) Understands the measurements and applications of adsorption phenomena.
(iii) Learn the methods of preparation; know the properties, and applications of different types of colloids and emulsions.
(iv) Impart knowledge on the basic characteristics of nanoparticles and nanofabrication.
(v) Acquaint with the different phases of substances and phase transition phenomena for single and multiple component systems.

**Course Content**

1. **Surface Chemistry:** Solid surfaces and their characterization, adsorption on solid surfaces, techniques for measurement of adsorption on solids from the gas phase and solutions, adsorption isotherms: Langmuir, Freundlich and BET, enthalpy of adsorption, role of adsorption in heterogeneous catalysis.

2. **Adsorption on the Surface of Liquid:** Gibb's adsorption equation, determination of surface excess concentrations, electrocapillary phenomenon, surface films, surface pressure, determination of the cross sectional area of surface active molecules by surface tension measurements, Langmuir trough, Langmuir films, Langmuir-Blodgett

films, preparation and characterization, nanofabrication with self-assembled monolayers.

3. **The Colloidal State of Matter:** Classification, preparations and physical properties of colloids, structure and stability of colloids, the electrical double layer, zeta potential, flocculation and coagulation, electrokinetic phenomena, colloidal electrolytes and their uses, micelles and biological membranes, emulsions: preparation, properties, stability and uses of emulsions, micro-emulsions.

4. **Phase Equilibria:** Phase rule and its application in one component system like water and sulphur, Duhemm-Margules equation, completely and partially miscible liquid pairs, solid-liquid systems comprising two components, efflorescence and deliquescence, vapour pressure of saturated solutions, solid-solid binary systems with reference to alloys, cooling curves, systems without compound formation, congruent and incongruent melting points, introductory ideas about ternary systems and triangular phase diagram.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Explain the physicochemical characteristics of different solid surfaces and their functions.
(ii) Describe the nature of adsorption isotherms and determine cross sectional area of surface active molecules.
(iii) Gain knowledge on about the behavior of liquid surface and know the properties of surfactant molecules.
(iv) Prepare different colloids and emulsions and determine their properties for practical applications.
(v) Understand the different phases of materials and phase equilibrium of one and more than one-component systems.

**Books Recommended**


1. Colloid Science, A. E. Alexander and P. Johnson.
2. Physical Chemistry, P. Atkins and J. de Paula.
3. A Short Textbook of Colloid Chemistry, B. Jirgensons and M. E. Straumains.
4. Colloid Chemistry: A Textbook, H. B. Weiser.
5. The Phase Rule, A. Findlay (revised by A. N. Campbell).
6. Physical Chemistry of Surfaces, A.W. Adamson and A.P. Gast.

**CH321 Organic Reaction Mechanism I (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(iii) Impart knowledge on reaction mechanism of different types of substitution reactions at aliphatic and aromatic carbons, and their kinetics, thermodynamics and stereochemistry. Give knowledge on different factors affecting the substitution reaction.

(iv) Provide knowledge on the mechanism of electrophilic and nucleophilic addition reactions.

(v) Aware on mechanism of E1, E2 and E1cB reactions, stereoselectivity and orientation of E2 reaction mechanism, Sayetzev vs Hofman products.

(vi) Give detailed knowledge on reaction mechanism of some well known reactions.

**Course Content**

**1. Substitution Reactions**

**(i) Nucleophilic Substitution at a Saturated Carbon Atom:** Mechanism of $S_N2$, $S_N1$and $S_ni$ reactions, kinetics, thermodynamics, and stereochemistry, effect of structure, solvent, leaving, attacking and neighbouring groups in substitution reactions.

**(ii) Electrophilic Substitution in Aromatic System:**Electrophilic substitution in benzene, formation of$\pi$- and $\sigma$- complexes, electrophilic substitution in monosubstituted benzene.

**(iii) Nucleophilic Substitution in Aromatic System:**Nucleophilic substitution in pyridine and diazonium salts, nucleophilic substitution in substituted benzene through benzyne intermediates.

**2. Addition Reactions**

**(i)Electrophilic addition to Carbon-Carbon Double Bonds:**Mechanism of electrophilic addition to carbon-carbon double bonds, 1,2- and 1,4- additions, their stereochemistry, kinetics and thermodynamics.

**(ii) Nucleophilic Addition to Carbonyl Compounds:**Addition to conjugated system like conjugated dienes and conjugated unsaturated carbonyl compounds, effect of structure on reactivity.

**3. Elimination Reaction:**E1 and E2 reactions, stereoselectivity of E2 reactions, mechanism of E1cB reaction, orientation in E2 reaction, elimination vs substitution reaction, Saytzev vs. Hofmann products in elimination reactions.

4. **Formation and Reaction of Esters and Related Compounds:** Acyl-oxygen and hydrolysis, reactivity in thehydrolysis and formation of esters, formation and hydrolysis of amides.

5. **Mechanism of Some Important Reactions:** Aldol condensation, Benzoin condensation, Cannizzaro reaction, Perkin reaction, Diels-Alder reaction, Michael and Mannich reactions, Reimer-Tiemann reaction, Meerwein-Ponndorf, Clemmensen, Wolf-Kishner reduction and Oppenauer oxidation reaction.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Explain reaction mechanism of different types of substitution reactions at aliphatic and aromatic carbons, and their kinetics, thermodynamics and stereochemistry and also factors affecting the substitution reaction.
(ii) Demonstrate knowledge on the mechanisms of electrophilic addition to carbon-carbon double bonds and nucleophilic addition to carbonyl compounds.
(iii) Understand mechanism of E1, E2 and E1cB reactions, stereoselectivity and orientation of E2 reaction mechanism, Sayetzev vs Hofman products.
(iv) Express the formation and reaction of esters and related compounds.
(v) Furnish detailed knowledge on reaction mechanism of some well-known reactions.

**Books Recommended**


1. Stereochemistry of Carbon Compounds, I.L. Eiel.
2. Organic Chemistry,T. Morrison and R. N. Boyd.
3. Organic Chemistry, S. H. Pine, J. B. Hendrickson, D. J. Cram, and G. S. Hammond.
4. A Guidebook to Mechanism in Organic Chemistry, Peter Sykes.
5. Organic Reaction Mechanism: An Introduction, R. Breslow.
6. Principles of Organic Synthesis, R. O. C. Norman and J. M. Coxon.
7. Organic Chemistry, Volume 2,I.L. Finar,


**CH322 Chemistry of Natural Products (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Give fundamental concept of natural products with their classification.
(ii) Impart knowledge on isolation, purification and determination of structure by chemical and spectroscopic methods with reference to alkaloids, terpenoids, steroids, hormones etc.

(iii) Realizethe biosynthesis of some secondary metabolites such as alkaloids and terpenoids.
(iv) Understand the relationship between colour and constituents of organic colouring materials.
(v) Give knowledge on pheromones, their stereospecificity and action in biological system.

**Course Content**

1. **Natural Products:** General methods of isolation, purification and determination of structure of natural products by chemical and spectroscopic methods with reference to alkaloids, terpenes, steroids and hormones, primary and secondary metabolites.

2. **Alkaloids:** Definition, isolation of alkaloids from plant sources, test of alkaloids, characterization of alkaloids by chemical, spectroscopic and synthetic methods with reference to ephedrine, adrenaline, nicotine, atropine, quinine and papaverine, biosynthesis of alkaloids.

3. **Terpenoids:** Terpenes and terpenoids, classification of terpenoids, isoprene rule, essential oils, detection, isolation and purification of terpenoids, determination of structure of citral, menthol cadenine and camphor by chemical, spectroscopic and synthetic methods, biogenesis of terpenoid compounds.

4. **Steroids and Hormones:** Introduction of steroids and hormones, nomenclature and functions of steroids and hormones, cholesterol and its effects in biological systems, steroidal hormones and glycosides, natural and synthetic hormones.

5. **Organic Colouring Materials:**A relationship between colour and constitution, anthocyanidines, flavones, xanthenes and other materials, naturally occurring coloured compounds: chlorophyll andhemoglobin.

6. **Pheromones:**Pheromones, their stereospecificity and actions in biological systems.

**Learning Outcomes**

Upon completion of this course, the students will be able to
(i) Gain knowledge on fundamental concept of natural products with their classification.
(ii) Apply the knowledge for the extraction, isolation, purificationand structural elucidation of various classes of natural products from plant animal origins.
(iii) Utilize the knowledge of natural product synthesis for drug discovery.
(iv) Demonstrate the colour of organic colouring materials.

**Books Recommended**

1. Organic Chemistry,I.L. Finar, Vol. 2.
2. Organic Chemistry,T. Morrison and R. N. Boyd.
3. Organic Chemistry - Natural Products, O. P. Agarwal,(Vol. I and II).

**CH323 Bioorganic Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart knowledge on the chemistry of carbohydrates and polysaccharides; such as their synthesis, isolation and purification, chemical properties etc. and their structural elucidation by chemical and spectroscopic methods etc.

(ii) Specify the knowledge on biochemical pathway of carbohydrates, proteins and lipid metabolism and protein biosynthesis including the related biochemical reactions.

(iii) Give thorough idea about the digestive system for the digestion and absorption of protein, fat and carbohydrates.

(iv) Motivate students to advance study of different important biomolecules like nucleic acids, proteins and enzymes.

**Course Content**

**1.** **Carbohydrates:** Definition, classification, constitution and configuration of monosaccharides, synthesis of monosaccharides, ring structure of monosaccharides and their conformations, action of acids and bases on sugars, epimers, anomers and anomeric configurations,reaction of mono-, di-, tri- and tetrasaccharides, their structures, chemical and physical properties.

**2.** **Polysaccharides:** Definition, constitution classification and importance of polysaccharides, isolation of polysaccharides and their purification using different physical and chemical methods, structural elucidation of polysaccharides using chemical and spectroscopic methods.

**3.** A brief introduction of some important polysaccharides such as starch, cellulose, pectin, algininc acid, chitin, glycogen, heparin and darmatan sulphates.

**4.** **Amino Acids, Peptides and Proteins:** Definition, sources, classification and importance of amino acids, its buffer action in biological system, structure and configuration of amino acids, isoelectric point, preparations and reactions of amino acids, biosynthesis of amino acids, peptides - its occurrence, constitution and geometry, C-terminal and N-terminal residues of peptides, proteins, their classifications and functions, denatured and conjugated proteins,

primary and secondary structure of proteins, a brief treatment of enzymes and coenzymes.

5. **Lipids:** Definition, occurrence, classification and function, composition of fats and oils, hydrolysis of fats, saturated and unsaturated fatty acids, phosphoglycerides, phosphate esters, phospholipids and cell membranes, biosynthesis of lipids.
6. **Nucleic Acids:** Definition, sources and importance, structure of nucleic acid, nucleosides and nucleotides, DNA and RNA.
7. **Purines:** Chemistry of purines and uric acid, purine derivatives, xanthine bases.
8. **Glycoconjugates:** A brief introduction of glycoprotein, proteoglycan and glycolipid.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand the physiological functions and consequence of the deficiency of some special biomolecules, such as lipids involved in the cell functions, carbohydrates for cell organellesand protein synthesis, amino acids and proteins related to nutrition.
(ii) Explain the impact of nucleic acid in genetics.
(iii) Explain the photosynthesis of carbohydrates and chemistry of polysaccharides.
(iv) Aware about the organic bio macromolecules those were responsible for the pollution of environment seriously.

**Books Recommended**

1. Organic Chemistry,I.L. Finar, Vol 2.
2. Organic Chemistry, R. T. Morrison and R. N. Boyd.
3. Organic Chemistry -Natural Products, O. P. Agarwal, (Vol. I and II).
4. Introduction to Carbohydrate Chemistry,R. D. Guthrie and J. Honeyman.

**CH341Advanced Concepts of Atomic Structure and Chemical Bonding (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Present the important features of the quantum mechanical model of the atom.
(ii) Explain the solution of Schrodinger wave equation as a product of $\psi_{n,\,l.\,m}(r, \theta, \phi) = \psi_{n,\,l}(r)\,\psi_{l,\,m}(\theta, \phi)$.

(iii) Impart knowledge on the periodic properties deriving from atomic structure, ionization energies, electron affinity, electronegativity, effective nuclear charge and size of the atoms/ions.
(iv) Discuss the nature of different kinds of chemical forces and their affects on inorganic molecules.
(v) Illustrate how the sp, $sp^2$ and $sp^3$hybrid orbitals are constructed by mathematical combination of s, $p_x$, $p_y$ and $p_z$ orbitals.

**Course Content**

1. **Atomic Structure:** Modern concepts of the structure of atoms, wave nature of electron, de Broglie's theory of matter, standing waves and quantization, Heisenberg's uncertainty principle, significance of the uncertainty principle, Schrödinger's wave equation and its application to hydrogen atom, solutions of Schrödinger wave equation, quantum numbers and their properties, angular wave functions and shapes of the orbitals, radial wave functions, probability distribution, nodal surface – angular nodes and radial nodes, Aufbau's principle, Pauli's exclusion principle, Hund's rule, classification of elements, periodic properties - size of atoms or ions, ionization energy, electron affinity and electronegativity, shielding effect and effective nuclear charge, Slater's rule for calculating shielding effect and effective nuclear charge, factors affecting the magnitude of shielding effect and effective nuclear charge, applications of Slater's rules and concept of effective nuclear charge.

2. **Chemical Bonds:** Chemical bond, types of chemical bonds,

   (i) *Ionic Bond:* Ionic bond, characteristics of ionic bonds and ionic compounds, factors favoring the formation of ionic bond, close packing, close-packed structures, interstitial sites, radius ratio, coordination number and radius ratio value, structure of NaCl, lattice energy of ionic crystals, theoretical calculation of lattice energy of NaCl crystal, Madelung constant, experimental determination of lattice energy of NaCl crystal, factors affecting the magnitude of lattice energy of ionic solids, applications of lattice energy calculation.

   *(ii) Covalent Bond:* Covalent bond, types of covalent bond, factors favoring the formation of covalent bond, characteristics of covalent bonds and covalent compounds, dipole moments, dipole moment and percentage ionic character, factors affecting the magnitude of dipole moment, bond length, bond order, bond energy, Lewis dot structure, limitations of Lewis dot structure, resonance, valence shell electron pair repulsion theory and its limitations, valence bond theory, hybridization, mathematical formulation of hybrid orbitals, limitations of valence bond

method, molecular orbital theory, the LCAO method, molecular orbital diagram, HOMO and LUMO, MO descriptions of homonuclear diatoms of $He_2$ to $F_2$, Mixing of MOs and the correlation diagrams, MO descriptions of heteronuclear diatoms, HF and CO, and polyatoms, $H_2O$, $BeH_2$, $BH_3$, $NH_3$, and $CH_4$, Walsh diagram, MO descriptions involving $\pi$ bonding electrons in $C_6H_6$, comparison and contrast between VBT and MOT, frontier orbital concept and its applications.

*(iii)* *Bonding in Metals:*Metallic bond, factors favoring the formation of metallic bond, theories of metallic bond - electron sea theory, valence bond theory, molecular orbital theory, characteristics of metals, conductors, semiconductors and insulators.

*(iv)* *Hydrogen Bond:*Hydrogen bond, types of hydrogen bond, theories of hydrogen bond – electrostatic approach, valence bond approach, molecular orbital approach, properties of hydrogen bond, and hydrogen bonded compounds.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Familiar about sinusoidal wave, dual behavior of electron, Heisenberg uncertainty principle, Schrodinger wave equation.
(ii) Describe the shape and orientation of atomic orbitals using simple diagrams of radial and angular parts of wave functions.
(iii) Explain bonding and lattice energy in ionic crystals.
(iv) Demonstrate the applications of MO theory to polyatomic molecules and to derive the MOs of simple, n-atom molecules (where $2<n<5$).
(v) Understand theories of metallic bonding and analyze the thermal and electrical conductivity of metals and explain various theories of hydrogen bonding and properties of hydrogen bonded compounds.

**Books Recommended**

1. Inorganic Chemistry, G. L. Miessler and D. A. Tarr.
2. Chemical Structure and Bonding, R. L. DeKock and H. B. Gray.
3. Atomic Structure and the Chemical Bond, M. Chanda.
4. Inorganic Chemistry, D. F. Shriver, P. W. Atkins and C. H. Langford.
5. Physical Chemistry, G. M. Barrow.
6. Valence and Molecular Structure, E. Cartmel and G. W. A. Fowles.

**CH342 Transition Metals and Coordination Chemistry (3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Describe typical properties of main and inner transition elements.

(ii) Impart knowledge on different theories of bonding in coordination compounds and systematic way of naming coordination compounds.
(iii) Provide knowledge to predict the relative stabilities of metal complexes with different ligands.
(iv) Inform the stereochemistry of complex compounds as well as why different isomeric compounds have different properties.
(v) Convey knowledge on the inorganic reaction mechanism of coordination complexes and redox reactions.

**Course Content**

1. **Transition and Inner Transition Elements:** General characteristics of transition metals and inner transition metals, shapes of *d* and f orbitals, energetics of d and f orbitals as functions of atomic numbers, magnetism in transition metal chemistry, origin of paramagnetism and diamagnetism, magnetic susceptibility, Curie's law, techniques of magnetic measurements, Gouy balance, lanthanides and actinides: oxidation states, atomic and ionic radii of $M^{3+}$ ions, magnetic properties of $M^{3+}$ ions, lanthanide contraction, chemical reactivity of lanthanides, separation of lanthanide and actinide compounds, comparison between 3d and 4f block elements.

2. **Bonding in Coordination Compounds:** Classical coordination compounds, double salts and coordination compounds, coordination number, ligand types, Werner's coordination theory, limitations of Werner's postulate, Sidgwick's electronic concept, application of EAN rule, limitations of Sidwick's concept, assumptions of valence bond theory (VBT), hybridization and geometry of complexes, inner orbital and outer orbital octahedral complexes, limitations of VBT, important features of crystal field theory (CFT), orbital splitting and electron spin, factors influencing the magnitude of 10dq, spectrochemical series, crystal field stabilizing energies of $d^n$ configuration (n = 0 to 10), magnetic moments, colour of transition metal complexes, distortion of octahedral complexes and Jahn-Teller theorem, limitations of CFT, ligand field theory (LFT), molecular orbital theory (MOT), MOT as applied to octahedral complexes, comparison of different theories.

3. **Stability of Complex Compounds:** Stability, stepwise formation constants and overall formation constants, kinetic vs. thermodynamic stability, labile and inert octahedral complexes, factors affecting the stability of a complex, experimental determination of stability constant and composition of a complex.

4. **Nomenclature and Isomers in Coordination Compounds:** Names of coordination compounds, use of abbreviated names, four and six coordination preferences, isomerism – structural and stereoisomerism

in complex compounds, geometrical and optical isomerisms in 4- and 6- coordinate complexes, chirality.

5. **Reactions and Mechanisms in Coordination Chemistry:** Substitution reactions in octahedral complexes, types of substitution reactions, nucleophilic substitution reactions, association, dissociation and interchange mechanisms, factors affecting the rate of substitution reactions, acid and base hydrolysis reactions, the conjugate base mechanism, stereochemistry of octahedral substitution, substitution in square planar complexes, trans effect – theories of trans effect, uses of trans effect, substitution in tetrahedral complexes, fluxionality in coordination compounds.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Describe the chemistry of main and inner transition elements and their properties.
(ii) Aware with the concepts of different bonding theories (e.g. CFT and MOT) of complex compounds.
(iii) Apply CFT to octahedral, tetrahedral and square planar complexes to explain the electronic, thermodynamic and magnetic properties of complex compounds.
(iv) Construct molecular orbital diagrams ofmetal complexes and obtain bonding information from them.
(v) Explain the mechanism of ligand substitution reactions of square planar and octahedral complexes.

**Books Recommended**


1. Advanced Inorganic Chemistry, F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann.
2. Inorganic Chemistry – Principles of Structure and Reactivity, J. E. Huhee, E. A. Keiter and R. L. Keiter.
3. Selected Topics on Advanced Inorganic Chemistry, S. Z. Haider.
4. Inorganic Chemistry, D. F. Shriver, P. W. Atkins and C. H. Langford.
5. Complex and First-row Transition Elements, D. Nicholls.
6. Elements of Magnetochemistry, R. L. Dutta and A. Syamal.
7. Kinetics and Mechanism, A. A. Frost and R. G. Pearson.
8. Inorganic Reaction Mechanisms, M. L. Tobe.
9. Mechanism of Inorganic Reactions, F. Basolo and R. G. Pearson.
10. Ligand Substitution Process, C. H. Langford and H. B. Gray.

**CH 361Instrumental Methods of Analysis (3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Extend skills in procedures and instrumental methods applied in analytical tasks.

(ii) Inform the principles,instrumentation and applications of thermal analysis, atomic spectrometry, polarographic and voltammetric analysis,chromatography, mass spectrometry.

(iii) Demonstrate how is the results of statistical analyses help oneto understand the outcome of his study.

**Course Content**

1. **Thermal Analysis:** Thermogravimetry (TG), types of TG,instrumentation, application of TG, derivative thermogravimetry (DTG), simultaneous TG and DTG, differential thermal analysis (DTA): working principle, instrumentation, factors affecting DTA, applications, differential scanning calorimetry (DSC): principle, instrumentation and applications.

2. **Atomic Spectrometric Methods:** Atomic absorption and atomic emission, absorption line width, choice of absorption line, flame emission spectrometry: instrumentation, flame emission analysis, atomic absorption spectrophotometry: principles, instrumentation and interferences, electro-thermal atomizers, sample requirements and general preparation techniques, the effect of different solvents, sensitivity, qualitative and quantitative analysis, hydride vapour generation technique, cold vapour technique, advantages and disadvantages of AAS.

3. **Polarographic and Voltammetric Analysis:** Current voltage relationship, mass transport processes, direct current polarography (DC), diffusion current, charging current, factors affecting the diffusion current, characteristics of dropping mercury electrode, three electrode potentiostat, polarographic maxima, oxygen interference, half wave potential, alternating current and pulse polarography, principle and advantages over dc polarography, voltammetry – ASV, CSV and CV, multicomponent analysis, quantitative applications.

4. **Chromatographic Techniques:** Overview, retention behaviour, efficiency, selectivity, resolution, chromatographic theory, measured chromatographic parameters, evaluation methods, and classification of chromatography.

   **(I) Liquid Chromatography:** Types of liquid Chromatography;

(a) ***Planar Chromatography:*** Theories and mechanism of PC and TLC, nature of stationary phases, general properties required of a mobile phase, development of the chromatograms, location of spots, superiority of TLC, analytical applications.

(b) ***Column Chromatography:*** Column selectivity, efficiency, capacity factor etc.

*(i) Ion-Exchange Chromatography:* Ion-exchange resin, types of resins and their structure and properties, factors affecting the ion-exchange-equilibria, eluting solvents, effect of pH, effect of complexing agents, and application of ion-exchange chromatography.

*(ii) Gel Chromatography*: Mechanism of gel chromatography, advantages of gel chromatography, technique of gel chromatography, applications of gel chromatography.

*(iii) High-Performance Liquid Chromatography:* The HPLCsystem, particle size and support material, filtration and degassing, HPLC columns, solvent requirements, solvent pumping systems, injection systems, HPLC detectors, applications.

**(II)Gas Chromatography:** Principles, GC columns, selection of materials and column design, stationary phases, carrier gas, sample injection system, general properties of detectors, detector types, scope of gas chromatography.

5. **Analytical Mass Spectrometry:** The general principles and basic instrumental aspects of mass spectrometry, interpretation of mass spectra, analytical-chemical aspects of mass spectrometry.

6. **Statistical Treatment of Data:** Population and sample mean, standard deviation, relative standard deviation, coefficient of variation, variance, confidence limit, Gaussian distribution, statistical tests, coefficient of correlation, regression lines, least square method.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Applythermal and atomic spectroscopic methods for qualitative and quantitative analysis.
(ii) Solve analytical science problems involving polarographic and voltammetric techniques.
(iii) Understand chromatographic separations, liquid chromatography,gas chromatography, chromatographic columns, detectors, interpretation of chromatograms, applications.
(iv) Know the fundamentals of mass spectrometer functioning and the applications of mass spectrometry to analytical problems.
(v) Understand how the presentation of the same analytical data can be improved through statistical analysis.

**Books Recommended**


1. Instrumental Methods of Analysis, H. W. Willard, L. L. Merritt Jr., J. A. Dean and F. A. Settle Jr.
2. Modern Methods of Chemical Analysis, R. L. Pecsok, L. D. Shields, T. Cairns and L. G. McWilliam.
3. Fundamentals of Analytical Chemistry, D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch.
4. Analytical Chemistry, G. D. Christian.
5. Modern Analytical Chemistry, D. Harvey.
6. Analytical Chemistry, R. Kellner, J. -M. Mermet, M. Otto and H. M. Widmer edited.
7. Analytical Chemistry Principles, J. H. Kennedy.
8. A Textbook of Quantitative Analysis, A. I. Vogel.
9. Quantitative Chemical Analysis, S. E. Manahan.


**CH 371 Quantum Chemistry and Statistical Mechanics (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Give knowledge on several features of classical mechanics and their failure for microscopic systems.

(ii) Introduce fundamental knowledge on principles of quantum chemistry and to demonstrate their applications.

(iii) Correlate between quantum chemistry and thermodynamics through the concept of distribution statistics and partition function.

**Course Content**

1. **Classical Mechanics:** Failures of classical mechanics, black-body radiation, heat capacities of solids, photoelectric effect, the Compton effect, atomic spectra, Planck's quantum theory, Einstein's explanation of photoelectric effect, de Broglie's postulate, Heisenberg's uncertainty principle, wave equation.

2. **Time Independent Schrödinger Equation and Stationary State:** Interpretation of the wave functions: normalization of the wave functions, orthogonality and completeness of the wave function, significance of wave functions.

3. **Operators and Observables:** Constitution of quantum mechanical operator, some important operators: Hamiltonian operator, Laplacian operator, operator algebra, eigen functions, eigen values, eigen value equation, expectation values.

4. **Application of Quantum Mechanics:** Translational motion, particle in a box, properties of solutions and the consequences, vibrational motion, one-

dimensional harmonic oscillator: the formal solution, the energy levels, the wave functions, properties of the solutions, rotational motion: rotation in two dimensions, the formal solution, significance and application.

5. **The Structure of Hydrogen and Hydrogen-like Atom:** The formal solution of the Schrödinger equation; the separation of the R, Θ and Φ equations, total wave functions of the hydrogen and hydrogen-like atoms, probability density and radial distribution function, atomic orbitals and their shapes, orthonormality of atomic orbitals, approximation methods, variation principle, perturbation theory.

6. **Statistical Mechanics:** Basic concepts, macroscopic system, distribution of molecules, configuration, population, weight, most probable configurations, Boltzmann distribution, molecular partition function, internal energy of a system, the canonical ensemble, Fermi-Dirac and Bose-Einstein statistics, evaluation of partition functions, calculation of thermodynamic functions, applications of statistical mechanics, mean energies and the equipartition principle, heat capacities of solids, Einstein and Debye equations, chemical equilibrium: statistical treatment, evaluation of equilibrium constants.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand the failure of classical mechanics for microscopic systems for describing black body radiation, heat capacity of solids, Compton effect, photoelectric effect etc.
(ii) Acquainted with the development of knowledge of quantum mechanics, quantization of energy and their applications.
(iii) Gain knowledge on the modern quantum chemistry through the dual nature of particle by using the basic postulates.
(iv) Apply wave theories for solving Schrodinger equation for simple systems like one-dimensional box, three dimensional box etc. and for a real one-electron system like hydrogen atom.
(v) Use the basis of statistical mechanics to bridge quantum chemistry with thermodynamics and to analyze partition functions and its relation with thermodynamic functions.

**Books Recommended**


1. Quantum Mechanics in Chemistry, M. M. W. Hanna and W. A. Benjamin.
2. Quantum Chemistry,D. A. McQuarrie.
3. Atkins' Physical Chemistry, P. Atkins and J. D. Paula.
4. Introductory Quantum Chemistry, A. K. Chandra.
5. Molecular Quantum Mechanics, P. W. Atkins.
6. Quantum Chemistry, I.N. Levine.

**CH 381 Chemical Spectroscopy I: Theory (3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Give knowledge on the interactions of electromagnetic radiation with matter.

(ii) Acquaint with the spectroscopic terms and different components of a spectrophotometer.

(iii) Give concepts on the existence of different types of energies of mater and their quantization that leads to absorption of different types of radiation leading to the appearance of different types of spectrum.

(iv) Impart knowledge on the principles of spectroscopic techniques like mw, ir uv-vis, nmr etc.

(v) Demonstrate skills and abilities needed for advanced studies involving spectroscopic techniques.

**Course Content**

1. **Electromagnetic Radiation:** The nature of electro-magnetic radiation,emission and absorption spectra,spectrometers, basic components of dispersive spectrometers, modulation technique: transmittance and absorbance, Beer-Lambert law: molar absorption cross section, representation of spectra, spectral peaks,intensities, width and resolution, signal to noise ratio and signal averaging, Fourier transform technique and its advantages.

2. **Atomic Spectroscopy:** Atomic spectra, spectra of hydrogen and hydrogen-like elements, energy level diagrams, angular momentum of atoms, coupling of orbital and spin angular momenta, term symbols, fine structure of atomic spectra.

3. **Rotational Spectroscopy:** Rotation of molecules and their classification, interaction of rotating molecules withradiation, microwave spectrometer, rotational energies of linear rotors, distribution of molecules and rotational spectra, centrifugal distortion, effect of isotopic substitution, Stark effect and its use in microwave spectrometers, determination of molecular geometry from microwave spectra.

**4.Infrared Spectroscopy:** Vibration in molecules, normal modes, harmonic and anharmonic, potential-energy diagrams, Morse equation, vibrational energy, dissociation energy of diatomic molecules, population of vibrational levels, transition probabilities, fundamental, overtone and hot band transitions, combination and difference bands, Fermi resonance, vibration-rotation spectra of gaseous molecules, P, Q, and R branches,infrared spectra of polyatomic molecules, characteristic

group vibrations and skeletal vibrations, shifts in group frequencies, techniques: radiation sources, optics, monochromators, sample holders, detectors for infrared spectrometers, handling of samples: gaseous, liquid and solid samples, principle of FTIR spectrometer and its advantages.

5. **Ultraviolet-visible Spectroscopy:** Electronic states of molecules, spectra of simple gaseous diatomic species and their vibrational coarse structure, Franck-Condon principle and intensities of spectral lines, dissociation energy,pre-dissociation spectra of species in condensed phase, various electronic transitions in organic and inorganic species, width of electronic bands, effect of solvent on band width and band position, chromophores, bathochromic and hypsochromic shifts, auxochromes.

6. **Fate of Excited Species:** Spontaneous and stimulated emission, flurorescence and phosphorescence, basic principle of LASER, working principles of some common lasers.

7. **Raman Spectroscopy:** Raman effect, classical theory of Raman scattering, criterion of Raman activity, Raman spectrometers, use of laser in Raman spectroscopy, vibrational and rotational Raman spectra, use of polarized light, applications of Raman spectroscopy.

8. **Principles of Resonance Spectroscopy:** Electron spin and nuclear spin, effect of magnetic field on the energies of spinning electrons and nuclei, the Larmor precession, resonance absorption of radiation through spin flipping, Relaxation times, the NMR spectrometer, the ESR spectrometer.

9. **NMR Spectroscopy:**Electron density at the nucleus, the chemical shift, $\delta$ and $\tau$-scale for chemical shift, the coupling of nuclear spins, the coupling constant, exchange phenomenon, structures of simple compounds and NMR.

10. **ESR Spectroscopy:** The g-factor, hyperfine splitting, determination of electron density from ESR spectroscopic studies.

11. **Mössbauer Spectroscopy:** The nuclear energy levels, the Doppler effect, resonance absorption of $\gamma$-radiation by nuclei, Mössbauer spectrometer, the chemical shift, the quadrupole effects, Zeeman splitting, applications in chemistry.

12. **Mass Spectroscopy:** Basic principles, ionization techniques, electron impact ionization, appearance potential, photo-ionization, mass filters, sector magnet filter, quadrupole filter, fragmentation,base peak, meta-stable peaks, application in structure, determination and quantitative analysis.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Describe the characteristics of electromagnetic radiation and existence of different types of energies of mater and their quantization.

(ii) Predict the necessary conditions for activity of molecules towards various spectroscopic studies such as ir, nmr etc, and selection rules for different transitions applying these rules for allowed and forbidden transitions.

(iii) Explain the origin and characteristics of various types of spectrum and the appearance of non-degenerate energy levels for electron and nuclear spin under an external magnetic field.

(iv) Calculate bond length of heteronuclear diatomic molecule from MW spectra and homonuclear diatomic molecule from Raman spectra, relative atomic mass from mass spectra, and dissociation energy from UV-vis spectra and calculate relative population of different states.

(v) Interpret the UV-Vis, IR, NMR and mass data for simple organic and inorganic compounds.

**Books Recommended**


1. Introduction to Molecular Spectroscopy, G. M. Barrow.
2. Fundamentals of Molecular Spectroscopy, C. N. Banwell and E. M. McCash.
3. Molecular Structure and Spectroscopy, G. Aruldhas.
4. The Infrared Spectra of Complex Molecules, L. J. Bellamy.
5. Ultraviolet and Visible Spectroscopy, C. N. R. Rao.
6. Basic Principles of Molecular Spectroscopy, R. Chang.
7. Electronic Spectra and Electronic Structure of Polyatomic Molecules, G. Herzberg.
8. Atkins' Physical Chemistry, P. Atkins and J. De Paula.


**CHL 303 Physical Chemistry Laboratory II (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Develop knowledge on planning and designing simple experiments involving different principles of physical chemistry and gain insight into the concepts involved.

(ii) Impart skill on various experimental techniques like kinetics, adsorption phenomena, phase equilibria, spectroscopic absorption etc.

(iii) Teach experimental data treatment of experiments involving kinetics studies and partial molar quantities using computer program.

(iv) Impart knowledge on systematically collecting reliable and reproducible data and interpreting them properly for explaining the experiment clearly.

**Course Content**

1. **Electrochemical Measurements:** (a) Potentiometric titration involving oxidation-reduction reactions, and acid-base neutralization (b) Determination of activity coefficients of electrolyte (c) Determination of transport numbers (d) Determination of decomposition potentials of the electrolytes (e) Determination of equilibrium constants from e. m. f. measurements.
2. **Study of Kinetics of Chemical Reactions:** Using(a) Polarimeter (b) Dilatometer (c) Conductance bridge (d) Manometer (e) Spectrophotometer and (f) Chemical analysis.
3. **Study of Phase Equilibria:** (a) Study of partially miscible system in presence and absence of impurities (b) Boiling temperature vs. composition diagram of completely miscible binary liquid pairs (c) Determination of cooling curves of binary solid system.
4. **Study of Surface Phenomena:** (a) Study of adsorption on solids from solutions (b) Study of adsorption at liquid surface by surface tension measurements (c) Study of surface films using Langmuir trough.
5. **Thermochemical Measurements:** Measurement of enthalpies of (a) combustion and (b) reaction.
6. **Spectroscopic Experiments:** (a) Study of electronic spectra of selected species (b) Verification of Beer-Lambert law and its application in quantitative analysis (c) Determination of the composition of a complex compound (d) Determination of stability constant of a complex compound (e) Study of atomic and molecular spectra (f) Determination of isosbestic point.
7. Measurement of quantum yields of some photochemical reactions.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Apply different techniques, for instances, spectroscopic, polarimetric, and conductometric methods for kinetic study of different reactions.
(ii) Realize basic concepts of phase equilibria and understand the changes involved in the cooling curves and the phase diagrams of two components systems.
(iii) Understand the meaning of adsorption isotherm and find out isotherm which best fit a system.

(iv) Apply the concepts of thermodynamics and determine thermodynamic parameters like partial molar volume of a liquid in a binary liquid mixture and determine the molecular weight of a solute from depression of freezing point.
(v) Realize important concepts of spectroscopy and apply them for measuring the spectrum of a colored sample, determine the molar extinction coefficient, determine the molecular structure, and for systems of scientific importance.

**Books Recommended**


1. Practical Physical Chemistry, A. Faraday.
2. Experimental Physical Chemistry, G. P. Mathews.
3. Experiments in Physical Chemistry, F. Daniels, J. H. Matthews, P. Bender and R. A. Alberty.
4. Experiments in Physical Chemistry, J. M. Wilson, R. J. Newcomb, A. R. Denoro and R. M. W. Rickett.
5. Findlay's Practical Physical Chemistry, B. P. Levittedited.
6. Experiments in Physical Chemistry, D. P. Shoemaker, C. W. Garland and J. W. Nibler.
7. Chemistry Experiments for Instrumental Methods, D. T. Sawer, W. R. Heinman and J. M. Beebe.


**CHL324 Organic Chemistry Laboratory II (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to
(i) Give knowledge on the recording of physical and chemical properties, and elemental analysis of the organic molecules
(ii) Impart knowledge on the identification of functional groups.
(iii) Give idea on the evaluation of physical and chemical information to identify the organic compounds.
(iv) Be acquainted with the realistic approach of the synthesis of simple organic compounds those can be used as either drug or for industrial purpose.

**Course Content**

1. **Identification of Organic Compounds:** Detection and identification of different types of organic compounds both solid and liquid by physical and chemical methods, types of organic compounds: hydrocarbons, halogenated compounds, hydroxy compounds (alcohols and phenols), ethers, carbonyl compounds (aldehydes and ketones), carboxylic acids and the derivatives of alpha, beta-unsaturated carbonyl compounds and acids, keto and hydroxy acids, nitro compounds, amino compounds

(primary, secondary and tertiary), organo sulphur compounds amides and N-substituted amides.

2. **Synthesis of Organic Compounds: Aromatic substitution:**(a)Bromination of acetanilide and phenol, (b) sulphonation of aniline, (c) Diazotization of aromatic amines and preparation of (i) phenols, (ii) halobenzenes and azodyes.

3. **Hydroxylation:** Hydroxylation of cyclohexene, stereospecific hydroxylation, isolation and purification of the products.

4. **Preparation Involving Some Specific Reactions:**Aldol condensation, Perkin reaction, Cannizzaro reaction, Michael reaction.

**Learning Outcomes**

Upon completion of this course, the students will be able to
(i) Detect the presence of different elements in organic compounds.
(ii) Identify the functional groups present in the compounds.
(iii) Elucidate the structure of the compounds from physical and chemical information comparing with standard sample.
(iv) Synthesize derivatives of organic compounds those may be useful for medicinal and industrial purposes.

**Books Recommended**


1. Unitized Experiments in Organic Chemistry, R. Q. Brewster, C. A. Vanderwerfand W. E. McEwen.
2. Organic Experiments, W. W. Linstromberg andH. E. Baumgarten.
3. Textbook of Practical Organic Chemistry, A. I. Vogel.
4. A Handbook of Organic Analysis,E. A. Clarke.
5. The Systematic Identification of Organic Compounds, R. Shriner, C. Hermann, T. Morrill, D. Curtinand R. Fuson.


**CHL343Inorganic Synthesis and Characterization (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to
(i) Gain theoretical and practical knowledge for working in an inorganicchemical laboratory in a safe and skilled way.
(ii) Develop skills in procedures and instrumental methods applied in analytical and synthetic tasks of inorganic chemistry.
(iii) Promote the idea in the scientific method of planning, developing, conducting, reviewing and reporting experiments.

**Course Content**

**1.** Recrystallization of NaCl crystals from crude NaCl and its characterization.

**2.** Preparation of $FeSO_4.7H_2O$ and its characterization including estimation of water of crystallization and determination of $Fe^{3+}$ as impurity, if any.

**3.** Preparation of $CuSO_4.5H_2O$ from metallic copper and its characterization by elemental analysis, IR and UV-visible spectra, and thermal analysis.

**4.** Synthesis of $[Cu(NH_3)_4]SO_4.H_2O$ from $CuSO_4.5H_2O$ and its investigation by infrared spectrometer.

**5.** Preparation of $[Co(NH_3)_6]Cl_3$ and its characterization by chemical analysis, infrared spectroscopy and magnetic measurement.

**6.** Preparation and characterization of tris(thiourea)copper(I) chloride, $[Cu(NH_2CSNH_2)_3]Cl$.

**7.** Synthesis of an ethylenediamine complex of cobalt and its characterization by infrared and $^1H$ NMR spectroscopy.

**8.** Preparation and investigation of potassium tris(oxalato)ferrate(III), $K_3[Fe(C_2O_4)_3]$.

**9.** Preparation and characterization of the optical isomers of tris(ethylenediamine)cobalt(III) iodide, $[Co(en)_3]I_3$.

**10.** Synthesis and characterization of a saccharin complex.

**11.** Spectrophotometric determination of $Cr_2O_7^{2-}$ and $MnO_4^-$ concentration from their solution.

**12.** Preparation of anhydrous $AlCl_3$ and anhydrous $FeCl_3$.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Synthesize, purify and isolate representative examples of main group and transition - metal inorganiccompounds following proceduresreported in the literature.

(ii) Know how to operate UV-VIS, FTIR, Flame Photometer, Magnetic Susceptibility measurement and X-ray Powder diffraction instruments.

(iii) Analyze IR, UV-VIS, NMR or XRDdata to characterize Inorganic compounds.

(iv) Elucidate the structure of the inorganic compounds from their physical and chemical data and defend experimental results orally in front of class.

**Books Recommended**

1. A Textbook of Quantitative Inorganic Analysis, A. I. Vogel.
2. Microscale Inorganic Chemistry, Z. Szafran, R. M. Pike and M.M. Singh.
3. Inorganic Experiments, J. D. Woollins.

## FOURTH YEARCOURSES

### CH401Physical Properties of Polymers(2 Credits)

**Learning Objectives**

The learning objectives of this course are to

(i) Acquaint with the basic concepts of polymers and macromolecules and their classifications.

(ii) Give knowledge on the properties of polymers like solubility, molecular weight, thermal and electrical property etc and the dependency of bulk properties of polymers on the chemical entity of the building unit(s).

(iii) Introduce concepts on the morphology of microstate of polymer molecules.

**Course Content**

1. **Structure of Synthetic and Biological Polymers:** Definitions, difference between polymers and macromolecules, classification of polymers, degree of polymerization, nomenclature and tacticity, basic structure of polymers: linear and branched polymers, moderately cross linked polymers, number average and weight average molecular weight, Z-average and viscosity average molecular weight, distribution of molecular weight, polydispersity, measurement of number average molecular weight: end group analysis, colligative properties, measurement of number average molecular weight: light scattering, ultracentrifugation, viscometry and gel permeation chromatography.

2. **Morphology and Order in Crystalline Polymers:** Configurations of polymer chains, crystal structures of polymers, amorphous polymers, liquid crystalline polymers, morphology of polymer single crystals, structure of polymers crystallized from melt and solution, factors affecting crystallinity.

3. **Polymer Solution:**Criteria for polymer solubility, size and shapes of polymers in solution, conformation of dissolved polymer chain, thermodynamics of polymer solutions, Flory-Huggins theory, theta temperature, concepts of a thermodynamically good and poor solvent, fractionation of polymers by solubility.

4. **Polymer Structure and Thermal Properties:** The crystalline melting point, the glass transition, factors affecting $T_m$ and $T_g$, experimental determination of $T_g$ and $T_m$.

5. **Rheology and Mechanical Properties of Polymers:** Introduction to Rheology, definition, Newton's and Hooke's laws, flow behavior of polymers, the ideal fluid, non Newtonian fluids, viscous flow, relationship between stresses and stain, viscoelasticity, mechanical models –Maxwell and Voigt Boltzmann's superposition principles. stress-strain behavior of elastomers, the mechanical properties of crystalline polymers.

6. **Other Polymer Properties:** Thermal stability, flammability and flame resistance, chemical resistance, degradability, electrical conductivity, conducting polymers, vulcanization, physical aspects of vulcanization.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Describe different types of polymers and different methods for the determination of molecular weight of different type polymers.
(ii) Demonstrate the crystallinity of polymer molecules, thermal behavior of polymers and molecular level factors affecting the behavior.
(iii) Explain the solubility of polymers, and the thermodynamic properties of polymers in solution.
(iv) Understand polymer flows, factor affecting flow of polymers and mechanical properties of polymers.
(v) Correlate the variation of different properties like electrical properties, bio-degradation, chemical and flame resistive behaviors etc. with the structure of the monomer unit.

**Books Recommended**

1. Polymer Chemistry-An Introduction, M. P. Stevens.
2. Polymer Science, V. R. Gowariker, N.V. Biswanathan and J. Sreadhar.
3. Polymer Chemistry, P. C. Hiemenz and T.P. Lodge.
4. Textbook of Polymer Science, F. W. Billmeyer.

**CH 402 Chemistry of Solids (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Enrich the knowledge on the perfection and defects in solids.
(ii) Give concepts on band theory of solids, perfect crystals and different types of defects like point defects, vacancies and non-stoichiometry in solids.

(iii) Impart knowledge on electrical, thermal, optical, magnetic and dielectric properties of solids.
(iv) Disseminate an understanding on the synthetic aspects involving solid state reactions and single crystal growth techniques.

**Course Content**

1. **Chemistry of the Defect of Solids and Solid Surfaces:** Perfect crystal, defects in solids, vacancies, point defects: intrinsic and extrinsic point defects, line defects: edge and screw dislocations, plane defects, calculation of the Schottky and Frenkel defects in ionic solids, influence of defects on the physical properties of the solids, colour centers.

2. **Bonding in Solids and Electronic Properties of Solids:** Introduction, bonding in solids, the band theory, electrical conductivity, thermal conductivity, origin of band gap, the hole concept,semiconductors and their types, sensitization and doping, measurement of semiconductivity, Hopping conduction, Hall effect, non-stoichiometric metal oxides,electronic properties of non-stoichiometric oxides, superconductors, SQUID.

3. **Optical Properties:**Interaction of light with solids, colour and photoconductivity.

4. **Magnetic and Dielectric Properties:** Magnetic susceptibility, classification of magnetic materials, diamagnetism, paramagnetism, ferromagnetism, anti-ferrimagnetism.

5. **Preparative Methods in Solid State Chemistry:** Introduction, microwave synthesis, sol-gel method, precursor method, hydrothermal method, chemical-vapour deposition.

6. **Reactions of Solids:** Solid-state reactions, role of defects, kinetics of thermal decomposition of solids, the Wagner's theory, tarnishing reactions, kinetics of oxide film growth, photoconductivity, chemistry of photography, photocells for solar energy conversion, dye-sensitized solar cells based on nanocrystalline oxide semiconductor films.

**Learning Outcomes**

Upon completion of this course, the students will be able to
(i) Understand point, lineandplane defects in crystalline solids and use of thermodynamics to explain the presence of point defects in crystalline solids and able to explain electrical and thermal conductivity.
(ii) Calculate the Schottky and Frenkel defects in ionic solids and explain their influence on the physical properties of the solids.

(iii) Recognize superconductors and semiconductors, measure semi-conductivity and describe the operation of modern semiconductor devices using band theory.
(iv) Synthesize solid materials in various forms, such as fibres, films, foams, ceramics, powders, nanoparticles and single crystals etc. and explain their optical, magnetic and dielectric properties.
(v) Apply reaction kinetics to determine the rate of solid state reactions and explain the role of defects on those reactions.

**Books Recommended**


1. Solid State Chemistry: An Introduction, L. Smart and E. A. Moore.
2. Solid State Chemistry, N.B. Hannay.
3. Chemistry of Solids, A.K. Galwey.
4. Solid State Chemistry, D. K. Chakrabarty.
5. Fundamentals of Material Science and Engineering, W. D. Callister.


**CH 421Organic Reaction Mechanism II (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to
(i) Impart understanding on molecular orbital theory, phase of an orbital and its role in bonding and antibonding and their shapes and energy states.
(ii) Give knowledge on chemical reactions of organic molecules and application of Woodward and Hofmann's rule for different reactions.
(iii) Convey conceptions on kinetics and energetics in reaction mechanism and role of different types of catalyst.
(iv) Teach the advanced approaches to study organic reaction mechanisms of addition, elimination and substitution reactions, pericyclic reactions, rearrangement and photochemical reactions.
(v) Give knowledge on conformational effects on stability and reactivity of organic molecules.

**Course Content**

1. **Molecular Orbital Theory:**Phase of an orbital and its role in bonding and antibonding,Hückel molecular orbital theory, LCAO`S theory and M.O`s theory - their shapes and energy states, illustration with 1,3-butadiene, allyl system and 1,3,5-hexatriene.

2. **Orbital Symmetry and Chemical Reactions:** Woodward and Hofmann rules and their applications in thermal and photochemical reactions, electrocyclic reactions, cycloaddition reactions and sigmatropic rearrangements.

3. **Kinetics and Energetics in Reaction Mechanism:** Mechanistic implication of rate-law, energy of activation and entropy of activation in

chemical reactions, kinetic control and thermodynamic control over product formation, salt effects, primary and secondary kinetic isotope effects.

4. **Catalysis:** Electrophilic and nucleophilic catalysts, catalysts of non-ionic reactions, "physical catalysts", acid-base catalysts, intramolecular catalysts.

5. **Special Addition, Elimination and Substitution Reactions:**

6. **Addition:** 1,3-Dipolar addition and 1,4-addition reactions.

7. **Elimination:** Ionic elimination, thermal andsyn-elimination (Chugaev and related reactions), detailed treatment of Saytzeff and Hofmann rules of elimination reaction leading to product formations.

8. **Substitution:** Orbital picture of$S_N1$ and $S_N2$ reactions, combination of $S_N1$ and $S_N2$ in solvolysis reactions, ion-pairs in $S_N1$mechanism, role of complex in aromatic reactions (substitution).

9. **Molecular Rearrangements:** Base-catalysed rearrangements, rearrangements involving migration to electron-deficient nitrogen and oxygen atoms, aromatic rearrangement passing through "No mechanism pathways", Claisen, Cope and related rearrangements.

10. **Photochemistry:** Excited states (Generation of singlet and triplet states), energy transfer, photosensitizer, quantum yield, photochemical synthesis and degradation, photochemical cycloaddition,photopoly-merisation, flash photolysis.

11. **Conformational Analysis and Its Effect on Reactivity:** Conformational effects on stability and reactivity, Curtius-Hammet principle, transannular effects, the concept of I-Strain.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Apply orbital symmetry considerations in understanding organic reactions.
(ii) Explain different chemical reactions of organic molecules applying Woodward and Hofmann’s rule.
(iii) Demonstrate kinetics and energetics involved in different steps of a reaction and role of different types of catalyst.
(iv) Elucidate advanced approaches of studying organic reaction mechanisms of various types of reactions such as addition, elimination, substitution reactions, etc.
(v) Explain conformational effects on stability and reactivity of organic molecules.

**Books Recommended**


1. Physical Organic Chemistry,T. H. Lowry and K. S. Richardson.
2. Problems in Physical Organic Chemistry,A. R. Butler.
3. Physical Organic Chemistry, J. S. Hine.
4. Organic Chemistry,H. S. Pine, J. B. Hendrickson, D. J. Cram and G. S. Hammond.
5. Symmetry in Organic Molecules,T. L. Gilchrist and R. C. Storr.
6. Frontier Orbital Theory, I. Fleming.
7. Organic Reaction Mechanism, E.S. Gould.


**CH 441 Selected Topics in Inorganic Chemistry(3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Introduce with molecular symmetry and symmetry operations, molecular point groups, and character tables.

(ii) Impart knowledge on several aspects of inorganic chemistry such as metal-ligands interactions, organometallic compounds, non-aqueous solvent system, the polymer chemistry of carbon, silicon, boron, phosphorus, sulphur and nitrogen, electron deficient and non-stoichiometric compounds, cluster compounds.

(iii) Convey knowledge on the product of organometallic reactions based on fundamental principles.

(iv) Discuss some current applications of transition metal complexes in the fields of industrial and medicinal chemistry.

**Course Content**

1. **Molecular Symmetry and Group Theory:** Symmetry elements and operations, point groups of molecules, multiplication of symmetry operations, rules for multiplications, symmetry point groups and molecular systems, groups of very high and low symmetry, use of flow chart to identify a point group, optical activity and dipole moments on the basis of point group symmetry, symmetry operations and matrix representations, reducible and irreducible representations, character tables for point groups.

2. **Metal Carbonyls and Nitrosyls:** Pi-acid ligands and pi-acid complexes, metal carbonyl and metal nitrosyl complexes, preparation and properties of metal carbonyl and nitrosyl complexes, M-C-O and M-N-O bonding, bridging and terminal COs and NOs, cluster carbonyls and nitrosyls, infrared and $^{13}C$ NMR analysis, side-on-bonding in carbonyls, nitrosyls, biological importance of carbonyls and nitrosyls.

3. **Organometallics and Their Catalytic Aspects:** Introduction, general characteristics, stability of organometallic compounds, ligands in organometallic chemistry, classification of organometallic compounds, preparative routes for metal-carbon bond formation, bonding between metal atoms and organic pi systems, structures of Zeise's salt and ferrocene, complexes containing M–C, M=C, and M≡C bonds, organometallic reactions – ligand dissociation and substitution, oxidative addition, reductive elimination, carbonyl insertion, homogeneous catalysis – hydrogenation by Wilkinson's catalyst, hydroformylation, heterogeneous catalysis – Ziegler-Nata polymerize-tions, water gas reactions, Fisher-Tropsch reaction.

4. **Nonaqueous Solvents:** Classification of solvents, general properties of ionizing solvents, leveling and differentiating solvents, types of chemical reactions in solvents, measurement of solvent strength, liquid ammonia, anhydrous sulfuric acid, liquid $SO_2$, molten saltsas solvents.

5. **Inorganic Polymers:** Concept of inorganic polymers as distinct to organic polymers, classification of inorganic polymers, properties of inorganic polymers, studies of some typical inorganic polymers: (i) phosphazines, (ii) silicones, and (iii)S-N polymers.

6. **Non-stoichiometric Compounds:** Introduction, characteristics of non-stoichiometric compounds, structure of non-stoichiometric compounds, methods for studying non-stoichiometric compounds.

7. **Metal Clusters:** Introduction, synthesis, reactions of metal clusters, structures of metal clusters, applications.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Recognize symmetry elements in a molecule and state the point group a molecule belongs to.
(ii) Use molecular symmetry to predict the chemical properties of a molecule, such as dipole moment and allowed spectroscopic transitions.
(iii) Understand the bonding and properties of metal carbonyls and nitrosyls, transition metal organometallics andexplain the catalytic cycle for production of alcohol, carbonyls, polymers and the role of metals in living systems.
(iv) Know the nature and properties of non-aqueous solvents.
(v) Explain the bonding and structures of inorganic polymers, electron deficient compounds and metal clusters.

**Books Recommended**


1. Chemical Applications of Group Theory, F. A. Cotton.
2. Inorganic Chemistry, D. F. Shriver and P. W. Atkins.
3. Concepts and Models of Inorganic Chemistry, B. E. Douglas, D. H. McDaniel and J. J. Alexander.
4. Modern Aspects of Inorganic Chemistry, H. J. Emeleus and A. G. Sharpe.
5. Inorganic Chemistry, G. L. Miessler and D. A. Tarr.
6. The Organometallic Chemistry of the Transition Metals, R. H. Crabtree.
7. Chemistry in Non-aqueous Solvents, H. H. Sisler.
8. A Text Book of Inorganic Polymers, A. K. Bhagi and G. K. Chatwal.


**CH442 Elements of Chemical Crystallography (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Deepen and widen students' knowledge on the structures of solids.
(ii) Achieve fundamental knowledge on X-rays, X-ray diffraction, Bragg's equation for X-ray diffraction, uses of powder and single crystal X-ray diffraction.
(iii) Discuss about the elementary crystal optics.
(iv) Impart knowledge on crystal structures of ionic materials in terms of close packing.

**Course Content**

1. **Solids:** The solid state, properties of solids, crystalline and amorphous solids, distinction between crystalline and amorphous solids, classification of crystalline solid, isomorphism, polymorphism and allotropy.

2. **Crystal lattice and Crystal Symmetry:** Crystal lattice, unit cell, unit cell volume, crystal systems, Bravais lattices, lattice types, Miller indices, symmetry and symmetry elements, point groups, the Laue classes, space groups, transformation theory, systematic absences and space groups.

3. **Elementary Crystal Optics:** Crystal forms, crystal zones and zone symbols, cleavage, parting and fracture, crystal habit, crystal projections, crystal twins.

4. **X-ray Diffraction by Crystals:** X-rays,generation of X-rays, properties of X-rays, X-ray filters, diffraction of X-rays by crystals, Bragg's equation, reciprocal lattice, Bragg's law in reciprocal lattice, sphere of reflection, limiting sphere.

5. **Powder Diffraction Technique:** The powder method – principles and uses, the Debye-Scherrer powder camera, Guinier focusing camera, the powder diffractometer, comparison of diffractometry with film methods, high temperature powder diffraction, effect of crystal size on the powder pattern, measurement of d-values, refinement of unit cell parameters, indexing of powder patterns, structure determination from powder patterns.

6. **Single Crystals and Data Collection:** Single crystal, techniques of single crystals growth, choosing a crystal, crystal mounting and alignment, measurement of crystal properties, data collection method – rotation and oscillation technique, precession camera, and four-circle diffractometer, unique data, data reduction, structure factor, electron density mapping, Fourier synthesis, the phase problem, the Patterson synthesis, the overall procedure, computational task.

7. **Structures of Solids:** Close packing, closed-packed structures, packing coefficient, interstitial sites, radius ratio, radius ratio rule, structure of some inorganic solids - NaCl, CsCl, zinc blende, wurtzite, NiAs, $CaF_2$, $TiO_2$, perovskite, normal spinel and inverse spinel and ilmenite, Structure of some organic solids -flavones and isoflavones, alkaloids.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Classify solids.

(ii) Describe basic solid state structures for elements in terms of crystal systems, Bravais lattices, unit cells.

(iii) Identify the point symmetry and space group symmetry of crystalline materials and explain the elementary idea about crystal optics.

(iv) Understand the principle of X-ray generation, X-ray powder diffraction by crystals and their interpretation and can demonstrate the elementary idea about the single crystal X-ray diffraction.

(v) Apply radius ratio rule to evaluate the coordination number of an ion in inorganic compounds and can describe the solid state structure of some inorganic compounds (NaCl, CsCl, zinc blende, wurtzite, NiAs, $CaF_2$, $TiO_2$, perovskite, normal spinel and inverse spinel and ilmenite) in terms of atomic lattices, octahedral and tetrahedral holes.

**Books Recommended**


1. X-ray Structure Determination – A Practical Guide, G. H. Stout and L. H. Jensen.
2. Structure Determination by X-ray Crystallography, M. F. C. Ladd and R.A. Palmer.
3. Solid State Chemistry and Its Applications, A. R. West.
4. Inorganic Solids, D. M. Adams.

5. An Introduction to Crystal Chemistry, R. C. Evans.
6. X-ray Methods - Analytical Chemistry by Open Learning, C. Whiston.
7. Optical Crystallography, E. E. Wahlstrom.

**CH 451 Chemical Spectroscopy II: Applications (3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart knowledge on the interaction of ultra-violet and visible radiation with organic and inorganic molecules, calculation of $\lambda_{max}$, analyzing UV-Visible spectrum and predicting the presence of different types of chromospheres and auxochromes.

(ii) Give knowledge on infra-red spectra of molecules, assignment of spectral bands to characteristic functional groups, structure elucidation and investigation of reaction mechanism.

(iii) Acquaint with the principle and various common terms used in nmr spectroscopy, interpretation of nmr spectra and variable temperature spectra, simplification of complex spectra and brief knowledge on two dimensional nmr.

(iv) Give knowledge on mass spectroscopy to find the molecular mass and structure of compound.

(v) Give guidelines to elucidate the structure of unknown molecules using a combination of all spectroscopic techniques.

**Course Content**

1. **Ultra-violet and Visible Spectra of Organic and Inorganic Compounds:** Woodward-Hoffman rules for the calculation of $\lambda_{max}$,solvent effect on band position, conjugated system, chromophore - stereochemical aspects, kinetic studies using uv-visible spectroscopy, spectra of complex compounds- free ions, d-configuration and correlation diagrams, and Tanabe-Sugano diagrams, UPS and XPS.

2. **Infra-red Spectra of Organic and Inorganic Compounds:** Characteristics group frequencies, assignment of spectral bands, structural factors, including common organic functional groups, affecting group frequencies, frequency shifts associated with structural changes in the compounds containing hetero atoms, applications in structure elucidation and investigation of reaction mechanism,combined infra-red and Raman spectroscopic studies for structure determination, infra-red spectra of transition metal complexes, infra-red spectra of adsorbed species.

3. **Nuclear Magnetic Resonance Spectroscopy:** Nuclear spin, common nuclei with spin ($^{1}H$, $^{13}C$, $^{15}N$, $^{19}F$, $^{31}P$), interaction of magnetic field with nuclear spin, Larmour precession, resonance absorption of radiation, the

nmr spectrometer, nmr spectrum, chemical shift, shielding and deshielding of nuclei, spin-spin coupling, coupling constant, vicinal, geminal, ortho, para and meta coupling, proton exchange reactions, rotation about single bonds, variable temperature spectra, geminal coupling non-equivalence of protons, relaxation, NOE, simplification of complex spectra, double irradiation, Fourier transform spectra, two-dimensional nmr - a brief treatment of COSY and NOESY.

4. **Mass Spectroscopy:** Techniques of ionization, electron impact, fast atom bombardment, field desorption, photoionization, multiphoton ionization, thermal methods, principles of mass separation, sector magnet technique, quadrupole mass separator; time of flight in mass spectrometer, ion optics, sampling for mass spectrometric measurements, molecular beam sampling, ionization potentials and measurements, fragmentation of ions, rearrangement of ions, base peak, molecular mass determination, mass spectra of various classes of compounds, CI, EI and FAB mass spectroscopy.

5. **Combination of Spectroscopic Methods:** Structure elucidation of compounds by combined application of UV, IR, NMR ($^{1}H$ and $^{13}C$) and mass spectroscopy.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Analyze the UV-Visible spectrum and predict the presence of different types of chromospheres and auxochromes.
(ii) Interpret different functional group present in a molecule from its IR spectrum.
(iii) Understand the principle and various common terms used in nmr spectroscopy, interpretation of nmr spectra and variable temperature spectra, simplification of complex spectra and brief knowledge on two dimensional nmr.
(iv) Explain the principle of mass spectroscopy and can find out the molecular mass and structure of compound from the mass spectrum.
(v) Assign the structures of unknown molecules exploiting the combination of data of different spectroscopic techniques.

**Books Recommended**


1. Introduction to Spectroscopy: A Guide for Students of Organic Chemistry, D. L. Pavia, G. M. Lampman and G. S. Kriz.
2. Spectrometric Identification of Organic Compounds,R. M. Silverstein, G. C. Bassler and T. C. Morrill.
3. Spectroscopic Methods in Organic Chemistry, D. H. Williams and I. Fleming.
4. Spectroscopy, B. K. Sharma.

**CH 461Organic Process Industries (3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Give knowledge on the unit processes and unit operations of different industries and their corresponding equipment.

(ii) Discuss about the process technologies of various organic process industries.

(iii) Offer knowledge on the requirement of raw materials, processes involvedfor the production of various commercially important organic compounds at industrial level for daily consumption.

(iv) Concern about the quality of these products and their maintenance.

**Course Content**

1. **Sugar and Starch Industries:** Steps in the industrial extraction of cane sugar and inversion of sugar, refining of sugar, production of sugar from sugar beet, by products of sugar industries, management of industrial waste of sugar industries, production of starch from corn., production of glucose and dextrin from starch, Starch derivatives and its importance.

2. **Cellulose and Allied Industries:** Natural sources of cellulose, its constituents and estimation, different processes for the manufacture of paper from pulp, production of paperboard, viscose rayon and other modified cellulose fiber, wood chemistry and wood chemicals.

3. **Fuels:**Solid, liquid and gaseous fuels, coal and its constituents, different stages of coal formation, analysis and calorific value of coal and other fuels, carbonization, distillation of coal tar, hydrogenation of coal, manufacture of producer gas and water gas, refining and distillation of crude oil, motor and aviation fuels, thermal and catalytic cracking, production of motor fuels by alkylation, cyclization and polymerization, lubricating agents, hydrocarbons and petroleum, their distribution in Bangladesh, methods of harnessing hydrocarbons in Bangladesh, petrochemicals from liquid and gaseous hydrocarbons, natural gas and its utilization.

4. **Natural Oils, Fats and Waxes:** Extraction and refining of vegetable oils, analysis of fats and oils and their uses, hydrogenation of oils, cotton seed, soybean, sunflower and linseed oils and their uses.

5. **Soaps and Detergents:** Methods of fat splitting, manufacture of laundry and toilet soaps, recovery and refining of glycerin, detergent: definition, classification and their manufacture, comparison between soaps and detergents, biodegradability of detergents.

6. **Biotechnology Related Industries:** Enzymes and micro-organism, production and application of enzyme, microbial activity, fermentation unit processes and unit control, instrumentation and control, recovery of fermentation products and waste treatment, manufacture of industrial alcohol and absolute alcohol, principle and production of citric acid, lactic acid, butyl alcohol, acetone and acetic acid.

7. **Surface Coating Industries:** Pigment - its classification and manufacture, paints - its constituents, functions and manufacturing process paint application and paint failure, printing ink - its classification and manufacture, varnishes, lacquers and enamels and its functions, industrial polishes.

8. **Chemical Explosives:** Definition, objective, classification and characteristics, principles of explosives technology, toxic chemical agents and propellants, industrial explosives (nitroglycerine, dynamite), military explosives - TNT, tertyl, picric acid, nitrocellulose, toxic chemicals and chemical vapors, propellants of rocket guided missiles.

9. **Rubber Industries:** Natural rubber - its production and processing, synthetic rubber - its classification, production of monomers and their polymerization processes, latex compounds, rubber compounding, vulcanization of rubber, different rubber processing chemicals and their functions.

10. **Agrochemical Industries:** Agrochemicals, their characteristics and composition, chemical pesticides manufacture and formulation of pesticides.

11. **Food Processing Industries:** Types of food processing, its instrumentation and methods, by products of food and their uses, food additives.

12. **Pharmaceutical Industries:** Classification of pharmaceutical products and their raw materials, methods of chemical manufacturing and different reactions involved in pharmaceutical products.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Handle unit processes and unit operations of different industries and their corresponding equipment used in distillation, extraction, leaching, drying, absorption, filtration etc.
(ii) Understand the process flow diagram and various process parameters.
(iii) Gain knowledge about raw materials, agents and reaction conditions required for carry out for the manufacture of sugar, paper, soaps and detergents, pigments, paints and varnishes, explosives, etc.
(iv) Understand possible environmental threats and their remedies for the production of organic compounds at industrial level.

(v) Apply critical thinking and problem-solving skills to address present and future challenges in the agrochemical, pharmaceutical, food processing industries.

**Books Recommended**

1. Shreve's Chemical Process Industries,G. T. Austin.
2. Riegel's Handbook of Industrial Chemistry, J. A. Kent.
3. Industrial Organic Chemistry, K. Weissermel and H. J. Arpe.

**CH462Inorganic Process Industries (3 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart a knowledge linkage in engineering, chemical processing, economics and industrial management.

(ii) Provide details about the fact that every industrial chemical processis based on unit operations (physical treatment) and unit process (chemical treatment) to produce economically a desired product from specific raw materials.

(iii) Give a general understanding of classification, properties, uses and industrial manufacturing processof some important materials in Bangladesh.

(iv) Impart knowledge on analysis and quality control of various industrial products.

**Course Content**

1. **Fundamentals in the Development of Chemical Industries:** General ideas about unit processes and unit operations, raw materials, process design, commercial energy sources, skilled manpower, catalysts, water as the basic process fluid, heat transfer, mass transfer, separation processes, concepts of consumption, production, and market evaluation, the balance of supply and demand, safety, environmental considerations, site and technology selection criteria, cost-benefit analysis.

2. **Chlor-alkali Industries:** Raw materials, manufacture of caustic soda, soda ash, sodium bicarbonate, chlorine, bleaching powder, sodium chlorite, environmental hazards of these chemicals.

3. **Fertilizer Industries:** Plant nutrients, classification of fertilizers, natural inorganic fertilizers, nitrogen fixation, artificial fertilizers, manufacture of ammonia, urea, ammonium sulfate, ammonium nitrate, action of urea as fertilizer, potassium fertilizer, calcium phosphate and other phosphatic fertilizers, potassium fertilizer, NPK fertilizer.

4. **Cement Industries:** Portland cement,raw materials, important process parameters for manufacturing a good cement clinker, methods of manufacturing Portland cement, sequence of operations, additives for cement, properties of cement, testing of cement, setting of cement, other types of cement, manufacture of gypsum, Plaster of Paris.

5. **Glass Industries:** Properties of glass, raw materials and fundamentals of glass industries, methods of manufacture, choice of the furnace, chemical reactions in the furnace, annealing, special glasses.

6. **Ceramic Industries:** Ceramics, properties of ceramics, basic raw materials, manufactures of ceramics, refractories, requisites of a good refractory, classification of refractories, properties of refractories, manufacture of refractories, types of refractory products.

7. **Acids:** Raw materials, manufacturing of hydrochloric, phosphoric, sulfuric acids, concentration and purification of acids, industrial uses of mineral acids, safety and hazards.

8. **Iron and Steel Industry:** Fundamentals of metallurgy, ores of iron, three commercial forms of iron, construction and operation of blast furnace, reactions in blast furnace, byproduct in blast furnace, classification of steel, steel manufacturing processes, effects of impurities on steel, phases in Fe-C system.

9. **Composite Materials:** Introduction, constitution, classification, fiber-reinforced composites.

10. **Inorganic Drugs:** Introduction, antacids, antimicrobials and astringents, arsenicals and cisplatin.

11. **Water Treatment:** Water quality parameters, types of impurities present in water, effects of impurities in natural waters, methods of treatment of water for domestic and industrial purposes.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Handle unit processes and unit operations of different inorganic process industries.
(ii) Describe the properties, classification, uses and the industrial manufacturing methods of caustic chlorine products, fertilizers, cement and lime, glass and ceramics, mineral acids, inorganic drugs, composite materials.
(iii) Discuss the ore processing of iron and explain the extraction of iron and steel.
(iv) Analyze various industrial products.
(v) Discuss the adverse effects and the remedies for the presence of various impurities in natural waters.

**Books Recommended**


1. Chemical Process Industries, R. N. Shreve and J. A. Brink, Jr.
2. Industrial Chemistry, B. K. Sharma.
3. Reagel's Handbook of Industrial Chemistry, J. A. Kent edited.
4. Shreve's Chemical Process Industries, G. T. Austin edited.
5. Materials Science and Engineering – An Introduction, W. D. Callister, Jr.
6. Inorganic Medicinal and Pharmaceutical Chemistry, J. H. Block and E. B. Roche.
7. Environmental Chemistry,H. J. M. Bowen, Vol. 1–3.


**CH471 Nuclear Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart basic knowledge on the different areas of nuclear chemistry including radioactivity, nuclear reactions, radioisotopes, nuclear reactor, radiation detectors, particle accelerators, etc.

(ii) Promote knowledge on radiochemical methods of analysis and their applications.

(iii) Realize the safety and threats of nuclear radiation.

**Course Content**

1. **The Atomic Nucleus and Its Properties:** Atomic nucleus and its composition, nuclear radius and nuclear density, nuclear force, mass defect, packing fraction, binding energy, nuclear spin and moments, nuclear potential, concepts of nuclear structure - shell model, nuclear statistics, nuclear stability, nuclidic mass and atomic mass, nuclear mass and energy correlation, classification of nuclides.

2. **Radioactivity and Radioactive Decay Laws:** Radioactivity**,** units of radioactivity, natural and artificial radioactivity, radioactive decay, radioactive decay constant, kinetics of radioactive decay, half-life and average life, radioactive decay series, radioactive equilibria, comparison between radioactive equilibrium and chemical equilibrium.

3. **Nuclear Reactions and Fission:** Nuclear reactions and their comparison with chemical reactions, types of nuclear reactions, conservation laws, energetics of nuclear reactions, nuclear reaction cross-section, excitation function, nuclear reactions mechanisms, liquid drop model of nuclear fission and fissionability parameters, general features of mass, charge and kinetic energy distributions in thermal neutron induced fission of $^{235}U$ and $^{239}Pu$.

4. **Interaction of Radiation with Matter and Detection of Nuclear Radiation:** Introduction, modes of interactions, interactions of gamma radiations with matters, interactions of charged particles with matters, Bremsstrahlung radiation, Ĉerenkov radiation, beta backscatter, the Auger process, radiation detection, measurements of radiations with ionization chambers, proportional counter, Geiger Müller counter, NaI(Tl) scintillation detectors, solid state semiconductor detector.

5. **Nuclear Reactors and Accelerators:** Nuclear reactors – principles, major components of reactors, types of reactors, application of reactors; working principles, basic components and utilization of Van de graaff, tandem Van de graaff and cyclotron accelerators.

6. **Production and Uses of Radioisotopes:** General principles of production of radioisotopes, radiochemical separation and purification of isotopes, uses of radioisotopes in chemical, physical, and biological sciences, medicine, agriculture and industry citing illustrations of current interests.

7. **Nuclear, Nuclear-related and Radiochemical Methods of Analysis and Their Applications:** Radiotracer, geochronology and radioactive dating, isotope dilution method in chemical analysis, neutron activation analysis of trace elements, PIXE analysis of trace elements, energy dispersive X-ray fluorescence analysis.

8. **Safety:** Radiation exposure, radiation dose, dose equivalent, quality factor, simple calculation of radiation exposure and radiation dose for γ- and β-rays, radiation hazards, radioactive wastes and their management.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand the decay of unstable nuclei and can differentiate between the different types of nuclear reactions.
(ii) Describe nuclear reactor and operations.
(iii) Explain the operational principles of different radiation detectors.
(iv) Understand the basic functionality of particle accelerators.
(v) Interpret and rationalize the radiochemical analysis.
(vi) Illustrate the safety recommendation and regulations of external and internal radiation.

**Books Recommended**

1. Radiochemistry and Nuclear Methods of Analysis, W. D. Ehmann and D. E. Vance.
2. Nuclear and Radiochemistry, G. Friedlander, J. W. Kennedy, E. S. Macias and J. M. Miller.
3. Introduction to Nuclear Physics and Chemistry, B. G. Harvey.

4. Essentials of Nuclear Chemistry, H. J. Arnikar.
5. Nuclear Chemistry and its Applications, G. R. Choppin and J. Rydberg.

**CH 481 Environmental Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart basic knowledge for future researchers on environmental science.
(ii) Impart idea of main segments of each environment and fundamental chemical process related to problem in these segments.
(iii) Promote knowledge for measuring environmental problems and mitigation of these problems through significant analytical analysis of environmental pollutants.

**Course Content**

1. **Basic Concept of Environmental Chemistry and Its Scope:** Fundamental components and structure of the environment, lithosphere, hydrosphere, atmosphere and biosphere and their natural, chemical compositions, structure of the biosphere.

2. **Water Pollution:** General causes of water pollution, types of chemical pollutants in water, inorganics, organics, nutrients, pesticides, PCBs, PAHC, toxic heavy metals, radioactivity in water, detergents, etc.

3. **Water Treatment:** Coagulation, flocculation and filtration techniques, ion exchange purification of water, photo-oxidation, adsorption of chemical pollutants from dilute solution, electrochemical processes for water purification and reverse osmosis technology, sewerage and industrial waste water treatment.

4. **Atmospheric Chemistry and Air Pollution:** Nature of chemical pollutants in the atmosphere and their sources, chemical and photochemical reactions and their consequent effects - ozone depletion, greenhouse effect and damage to physical structures, climate change, acid rain and photochemical smog, control of atmospheric pollution.

5. **Solid Waste Management:** Major sources of solid wastes – industry, municipality, household, nuclear and hospital waste etc., incineration process and filtration, sanitary landfills and oxidation ponds, composting and sewerage treatments.

6. **Toxic Effect of Chemical Pollutants on Living Systems:** Toxic chemicals, metals: Pb, Cd, Hg, As, Cu etc., pesticides, chlorinated hydrocarbons, polyaromatic hydrocarbons, toxic gases like CO, $H_2S$, $NO_2$, HCN etc.

7. **Environmental Chemical Analysis:** Importance of analytical methods in environmental chemistry, uses of analytical methods in analyzing environmental samples.

8. **National Policy for the Protection of the Environment:** International laws of the seas, clean air and clean water acts, national environment quality standards (EQS), EEC and WHO guidelines for air and water quality.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Identify the main components and structures of earth environment and impact of various pollutants on dynamic equilibria between these components.
(ii) Understand the chemistry of water and air environment, different types of water and air pollutants and their sources, different water and air quality parameters and their measuring techniques.
(iii) Demonstrate the toxicity of several chemical pollutants and heavy metals on animal health, and different types of wastes, and apply the waste and water treatment methods, waste utilization and waste recycling.
(iv) Gain knowledge on several national and international regulations and policies for the protection of environment.

**Books Recommended**


1. Environmental Chemistry, S. E. Manahan.
2. Air Quality, T. Godish.
3. Fundamental Concepts of Environmental Chemistry, G. S. Sodhi.
4. Environmental Analytical Chemistry, F. W. Fifield and P. J. Haines edited.
5. Environmental Chemistry, A.K. De.
6. Environmental Toxicology, M. Satake, Y. Mido, M. S. Sethi, S. A. Iqbal, H. Yasuhisa and S. Taguchi.


**CH 482 Applied Physical Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart knowledge on balancing energy and materials of a system in operation.
(ii) Acquaint with homogenous and heterogeneous catalysts.
(iii) Give knowledge on energy generation and storage including renewable and alternative sources of energy.

**Course Content**

1. **Fundamentals of Material Balances:** Process classification, balances, material balance calculations, balances on multiple-unit processes, recycle and bypass, balances on reactive systems, balances on reactive processes, combustion.
2. **Energy and Energy Balances:** Forms of energy, energy balances on closed systems, energy balances on open systems at steady state, energy balance procedures.
3. **Homogeneous and Heterogeneous Catalysis in Chemical Industries:** Commonly used catalysts, zeolites, mixed oxides, noble metal catalysts, preparation and characterization, new trends in catalyst development, nano-cluster preparation, micro-porous supports.
4. **Energy:** Conventional sources, coal, petroleum, natural gases, fuel cells, modern need of energy forms, commercial production of electricity, gasoline, LPG.
5. **Energy of the Future:** The energy crisis, coal gasoline and natural gas-gasoline, underground gasification of coal.
6. **Alternative and Renewable Sources of Energy:** Solar energy, solar cells, bio-gas, gasohol, wind energy, energy from waves, geothermal energy.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Realize the energy sources, importance of energy source and crisis sectors.
(ii) Explain the balancing of the mass and energy in an industrial process by applying the concepts of thermodynamics and chemical reactions.
(iii) Rrecognize different catalysts including shape-selective catalysts and design appropriate catalyst for chemical industries.
(iv) Gain knowledge on different forms of energy, conversion of energies such as chemical (fossil), electromagnetic, electrical, thermal, geothermal, wind, and wave and the conversion of fossil fuels from one form into another.
(v) Innovate alternative and renewable sources of energy for future.

**Books Recommended**

1. Elementary Principles of Chemical Processes, R. M. Felder and R. W. Rousseau.
2. Energy and Problems of a Technical Society, J. J. Kraushaarand R. A. Ristinen.

3. Energy Systems and Sustainability: Power for a Sustainable Future, G. Boyle, B. Everett and J. Ramage edited.

**CH483 Synthetic Organic Polymers (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart knowledge on different types of polymers, polymerization processes and their properties.
(ii) Give concepts on the mechanism of polymerization processes such as co-polymerizations, co-ordination polymerisation and their kinetics.
(iii) Teach about the configuration of polymers; such as syndiotactic, isotactic, and atactic polymers.
(iv) Impart detailed knowledge on the preparation of polymers, their physical properties and important uses of some widely used polymers such as polyethene, PVC, polystyrene etc.
(v) Give knowledge on the preparation and uses of thermosetting resins.

**Course Content**

1. **Polymers and Polymerization:** Addition (Chain reaction) and condensation (step reaction) polymerizations.
2. **Hydrocarbon Polymer:**Homopolymers and heteropolymers, low density and high density polymers and their properties, copolymers: alternating, random, block and graft copolymers, elastomer, thermoplastic and thermosetting polymers and their properties, fibre and elastomer.
3. **Mechanism of Polymerization:** Radical, cationic and anionic polymerizations, and their kinetics, chain termination, chain transfer, chain retardation and chain inhibition.
4. **Co-ordination Polymerisation:** Fluid-bed process, Ziegler-Natta catalysts, mechanism of co-ordination polymerization and its kinetics, metal oxide catalysed and olefin polymerizations, ring opening polymerization.
5. **Co-polymerizations:** Mechanism of co-polymerizations and their kinetics.
6. **Configuration of Polymers:** Syndiotactic, isotactic, atactic polymers.
7. **Some Important Polymers:** Production of monomer unit, physical properties and important uses of polymer, polythene, polyvinylchloride (PVC), polystyrene, polybutylene, polybutadiene, styrene, neoprene, polymethyl methacrylate, polyacrylonitrile, polyvinylacetate, polytetrafluoroethylene, polyamides: nylon-6, nylon-66, nylon-610, nylon-11 and nylon-12, silk and wool.

8. **Thermosetting Resins:** Phenol-formaldehyde, phenol-urea, melamine-formaldehyde polymers, their preparation and uses, epoxy resins and polyuranthanes.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Describe the different types of polymers, and their properties.
(ii) Achieve knowledge on various polymerization processes and techniques and uses of different catalysts.
(iii) Understand the mechanism and kinetics of polymerization processes.
(iv) Gain knowledge on the stereochemistry of polymers.
(v) Demonstrate knowledge on the preparation, physical properties and important application of some widely used polymers and thermosetting resins.

**Books Recommended**

1. Organic Chemistry, R. T. Morrison and R. N. Boyd.
2. Textbook of Polymer Science, F. W. Billmeyer, Jr.

**CH 484 Agricultural Chemistry(2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Give idea on various classes of pesticides, their toxicity, effects and formulation.
(ii) Acquaint with the metabolism and detoxification of pesticides and their metabolites in the environment.
(iii) Introduce knowledge of organochlorine and organophosphorus compounds, carbamates etc. as pesticides and their effects on biological system.
(iv) Give concepts on insect attractant, repellent, chemo-sterile retardants etc.
(v) Impart knowledge on pest control by natural pesticides and pheromones.

**Course Content**

1. Pesticides and its classification.
2. Insecticides, acaricides, nematocides, moluscicides, rodenticides, herbicides, fungicides etc.
3. **Toxicity of Pesticides:** Lethal dose, toxic sublethal dose $LD_{50}$, $ED_{50}$, $EC_{50}$, etc.
4. **Effects of Pesticides:** Acute effect, chronic effect, systemic effects etc.
5. **Formulation of Pesticides:** Grannular, wettable powder, emulsion etc.

6. **Metabolism** of pesticides in an organism. Detoxification of pesticides and their metabolites in the environment.

7. A brief introduction of organochlorine compounds as pesticides with reference to lindane, heptachlor, DDT endosulphane etc. The mechanism of action organochlorine compounds in the biological system, detoxicification of the organochlorine and the residual effects in the environment.

8. A brief introduction of organophosphorous compounds and carbamates and their mechanism of actions in the biological system, their metabolism and cause of resistance in the insect system, effects of the pesticides in red-blood animal, their phytotoxicity, tolerance level in food grains, fruits and vegetables.

9. **Studies of a Few Pesticides:** Metaphos, bromophos, metathion, diazinon, melathion, carbaryl, pirimicarb etc.

10. Fungicides, herbicides, rodenticides and their classifications.

11. Dithiocarbamic acids derivatives, zineb, captan, benomyl, pyrazophos, hexachlorobenzene (HCB), phenol derivatives, 2,3,6-TBA, 2,4-D, MCPA, MCPB, 2,4-DB etc.

12. Mechanism of action of 2,4-D derivatives.

13. Insect attractant, repellant, chemosterile retardants etc.

14. **Natural Pesticides:** Pest control by compounds from natural products. Pyrenthrines, rotenone, glucosoenolates, azadirctin etc.

15. **Pest control** by pheromones. Advantage of using pheromones over synthetic pesticides.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Demonstrate knowledge on various types of pesticides and their effects on biological system and environment.
(ii) Evaluate effects of the pesticides in red-blood animal, their phytotoxicity, tolerance level in food grains, fruits and vegetables.
(iii) Apply these pesticides in proper dose for the production of agricultural produce.
(iv) Manage safe environment by using natural pesticides and pheromones.
(v) Innovate more natural pesticides those may increase food production keeping the environment safer.

**Books Recommended**

1. The Chemical Protection of Plants,G.S. Gruzdyev, V.A. Zinchenko, V.A. Kalinin and R. I. Slovtsov.

**CH485 Medicinal Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Introduce concepts on medicinal chemistry.
(ii) Give preliminary knowledge on types of drugs, sources, physic-chemical properties and their biological activities.
(iii) Acquire knowledge on drug action, drug metabolism, receptor theories and drug design.
(iv) Impart concepts on drug discovery, drug development and production.
(v) Give knowledge on chemical and biological aspects of different classes of drugs.

**Course Content**

1. Physico-chemical properties and biological activity.
2. Structural features and pharmacological activity.
3. Drug metabolism.
4. Receptor site theory.
5. Theoretical aspects of drug design.
6. **Chemical and Biological Aspects of the Following Classes of Drugs:** (a) Anaesthetics (cocaine, ecgonine, procaine, tetracacine, lidocaine), (b) Antibacterial agents (sulfamethoxazole, sultanilamide, sulfadiazine), (c) Antibiotics (β-lactam antibiotics ampicillin, amoxycillin, cloxacillin, floxacillin),(d) Anti cancer agents (busulfan, mechloromethamine, 5-flurouracil, methotrexale, (e) Doxorubicin, duanorubicin, dactinomycin, vincristin, venblastin), (f) Antidiabetic agents (tolbutamide, chlorpropamide, tolazamide, acetohexamide, glyburide),(g) Cardiac agents (cardiac glycosides and related drugs, digitoxin, digoxin, diglialis, gitalin), (h) Central nervous system stimulants (amphetamine, strychnine, brucine), and (i) Depressants (diazepam, oxazepam, clobazam, nitrazepam, barbiturates).

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand the fundamental concepts of medicinal chemistry.
(ii) Achieve the knowledge on drug discovery, development and production.
(iii) Impart knowledge on the mechanism of drug receptor interaction, stereochemistry and drug design, structure-activity relationships, drug metabolism, factors affecting the metabolism etc.
(iv) Gain knowledge on chemical and biological aspects of different classes of drugs.

**Book Recommended**

1. Burger's Medicinal Chemistry, M. E. Wolff edited.
2. Principles of Medicinal Chemistry, W. O. Foye, T. L. Lemke and D. A. Williams edited.

**CH 486 Bioinorganic Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(v) Impart knowledge on the fundamentals of biological systems.
(vi) Promote knowledge on bioelements and their compounds.
(vii) Provide knowledge on biomolecules and their role in biological chemistry and natural chemistry.

**Course Content**

1. **Fundamentals of Biological Systems:** Living organisms from water, small organic molecules and inorganic nutrients such as $CO_2$, $NH_3$, $NO_3^-$, $SO_4^{2-}$ and $PO_4^{3-}$, energy and the biological systems, proteins and their structures, enzymes, carbohydrates, nucleic acids, lipids, biological membranes, carbohydrate and protein metabolism, photosynthesis and storage of solar energy, burning of carbohydrates.

2. **Bioelements and Their Compounds:** Periodic table and the bioelements, essential and trace elements, distribution of elements in biosphere and in biological cells, toxic elements and their regulatory levels, metallobiomolecules and their classification.

3. **Principles of Bioinorganic Chemistry:** Choice of elements by the organisms, efficiency and specificity of bioactive elements, fitness of an element and its reduction potential, evolutionary improvement of fitness and specificity.

4. **Ion Pumps and Transport Proteins:** Active transport and the energetics, eversion mechanism, selectivity in eversion, $Ca^{2+}$ biochemistry, role of calcium in smooth muscle contraction, oxygen transport, hemoglobin and myoglobin, tertiary structure of myoglobin, oxygen binding curve, electronic structures of oxyhaemoglobin, models of $O_2$ binding, hindrance of dimer formation and picket fence porphyrins.

5. **Enzyme Catalysis:** Oxidoreductases, transferases, hydrolases, lyases, ligases, heme catalysts such as cytochromes, peroxidases and catalases functioning to detoxify substances, decompose hydrogen peroxide and organic peroxides and store energy through ATP synthesis, mechanism of the addition of $O_2$ to substrate by cytochrome-P450, mechanism of

the decomposition of $H_2O_2$, zinc, manganese and copper catalysts, large number of zinc enzymes and the uniqueness of zinc as a bioelement, mechanism of oxaloacetate decarboxylase, carboxypeptidase and carbonic anhydrase.

6. **Nitrogen Fixation and Photosynthesis:** Nitrogenases, structure of the active site, model compounds, iron-sulfur proteins, photosystems and the four-electron oxidation of water to $O_2$, chloroplasts, chlorophylls, reaction centre organization.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Acquire knowledge about biological systems, bioelements and their compounds.
(ii) Gather knowledge about bioinorganic chemistry and role of bioinorganic chemistry in biological system.
(iii) Describe the operation of the sodium potassium pump and the proton pump, and the functions of transport proteins.
(iv) Identify and explain the different classes of enzymes and their catalytic role in biological processes.
(v) Understand the nitrogen fixation and photosynthesis.

**Books Recommended**

1. Advanced Inorganic Chemistry, F. A. Cotton and G. Wilkinson.
2. Inorganic Chemistry, J. E. Huheey.
3. Inorganic Chemistry, D. F. Shriver, P. W. Atkins and C. H. Langford.
4. Inorganic Chemistry, G. L. Miessler and D. A. Tarr.

**CHL 403 Physical Chemistry Laboratory III (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Develop knowledge on planning and designing experiments involving advanced principles of physical chemistry and gain insight into the concepts involved.
(ii) Impart skill on various experimental techniques like kinetics, adsorption phenomena, phase equilibria, thermal analysis, spectroscopic determination and electrochemical measurements etc.
(iii) Acquireknowledge on treating experimental data of certain experiments with computer program and computer controlled electrochemical measurements like cyclic voltammetry etc.
(iv) Give practical knowledge on the preparation of colloids and emulsions, their stability study and applications in real life.

(v) Impart knowledge on systematically collecting reliable and reproducible data and interpreting them properly for explaining the experiment clearly.

**Course Content**

Requisite numbers of experiments are to be chosen from the following list.

**1.** Measurement of vapour pressures of liquids at different temperatures.

**2.** Kinetics of thermal decomposition of solids.

**3.** Determination of the activation energy of a chemical reaction.

**4.** Determination of equilibrium constant of a reaction by the measurement of e.m.f.and by titration.

**5.** Characterization of polymers by measurement of density; viscosity, I.R. spectrum and by DTA.

**6.** Determination of particle sizes.

**7.** Determination of excess surface concentration and thermodynamic parameters by measurement of surface and interfacial tensions of different liquid pairs.

**8.** Determination of pK values of acid-base indicators.

**9.** Determination of various physical parameters of substances in solution by spectrophotometric method.

**10.** Determination of the intensity of a light source and study of various photochemical reactions.

**11.** Determination of Hall parameters of different types of semiconductors.

**12.** Study of the electrokinetic phenomena.

**13.** Study of adsorption of gases on solid surfaces.

**14.** Study of adsorption from solutions on solids.

**15.** Preparation and applications of ion-selective electrodes.

**16.** Turbidimetric method of determination of sulphate or ions forming insoluble sulphates in natural water.

**17.** Preparation of colloids and study of their catalytic properties.

**18.** Preparation and stabilization of emulsions.

**19.** Study of solubilization.

**20.** Project experiments - to be announced during the laboratory course.

**21.** Glass blowing practice and familiarization with vacuum line.

**22.** Computer simulation of product profiles in complicated reaction systems.

**23.** Computer-controlled electrochemical measurements.

**24.** Degradation of Pollutants by advanced Oxidation Process.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Carry out measurements of vapour pressure, viscosity, surface and interfacial tensions, adsorption on solids from solution, spectrophotometric measurements in solutions and activation energy of a chemical reaction.

(ii) Demonstrate theories of acid base indicators, buffer solution, buffer capacity, buffer mechanism and salt hydrolysis.

(iii) Understand theories of electrolytes, activity, activity coefficients, and computer controlled electrochemical measurements and the industrial applications of electrochemistry.

(iv) Prepare colloids, emulsions, solutions etc., investigate their different properties and apply in real life.

(v) Improve the degradation of the pollutants by advanced oxidation process using electrochemical processes.

**Books Recommended**

1. Findlay's Practical Physical Chemistry, B. P. Levitt edited.
2. Experiments in Physical Chemistry,F. Daniels, J. H. Mathews, P. Bender and R. A. Alberty.
3. Experiments in Physical Chemistry, J. M. Wilson,R. J. Newcombe and A. R. Denaro.
4. Journal will be referred to in case the methods are not available in Text Books.
5. Chemical Analysis, H. A. Laitinen.
6. Vogel's Quantitative Inorganic Analysis-Revised edition.

**CHL 423Organic Chemistry Laboratory III (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart knowledge on the quantitative estimation of different functional groups by chemical and instrumental methods.

(ii) Introduce concepts of different chromatographic techniques and their application for identification and quantitative estimation of different organic compounds.

(iii) Give practical experience on the organic reaction mechanism and stereochemistry.

**Course Content**

1. **Estimation of Functional Groups:** (i) Estimation of carboxylic acid group present in an organic compound by iodometric titration, (ii) Estimation of hydroxyl and amino groups by acetylation, (iii) Estimation of carbonyl group by derivatization followed by gravimetric analysis,(iv) Estimation of aldehyde group by oxidation (Using Fehling/Benedict solution), **(**v) Estimation of adjacent hydroxyl groups by periodic oxidation.

2. **Separation of Organic Compounds by Chromatographic Methods:*(A)Thin-layer Chromatography (tlc):*** Preparation of thin layer plates. Separation of mixture of coloured compounds by tlc, Separation of colorless compounds by tlc and detection of the separated compounds by UV light and iodine vapour, separation of colourless compounds by tlc and detection of the separated compounds by using charring reagent (vanillin-sulphuric acid reagent).***(B)Column Chromatography:***(i) Separation of coloured compounds by column chromatography using alumina and silica-gel as stationary phases. Sample application as solution and by adsorbing the compounds in the adsorbent.(ii) Separation of one coloured and another colourless compound by column chromatography.***(C)Paper Chromatography:***(i) Identification of free sugars by paper chromatography and detection of the separated compounds by dipping and spray reagents. (ii) Separation of free amino acids by paper chromatography and detection of the separated compounds by ninhydrin spray reagent. ***(D)High Performance Liquid Chromatography:*** Solvent and sample preparation for h.p.l.c. identification and quantification of caffeine and sodium benzoate present in soft drink. ***(E)Gas-liquid Chromatography (glc):***Identification and quantificationof fatty acid methyl esters by glc.

3. **Studies of Some Organic Reactions:**(a) Effect of solvents on $S_N1$ reactions,(b) Effect of stereochemical aspects on esterification,(c) Effect of structures with a common nucleophile leading towards nucleophilic additions,(d) *Cis-trans* isomerism: Conversion of maleic acid into fumeric acid and vice-versa.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Determine different organic function groups quantitatively by chemical and instrumental methods.
(ii) Separate and identify the components of a mixture of organic compounds by applying suitable chromatographic techniques.
(iii) Gain practical knowledge effect of solvents, effect of stereochemical aspects, etc. on the organic reactions.

**Books Recommended**

1. Elementary Practical Organic Chemistry, Part III: Organic Quantitative Analysis, A. I. Vogel.
2. Chromatography: Published by IFS and ICAT.

**CHL443 Advanced Inorganic and Analytical Chemistry Laboratory (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Provide a firm foundation in the fundamentals and applications of current chemical theories including those in inorganic and analyticalchemistry.
(ii) Demonstratethe basic and advanced laboratory procedures used in inorganic compounds synthesis including spectroscopic and analytical techniques for their identification and characterization.
(iii) Demonstrate experimental methods of determining the composition and the stability constant of complex compounds.
(iv) Show how to contribute to solutions of problems encountered in an experiment.
(v) Explain how to maintain high standards of professional and scientific ethics.

**Course Content**

**1.** Preparation and characterization of tris(thiourea)copper(I) sulphate, $[Cu(NH_2CSNH_2)_3]SO_4$.

**2.** Preparation and characterization of potassium trioxalatochromate(III), $K_3[Cr(C_2O_4)_3]$.

**3.** Preparation and characterization of tris(ethylenediamine)nickel(II) chloride dihydrate, $[Ni(en)_3]Cl_2.2H_2O$.

**4.** Preparation, characterization and structural analysis of *cis*- and *trans*-forms of potassium diaquodioxalato chromate(III) dihydrate, $K[Cr(C_2O_4)_2(H_2O)_2]. 2H_2O$.

**5.** Determination of composition of Cu-EDTA complex by continuous variation method.

**6.** Determination of the formula and stability constant of the silver ammonia complex.

**7.** Paper, and thin layer chromatographic separation of metals like Co(II), Cu(II), Fe(II), Mn(II), Ni(II), and Zn(II) from their mixtures.

**8.** Paper, and thin layer chromatographic separation of amino acids from their mixture.

**9.** Separation and determination of Fe(III) and Cu(II) from their mixture using cation exchange chromatography.

**10.** Separation and determination of $Cl^-$ and $Br^-$ from their mixture using anion exchange chromatography.

**11.** The effect of acid concentration on the extraction of Fe(III) from its aqueous solution by diethylether.

**12.** Solvent extraction of Fe(III) as the β-hydroxyquinolate in presence of aluminium and nickel ions and its quantification.

**13.** Determination of total salt content in brine/sea water by conductance measurement.

**14.** Determination of Fe(II) content in the supplied solution by UV-Visible spectrophotometric method.

**15.** Trace elemental analysis by atomic absorption spectrophotometry.

**16.** Cell parameters determination of crystalline solids (for example NaCl, KCl, CsCl, $CuSO_4.5H_2O$, etc.) by X-ray powder diffraction method.

**17.** An assay of pharmaceutical products: Paracetamol, antacid, ascorbic acids by UV-Visible method.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Design and carry out experiments as well as accurately record and analyze the results of such experiments.
(ii) Learn key concepts of inorganic chemistry including those related to synthesis, reaction chemistry, structure and bonding.
(iii) Apply different instrumental methods of chemical analysis, including electronic and vibrational spectroscopy, chromatographic separation methods, thermogravimetry, conductometry, magnetic measurement, and X-ray crystallography.
(iv) Gain an understanding of the performance of graphical analysis to analyze laboratory results.
(v) Use the proper scientific style in written reporting of laboratory results.

**Books Recommended**

1. Practical Inorganic Chemistry – Preparations, Reactions and Instrumental Methods, G. Pass and H. Sutcliffe.
2. Experimental Inorganic Chemistry, W. G. Palmer.
3. A Textbook of Quantitative Inorganic Analysis, A. I. Vogel, 3rd edition.
4. Chromatographic Methods, R. Stock and C. B. F. Rice.

**CHL 463Industrial Chemistry Laboratory (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Give the basic concepts and techniques related to the quantitative chemical analysis of industrial and environmental samples.
(ii) Provide experimental knowledge on assay of different types of drugs (tablets and syrups) like vitamin C and iron.
(iii) Inform experimental techniques used for the analysis of different organic industrial products such as fats and oil, carbohydrates, soaps and detergents, and food and drinks.
(iv) Teach the preparation of polymers and their molecular weight determination.
(v) Aware on how to assure the quality of industrial products by chemical analysis.

**Course Content**

1. **Water Analysis:** Analysis of water for temporary and permanent hardness, total suspended solids, chloride content, dissolve oxygen, arsenic and lead.

2. **Industrial Materials:** Analysis of an iron and a calcium compound,analysis of coal for sulphur and quality specifications in terms of carbon content and inorganic residues.

3. **Environmental Samples:** Air particulate matters for total suspended solids, analysis of lead, calcium, copper and sulphur, air pollutants: $SO_x$ and $NO_x$ levels in air.

4. **Metals and Alloys:** Analysis of steel for manganese and sulphur.

5. **Analysis of Fats and Oils:** Fats and oilanalysis for acid value, iodine value and saponification value.
6. **Analysis of Carbohydrates:** Analysis of cane sugar for glucose by Fehling's solution and Benedict solution methods, analysis of molasses for glucose content.

7. **Soaps and Detergents:** Analysis of soap for total acid and alkali, and free acid or free alkali values for quality control.

8. **Food and Drinks:** Analysis of milk for sugar and protein.

9. **Polymers:** Preparation of polymers, determination of molecular weight of a polystyrene sample by viscometer.

10. **Cosmetics:** Analysis of cosmetics.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Apply practical experiences about the analytical methods to analyze the industrial products.
(ii) Analyze different inorganic and organic industrial products such as iron,alloys, vitamin C tablets,fats and oils, carbohydrates, soaps and detergents, and food and drinks.
(iii) Know how to prepare polymers and determine their molecular weights.
(iv) Achieve fundamental idea on evaluating the quality of the product.
(v) Attain knowledge and experiences to become an analytical chemist for chemical industry.

**Books Recommended**

1. Standard Methods for the Examination of Water and Wastewater, APHA-AWWA-WPCF.
2. A Text Book of Quantitative Inorganic Analysis, A. I. Vogel.
3. Comprehensive Practical Organic Chemistry, V. K. Ahluwalia and R. Aggarwal.
4. Preparative Methods of Polymer Chemistry, W. R. Sorenson and T. W. Campbell.

# 1st year minor syllabus

Students of different disciplines wishing to study chemistry as a minor subject must study 4 credits of theory course (either CMG 100 (4 credits) or any two of the three two-credit courses , CM 102 , CM 103 and CM 104) and two credit laboratory course, CMGL 101 from the 1st year minor syllabus. Students may take more theory or laboratory courses from the 2nd year minor courses according to their need.

**CMG 100 Fundamentals of Chemistry (4 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Aware students with the fundamental principles of physical, inorganic and organic chemistry.

(ii) Acquaint with the states of aggregation of matter and energy changes during chemical reactions, equilibrium law, concepts of acids and bases, kinetics of reactions, fundamentals on catalysis, etc.

(iii) Impart knowledge on the structure of atom, quantum numbers, electronic configurations, periodic table, classification of elements, and variation of properties along a period and a group, chemical bonds, advanced theories of covalent bonding, molecular shapes and types of chemical reactions.

(iv) Convey knowledge on chemistry of different classes of organic compounds and organic polymers.

**Course Content**

1. **States of Matter:** States of aggregation of matter, changes of state, the perfect gas equation, the kinetic theory of gases, behavior of real gases, van der Waals equation and its success, the Maxwell-Boltzman distribution of molecular velocities, intermolecular forces, the critical phenomenon, principles of liquefaction of gases, vapour pressure of liquids, Raoult's law, ideal and non-ideal solutions, temperature-composition diagram for pairs of miscible liquids, fractional distillation, solution of non-volatile solutes, colligative properties of solutions, Henry's law, Nernst distribution law.

2. **Energetics in Chemical Reactions:** The first law of thermodynamics, internal energy and enthalpy, reversible and irreversible processes, measurement of enthalpy changes, enthalpy of reaction, formation,

neutralization and combustion, thermochemical laws and their applications, lattice enthalpy and its determination by Born-Haber cycle, concept of entropy, Gibb's free energy, thermodynamic feasibility of processes.

3. **Chemical Equilibrium:** Chemical equilibrium, the equilibrium law, the equilibrium constant, homogeneous and heterogeneous equilibria, the principle of Le Chatelier and Brown, the factors influencing the position of equilibrium and values of K, Acid-base equilibria -acids and bases, strong and weak acids, pH and its calculation, buffer solutions and their preparation, buffer mechanism, Henderson-Hasselbalch equation, pH titration curves of different acid-base pair.

4. **Chemical Kinetics:** Rates of chemical reactions, techniques of measurement of rate of elementary and complex reactions, rate law, order and molecularity, concentration-time profiles, kinetic characteristics of zero, first and second order reactions, half-life, temperature dependence of rate of reaction, activation energy, catalysis, collision theory of reaction rates.

5. **Structure of Atom:** Atomic masses, isotopes, mass spectroscopy, Bohr model, spectrum of atomic hydrogen, dual nature of electron, Heisenberg uncertainty principle, Schrödinger wave equation, quantum numbers, atomic orbitals, nodal point/plane, electronic configuration of atoms, radioactivity, radioactive decay kinetics, carbon dating, fission and fusion reactions, nuclear binding energy, stability of nuclei.

6. **Periodic Table:** Periodic law, periodic classification of elements, variation of properties such as ionization energies, electron affinity, electronegativity, atomic/ionic radius along a period and down a group, diagonal relationship, general properties of representative elements, transition elements and inner transition elements.

7. **Chemical Bonds:** Chemical bond, types of chemical bonds – ionic, covalent, coordination, metallic, hydrogen, Lewis dot structure, shapes of molecules, VSEPR theory, valence bond theory, hybridization, σ- and π-bonds and molecular orbital theory.

8. **Chemical Reactions:** Types of chemical reactions –combustion, decomposition, displacement, precipitation, hydrolysis, hydration, neutralization, redox reactions, charge and electronic concept of redox reactions, oxidation number, balancing of redox reactions.

1. **Chemistry of Organic Compounds:** Bonding in organic compounds. Sigma and pi bonds. Hybridization of atomic orbitals of carbon, nitrogen and oxygen. Nucleophiles, electrophiles, carbocations, carbanions and free radicals. Inductive, electromeric, mesomeric and hyperconjugative effect. Classification of organic compounds based on their functional

groups. Nomenclature of organic compounds. Preparation and reactions of different classes of organic compounds with reference of hydrocarbons, alkyl or aryl halides, alcohols, ethers, phenols, aldehydes, ketones, carboxylic acids and their derivatives, amines and nitro compounds. General idea of alicyclic compounds.

9. **Aromaticity:** Aromaticity of benzene, Electrophilic aromatic substitution reaction of benzene– sulphonation, nitration, Friedel-Craft's alkylation and acylation reactions. Nucleophilic aromatic substitution reaction.

10. **Organic Polymers:** Concepts of synthetic and natural organic polymers. Preparation, properties and uses of some synthetic organic polymers-polyethylene, polypropylene, polyvinyl chloride, polystyrene, polyester, teflon and nylon and polyacrolein. Structure and properties of some important natural organic polymers - wool, silk, cellulose and starch and natural rubber.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Realize the states of matter and how they depend on temperature and pressure.
(ii) Demonstrate concepts on thermodynamics, equilibrium law for chemical reactions, fundamentals of acid-base equilibria and chemical kinetics.
(iii) Understand the electronic structure of atoms, their classification and periodic properties.
(iv) Describe the hybridization and geometry of selected molecular species.
(v) Understand the preparation, reactions of different classes of organic compounds.
(vi) Describe the chemistry of natural and synthetic organic polymers.

**Books Recommended**


1. General Chemistry, D. D. Ebbing.
2. Chemistry-The Molecular Nature of Matter and Change, M. Silberberg.
3. Organic Chemistry, T. Morrison and R. N. Boyd
4. Introduction to Modern Inorganic Chemistry, S. Z. Haider.
5. Principles of Physical Chemistry, M. M. Huque and M. A. Nawab.
6. Essentials of Physical Chemistry, B. S. Bahl, G. D. Tuli and A. Bahl.
7. Advanced Organic Chemistry, B. S. Bahl and A. Bahl.

**CM 102 Fundamentals of Physical Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) aware the fundamental principles of physical chemistry.

(ii) inform the states of aggregation of matter and first and second law of thermodynamics, equilibrium law, kinetics of reactions, concepts of acids and bases, electrode reactions and cells, etc.

**Course Content**

1. **States of Matter:** States of aggregation of matter, changes of state, the perfect gas equation, the kinetic theory of gases, behavior of real gases, van der Waals equation and its success, the Maxwell-Boltzman distribution of molecular velocities, intermolecular forces, the critical phenomenon, principles of liquefaction of gases. vapour pressure of liquids, Raoult's law, ideal and nonideal solutions, temperature-composition diagram for pairs of miscible liquids, fractional distillation, solution of non-volatile solutes, colligative properties of solutions, Henry's law, Nernst distribution law.

2. **Energetics in Chemical Reactions:** The first law of thermodynamics, internal energy and enthalpy, reversible and irreversible processes, measurement of enthalpy changes, enthalpy of reaction, formation, neutralization and combustion, thermochemical laws and their applications, lattice enthalpy and its determination by Born-Haber cycle, concept of entropy, Gibb's free energy, thermodynamic feasibility of processes.

3 **Chemical Equilibrium:** Chemical equilibrium, the equilibrium law, the equilibrium constant, homogeneous and heterogeneous equilibria, the principle of Le Chatelier and Brown, the factors influencing the position of equilibrium and values of K. Acid-base equilibria-acids and bases, strong and weak acids, pH and its calculation, buffer solutions and their preparation, buffer mechanism, Henderson-Hasselbalch equation, pH titration curve curves of different acid base pair.

4. **Electrochemistry:** Electrolyte, electrolytic and electrochemical cells, conductance and its measurement, specific and molar conductance, molar conductances of weak and strong electrolytes, Debye-Huckel-Onsager equation, Kolrausch's law of independent migration of ions, conductometric titration, different types of electrode and electrode reactions, electrode potential, emf of cell and its measurement, electrochemical series.

**5. Chemical Kinetics:** Rates of chemical reactions, techniques of measurement of rate, elementary and complex reactions, rate law, order and molecularity, concentration-time profiles, kinetic characteristics of zero, 1st and second order reactions, half-life, temperature dependence of rate of reaction, activation energy, catalysis, collision theory of reaction rates.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) realize the states of matter and how they depend on temperature and pressure.

(ii) demonstrate concepts on thermodynamics, equilibrium law for chemicalreactions and chemical kinetics, colligative properties of solutions, fundamentals of acid-base, pH and buffer mechanism.

**Books recommended**

(1) General Chemistry, D. D. Ebbing.
(2) Chemistry - The Molecular Nature of Matter and Change, M. Silberberg.
(3) Principles of Physical Chemistry, M. M. Huque and M. A. Nawab.
(4) Essentials of Physical Chemistry, B. S. Bahl, G. D. Tuli and A. Bahl.

**CM 103 Basic Concepts of Inorganic Chemistry 2 Credits**

**Learning Objectives**

The learning objectives of this course are to

(i) Deliver the knowledge on the structure of atom, quantum numbers, electronic configurations, periodic table, classification of elements, and variation of properties along a period and a group.

(ii) Demonstrate the types of chemical bonds, molecular shapes and chemical reactions.

(iii) Give details on naming of inorganic compounds.

(iv) Provide fundamentals on both qualitative and quantitative analysis of inorganic compounds.

**Course content**

**1. Structure of Atom:** Atom, subatomic particles, atomic masses, isotopes, mass spectroscopy, Bohr atomic model, spectrum of atomic hydrogen, dual nature of electron, Heisenberg uncertainty principle, Schrödinger wave equation for H-atom, quantum numbers, atomic orbitals, nodal point/plane, Aufbau principle, Pauli exclusion principle, Hund's rule,

electronic configuration of atoms, nucleus, nuclide symbol, nuclear binding energy, stability of nuclei, radioactivity, radioactive decay kinetics, carbon dating, fission and fusion reactions.

2. **Periodic Table:** Periodic law, periodic classification of elements, variation of properties such as ionization energies, electron affinity, electronegativity, atomic/ionic radius along a period and down a group, diagonal relationship, general properties of representative elements, transition elements and inner transition elements.

3. **Chemical Bonds:** Chemical bond, types of chemical bonds – ionic, covalent, coordination, metallic and hydrogen bond, Lewis dot structure, VSEPR theory, predicting the shapes of molecules, valence bond theory (VBT) and orbital hybridization, σ-, π- and δ-bonds, molecular orbital theory (MOT).

4. **Chemical Reactions:** Types of chemical reactions - oxidation and reduction reactions, oxidizing and reducing agents, redox half reactions, rules for balancing redox reactions, synthesis reaction, combustion reaction, decomposition reaction, displacement reaction, precipitation reaction, disproportionation reaction, hydrolysis reaction, acid - base reaction , polymerization reaction.

5. **Inorganic Nomenclature:** Prefixes and affixes used in inorganic nomenclature, use of enclosing marks, numbers, letters, and italic letters, names for cations, anions, radicals and heteropolyanions, names of acids, salts, and salt like compounds.

6. **Chemical Analysis:**

   (i) Qualitative analysis - physical appearance of inorganic salts, solubility rules, basic radicals (cations) and acid radicals (anions), classification of basic radicals into groups, systematic analysis, dry tests, wet tests -preparation of solutions, precipitating reagents, precipitation and solubility product principle, dissolution of precipitates, confirmatory tests for some basic and acid radicals.

   (ii) Quantitative analysis - titrimetric analysis, gravimetric analysis, titration reactions, titration curves, significant figures, quantitative calculations, end point detection, errors.

**Learning Outcomes**

Upon completion of this course, the students will be able to
(i) Understand the electronic structure of atoms, their classification and periodic properties.
(ii) Understand different types of chemical bonds, hybridization of orbitals, and geometry of selected molecular
species.

(iii) Explain the concept of chemical reactions and the types of chemical reactions.
(iv) Apply IUPAC's rules for the naming of inorganic compounds.
(v) Identify and quantify the ionic species in an inorganic compound.

## Books recommended

1. General Chemistry, D. D. Ebbing.
2. Chemistry -The Molecular Nature of Matter and Change, M. Silberberg.
3. Introduction to Modern Inorganic Chemistry, S. Z. Haider.
4. A Textbook of Quantitative Chemical Analysis, A. I. Vogel.
5. Vogel's Textbook of Qualitative Chemical Analysis, A. I. Vogel

### CM 104: Fundamentals of Organic Chemistry 2 Credits

**Learning Objectives**

The learning objectives of this course are to

(i) to demonstrate the relationship between structure and function of organic molecules, the major classes of reactions, reaction energetics and mechanisms, synthesis of organic compounds.
(ii) to introduce the chemistry of natural and synthetic organic polymers.
(iii) to determine molecular structure via various spectroscopic techniques.

**Course content**

1. **Basic Principles of Organic Chemistry:** Atomic structure and chemical bonding, atomic orbital, molecular orbital, shapes of organic molecules and hybridization, bonding in aliphatic and aromatic compounds, structure and resonance of benzene, aromaticity of benzene - Huckel 4n+2 rule, bond angle, bond length and their energy. Nucleophiles, electrophiles, carbocations, carbanions and free radicals. Inductive, electromeric, mesomeric and hyperconjugative effect.
2. **Chemistry of Organic Compounds:** Classification of organic compounds based on their functional groups. Nomenclature of organic compounds. Preparation, properties and reactions of different classes of organic compounds with reference of hydrocarbons, alkyl halides, alcohols, ethers, phenols, aldehydes, ketones, carboxylic acids and their derivatives, amines and nitro compounds. General idea of alicyclic compounds.
3. **Types of Organic Reactions:** Addition, substitution, elimination reactions of aliphatic and aromatic compounds.

4. **Synthetic Organic Polymers:** Concepts of synthetic organic polymers. Classification, types of polymerization reaction. Preparation, properties and uses of some synthetic organic polymers-polyethylene, polypropylene, polyvinyl chloride, polystyrene, polyester, teflon and nylon and polyacrolein.

5. **Natural Macromolecules:** Brief description of natural macromolecules with reference to wool, silk, cellulose and starch and natural rubber.

6. **Spectroscopic Methods:** A brief treatment of different spectroscopic methods- UV, IR, NMR and Mass spectrometry. Their applications in organic chemistry with references to identification of organic compounds.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) understand bonding and structure of organic compounds.
(ii) predict the reactivity of specific functional groups, and construct mechanistic pathways for the synthesis of a given compound.
(iii) describe the chemistry of natural and synthetic organic polymers.
(iv) know the basic principle of different spectroscopic techniques in organic chemistry.

**Books Recommended**


1. Organic Chemistry, T. Morrison and R. N. Boyd, Problem and their solution in Organic Chemistry.
2. Organic Chemistry, Hendrickson and Pyne: McGraw-Hill.
3. Organic Chemistry Vol. I & II, I. L. Finar, ELBS, Problem and their solution in Organic Chemistry, ELBS.
4. Fundamentals of Organic Chemistry, T. W. Solomons, John Wiley & Sons, New York
5. Introduction to Organic Chemistry, A. Streitweiser and C. H. Heathcock, Macmillan Publishing Company, New York.
6. Advanced Organic Chemistry (Bangla), M. U. Ahmed: Bangla Academy.


**CMGL 101: General Chemistry Laboratory** **2 Credits**

**Learning Objectives**

The learning objectives of this course are to

(i) show how to engage in safe laboratory practices handling laboratory glassware, equipment, and chemical reagents.
(ii) demonstrate how to carry out practical laboratory experiments.
(iii) explain how to identify inorganic ions, and organic compounds by physical and chemical methods.
(iv) give a firm foundation in the fundamentals and application of current chemical and scientific theories including those in Physical, Inorganic, Organic and Analytical Chemistry.

**Course Content**

(i) *Kinetics Study*: Determination of order of the reaction between persulphate ion and hydrochloric acid.

(ii) *Equilibrium Study*: Determination of $K_d$ and $K_c$ of the reaction $I^- + I_2 \Leftrightarrow I_3^-$

(iii) *Electrolytic Property*: Study of conductance behavior of weak electrolyte (acetic acid) with concentration

(iv) *Enthalpy Change*: Determination of the enthalpy change for the thermal decomposition of $NaHCO_3$ into $Na_2CO_3$

(v) The identification of acid radicals (anions) in solution.

(vi) The identification of metal ions (cations) in solution: analysis of the silver group (Group I), copper group (Group IIA), iron group (Group IIIA), zinc group (Group IIIB), calcium group (Group IV), and the alkali group.

(vii) Preparation of Mohr's salt and determination of its iron content by titration against standard $KMnO_4$.

(viii) Purification of the organic solid compounds by recrystallization, separation of the mixture of organic liquids by distillation and check their purity by determination of the melting and boiling temperature.

(ix) Preparation of some organic compounds: Acetanilide, *p*-nitroacetanilide, *p*-nitroaniline, *t*-butyl chloride etc.

(x) Detection of the presence of nitrogen, halogen and sulphur in organic compounds and identification of the functional groups (alkenes, alcohol, phenol, carbonyl compounds, carboxylic acid, aromatic amine, amide and nitro groups) present in organic compounds by specific chemical tests.

(xi) Detection of the presence of amino acid/peptide, sugar, alkaloid, steroid etc. in the organic compounds by specific chemical tests.

(xii) Estimation of sugar in the supplied sample by volumetric analysis.

**Learning Outcomes**

Upon completion of this course student will be able to

(i) gain an understanding of the use of an analytical balance for mass measurement, the use of graduated cylinders, graduated pipettes, and volumetric pipettes for volumetric measurement, the use of thermometers for temperature measurement, titrations, the use of pH meter, conductivity meter, centrifuge machine, etc.

(ii) apply common laboratory techniques including pH measurement, acid/base titrations, calorimetry, etc.

(iii) prepare organic compounds, determine the melting and boiling temperature of organic compunds, detect element and functional groups of organic compounds through some simple reactions.

(iv) detect the absence or presence of cations or anions in solution, using tests based on the principles of qualitative analysis.

(v) learn how to write a detailed lab report and use that.

**Books Recommended**

Practical Physical Chemistry, A. Findlay.
Experimental Physical Chemistry, G. P. Matthews.
Experiments in Physical Chemistry, F. Daniels, J. H. Matthews, P. Bender and R. A. Alberty.
Vogel's Textbook of Qualitative Chemical Analysis, A. I. Vogel
A Textbook of Quantitative Chemical Analysis, A. I. Vogel.
Unitized Experiments in Organic Chemistry, R. Q. *Brewster*, C. A. *Van der Werf* and W. E. *McEwen*
Organic Experiments, **L. F. Fieser**
A Text book of Practical Organic Chemistry, A. I. Vogel.
Systematic Identification of Organic Compounds, Wiley. Shriner, Fuson, Curtin and Morrill

## SECOND YEAR COURSES

### CM 201 Physical Chemistry I (2 Credits)

**Learning Objectives**

The learning objectives of this course are to

(i) Familiarize the students with thermodynamics and chemical equilibrium and thermodynamics of biological processes.
(ii) Give preliminary knowledge on electrochemistry and chemical kinetics.
(iii) Introduce preliminary concepts on the phase rule and phase equilibria.
(iv) Familiarize with the colloidal state and their surface properties.
(vi) Gain an understanding of the interaction of radiation with matter; absorption, covering ultraviolet-visible, and infrared spectroscopy.

**Course Content**

1. **Thermodynamics:** The first law, internal energy enthalpy: enthalpy changes in chemical and physical processes; reversible and irreversible processes Joule-Thomson effect; heat capacity of gases, thermochemistry; measurement of enthalpy changes. Spontaneous processes; heat energy and Carnot cycle; concept of entropy; free energy; conditions of equilibrium; chemical potential; chemical equilibrium thermodynamics of biological processes.

2. **Electrochemistry:** Electronic and electrolytic conduction, Electrolysis and its practical application, quantitative aspects, electrolytic dissociation, conductance and its measurements, ionic migration and transference numbers, Electrochemical cells, reaction. Nernst equation, potentiometric titration of redox reactions.

3. **Chemical Kinetics:** Reaction rates, its measurement, rate law, rate equation, factors that influence the rate, order, molecularity of simple reaction, Catalysis (simple treatment).

4. **Phase Equilibrium:** Phase equilibrium diagram of water, $CO_2$, sulphur. Mixture of miscible liquids partially miscible liquids, fractional distillation, eutectic mixture, the vapour pressure of salt hydrates, phase rule.

5. **The Colloidal State and Adsorption:** Colloidal sol, properties of lyophobic and lyophilic sol, colloidal electrolytes, protective colloids, preparation and properties of colloids, emulsion, gels. Adsorption: physical adsorption and chemisorption, sorption isotherms.

6. **Elements of Molecular Spectroscopy:** Vibrational energy, electronic energy, transitions IR and UV-visible spectrometers, intensity of

spectral bands; Beer-Lambert law quantitative analysis structure determination.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand and apply the laws of thermodynamics.
(ii) Relate and explain reaction kinetics to different types of reactions.
(iii) Define the phases of matter, phase changes, construct and interpret phase diagrams.
(iv) Describe surface and colloidal phenomena for surfaces, interfaces and colloids.
(v) Apply knowledge on different spectroscopic techniques for both qualitative and quantitative determination and structure elucidation.

**Books Recommended**

1. Principles of Physical Chemistry, M. M. Huque and M. A. Nawab.
2. Physical Chemistry, G. W. Casteliar.
3. A Text Book of Physical Chemistry, S. Glasstone.
4. Elements of Physical Chemistry, S. Glasstone and D. Lewis.
5. Physical Chemistry, P. W. Atkins.

**CM 202 Physical Chemistry II (2 Credits)**
**(For the Students of the Faculty of Biological Sciences)**

**Learning Objectives**

The learning objectives of this course are to

(i) Familiarize the students with thermodynamics, chemical equilibrium and thermodynamics of biological processes.
(ii) Acquaint with the phenomena involved in electrochemical cells and conducting behaviour of electrolytic solutions.
(iii) Promote an understanding of the reaction rates, simple collision theory and mechanism of catalysis.
(iv) Impart knowledge on properties of macromolecules and different photobiological processes.
(v) Give idea on different spectroscopic techniques and their application for both qualitative and quantitative determination and structure elucidation.

**Course Content**

**1. Thermodynamics:** The first law, internal energy, enthalpy, enthalpy changes in chemical and physical processes, reversible and irreversible processes Joule-Thomson effect, heat capacity of gases,

thermochemistry, measurement of enthalpy changes. Spontaneous processes, heat energy and Carnot cycle, concept of entropy, free energy, conditions of equilibrium, chemical potential, chemical equilibrium thermodynamics of biological processes.

2. **Electrochemistry:** Metallic and electrolytic conduction, Electrolysis and its practical application, quantitative aspects, electrolytic dissociation, Conductance and its measurements, ionic migration and transference numbers, Electrochemical cells, cell reaction. Nernst equation, potentiometric titration of redox reactions.

3. **Chemical Kinetics:** Reaction rates, its measurement, rate law, rate equation, factors that influence the rate, order, molecularity of simple reaction, Simple collision theory, activation energy, Arrhenius equation, Catalysis (simple treatment).

4. **Macromolecules:** Methods for determining the size, shape and molecular mass of macromolecules, sedimentation, viscosity, electrophoresis, Solubility of protein in solution, the hydrophobic-bond, protein determination.

5. **Photochemistry and Photobiology:** Photosynthesis, chrlorophyl molecules, Biochemical reaction, chemifluminesence and bioluminescence.

6. **Elements of Molecular Spectroscopy:** Vibrational energy, electronic energy, transitions, IR and UV-visible spectrometers, intensity of spectral bands, Beer-Lambert law quantitative analysis structure determination,fluorescence and phosphorescence.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Apply the concept of thermodynamics and chemical equilibrium to the biological processes and calculate different thermodynamic parameters.
(ii) Write cell reaction, cell notation and Nernst equation for an electrochemical cell.
(iii) Illustrate different phenomena such as Joule-Thomson effect, catalysis, sedimentation, electrophoresis, photosynthesis, flourescence, phosphorescence, chemiluminesence and bioluminesence.
(iv) Determine the size, shape and molar mass of macromolecules.
(v) Apply knowledge on different spectroscopic techniques for both qualitative and quantitative determination and structure elucidation.

**Books Recommended**

1. Principles of Physical Chemistry, M. M. Huque and M. A. Nawab.
2. Physical Chemistry, G. W. Castellan.
3. A Text Book of Physical Chemistry, S. Glasstone.

4. Elements of Physical Chemistry, S. Glasstone and D. Lewis.
5. Physical Chemistry, P. W. Atkins.
6. Physical Chemistry with application to Biological system, Raymond Chang.
7. Comprehensive Chemistry,J. Hicks.

**CML 203 Physical Chemistry Laboratory Course (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Familiarize with and use of common laboratory equipment such as an analytical balance, pipette, volumetric flask, burette, pH meter, conductometer, centrifuge machine etc.
(ii) Impart practical knowledge on solubility, equilibrium constant, solubility products and colligative properties.
(iii) Give knowledge on the rate law, and determination of order of reaction.
(iv) Communicate calorimetric determination of enthalpy change in a chemical reaction and conductance behavior of electrolytes.
(v) Acquaint with the distribution of a solute between two immiscible solvents.

**Course Content**

**1.** Determination of molecular weight of a volatile liquid by Dumas method.

**2.** Determination of heat of solution of a solid calorimetrically.

**3.** Determination of heat of neutralization of a strong acid and a strong alkali calorimetrically.

**4.** Determination of partition coefficient of iodine between water and dichloromethane.

**5.** Determination of equilibrium constant of the reaction $I^-(aq) + I_2(aq) \rightleftharpoons I_3^-(aq)$.

**6.** Determination of solubility product of sparingly soluble salt.

**7.** Determination of strength of a strong acid by conductometric titration.

**8.** Determination of molecular weight by freezing point depression.

**9.** Determination of heat of solution of a solid by solubility measurement.

**10.** Determination of the e.m.f. of galvanic cells.

**11.** Colorimetric determination of metal ions in solution.

**12.** Determination of pH of aqueous solutions.

**13.** Determination of the order and rate constant of chemical reactions.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Determine molecular weight of a volatile liquid.
(ii) Understand the kinetics of some chemical reactions.
(iii) Appreciate Hess's law and calorimetric determination of enthalpy change in a chemical reaction
(iv) Understand the conductance behavior of strong and weak electrolytes.
(v) Investigate the distribution equilibria of a solute in two immiscible solvents and determine solubility product of various salts.

**Books Recommended**

1. Practical Physical Chemistry, A. Findlay.
2. Experimental Physical Chemistry, G. P. Matthews.
3. Experiments in Physical Chemistry, F. Daniels, J. H. Matthews, P. Bender and R. A. Alberty.

**CM 221 Stereochemistry and Organic Reaction Mechanism(2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart knowledge onthe basic concepts of stereochemistry.
(ii) Acquire concepts ongeometrical and optical isomerism, configuration and conformation.
(iii) introduce key concepts of organic reaction mechanism
(iv) Develop an understanding ofthemechanism of typical organic reactions, including nucleophilic and electrophilic substitution,nucleophilic and electrophilicaddition and elimination reactions.

**Course Content**

**(a) Stereochemistry**

1. **Stereochemistry and Stereoisomerism:** Different types of isomerism - structural and functional group isomerism, geometrical and optical isomerism.

2. **Geometrical Isomerism:***Cis*/*trans* (*E/Z*) and *syn*/*anti* isomers of compounds containing carbon-carbon, carbon-nitrogen and nitrogen-nitrogen double bonds and in cyclic compounds, condition of geometrical isomerism, properties of geometrical isomers and determination of configuration of geometrical isomerism.

3. **Optical Isomerism:** optical activity and optical isomerism, cause of optical activity, plane polarized light, optical rotation, specific rotation, chirality of a molecule, asymmetry and dissymmetry, enantiomer, diastereoisomer, meso compound and racemic mixture.

4. **Configuration and Conformation:**D-L and R-S configurations, configurational assignment of compounds having one and two chiral carbons, conformers of ethane, butane, cyclopentane and cyclohexane.

**(b) Reaction Mechanism**

1. Nucleophilic substitution at a saturated carbon atom, $S_N1$ and $S_N2$ mechanism, their kinetics, thermodynamics and stereochemistry, $S_N1$ vs $S_N2$ mechanism and their stereochemistry.
2. Electrophilic substitution in aromatic system, mechanism of nitration, halogenation and alkylation.
3. Electrophilic addition reaction in carbon-carbon double bond, mechanism of addition of halogens and halogen acids, addition of hydrogen halide to unsymmetrical alkenes, mechanism of *cis* addition to carbon-carbon double bonds ($KMnO_4$, $OsO_4$).
4. **Nucleophilic Addition to Carbon-Oxygen Double Bond:** addition of HCN, $NH_2OH$, $H_2NNH_2$, $PhNHNH_2$, $H_2NNHCONH_2$ to carbonyl compounds.
5. Mechanism of condensation reactions of carbonyl compounds.
6. Mechanism of dehydration of alcohols, mechanism of elimination of alkylhalides (E1 and E2 reactions), their stereochemistry and orientation.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand the chiralityand elements of symmetry in organic chemistry, polarimetry, and optical activity.
(ii) Understand geometric and optical isomerism and distinguish among enantiomers, diastereomers and meso compounds.
(iii) Gain knowledge of conformational and configurational isomerism, conformers of ethane, butane, cyclopentane and cyclohexane.
(iv) Learn about mechanisms of major classes of organic reactions, including substitution, elimination, and addition reactions.
(v) Develop skills in writing reasonable mechanistic schemes for organic reactions.

**Books Recommended**


1. Organic Chemistry, R.T. Morrison and R. N. Boyd, and Problems and Their Solution in Organic Chemistry.
2. Organic Chemistry, S. H. Pine and J. B. Handrickson.
3. Organic Chemistry, I. L. Finar, Vol. 1 and 2, and Problems and Their Solution in Organic Chemistry.
4. A Textbook of Organic Chemistry,M. U. Ahmed and A. J. Mian.
5. Fundamentals of Organic Chemistry,T.W. Solomons.

6. Introduction to Organic Chemistry, A. Streitwieser and C.H. Heathcock.
7. Advanced Organic Chemistry (Bengali), J.C. Roy.

**CM 222 Biologically Important Organic Compounds (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Introduce to various fundamentals and important biologicalmacro-molecules, including proteins, carbohydrates and nucleic acids.
(ii) Discuss the chemistry of common vitamins, their structures, and beneficial effects.
(iii) Discuss about theoretical concepts of chemical synthesis of drugmolecules and their biological action.
(iv) Learn about the pesticides and their risks.

**Course Content**

1. **Fats and Oils:** Occurrence, composition of fats and oils, hydrolysis of fats and oils, various uses of fats and oils, saponification of fats and oils, iodine value and saponification value of fats and oils, saturated and unsaturated fatty acids.

2. **Amino Acids, Peptides and Proteins:** Structure and configuration of amino acids, isoelectric points, preparations and reactions of amino acids and peptides, C-terminal and N-terminal residues of peptides, proteins, their classifications and functions, basic structure of protein.

3. **Carbohydrates:**Definition, classification and constitution of monosaccharides, ring structure of monosaccharides and their conformations, action of acids and bases on sugars, epimers, anomers and anomeric configurations, reaction of monosaccharides, di-and tri-saccharides, their structures and compositions, polysaccharides - cellulose, starch and their constituents.

4. **Vitamins:** Occurrence, symptoms due to deficiency of vitamins, chemistry of vitamins A, $B_1$, $B_2$, $B_6$, $B_{12}$, E and K and their structures.

5. **Synthesis of the Following Drugs and Their Actions in Biological Systems:** Sulpha drugs - sulfonamide, sulphapyridine, sulpha-guanidine, sulphadiazine, sulphamethazine and sulphathiazole.

6. **Antimalarials:** Plasmaquin, mepacrine, proguanil and quinine. **Antibiotics:** Penicillin, amoxicillin, streptomycin, chloromycetin etc.

7. **Insecticides, Fungicides and Herbicides:**(i) Organochlorine compounds - DDT, gammexane, methoxychlor and heptachlor,(ii) Organophosphorus compounds - malathion, parathion, dimecron and

diazinon, (iii) carbamates:2,4-D(2,4-dichlorophenoxyacetic acid) and 2,4,5-T (2,4,5-trichlorophenoxylacetic acid).

8. **Organic Pollutants**.

9. **Purines and Nucleic Acids:** Structure of uric acid, nucleosides and nucleotides, DNA and RNA.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Compare the functions and chemical compositions of the major groups of organic compounds: proteins, carbohydrates and nucleic acids.
(ii) Provide knowledge concerning the strategy drug design, synthesis,structure and activity relationships and biological activity of drugs.
(iii) Compare the signs and symptoms of malarial, identify the most commonly used antimalarial drugs.
(iv) Understand therapeutic effects, side effects, and administration routes of major antibiotics.
(v) State the origin, environmental transport and fate of some specific pesticides.

**Books Recommended**


1. Organic Chemistry, R.T. Morrison and R. N. Boyd, and Problems and Their Solution in Organic Chemistry.
2. Organic Chemistry, S. H. Pine and J. B. Handrickson.
3. Organic Chemistry (Vol. 1 and 2),I.L. Finar,and Problems and Their Solution in Organic Chemistry.
4. A Textbook of Organic Chemistry,M.U. Ahmed and A. J. Mian.
5. Fundamentals of Organic Chemistry T. W. Solomons.
6. Introduction to Organic Chemistry,A. Streitwieser and C.H. Heathcock.
7. Advanced Organic Chemistry,J. C. Roy, (In Bangla).


**CML 223Organic Chemistry Laboratory (2 Credits)**

**Learning Objective**

The learning objectives of this course are to

(i) Acquaint students with some common experimental techniques in organic chemistry.
(ii) Aware how to synthesize the simple organic compound and purify the crude product by different purification methods.
(iii) Demonstrate the estimation and detection of the functional groups by chemical tests and impart knowledge on simple chromatographic technique like thin layer chromatography (TLC).

**Course Content**

**1.** Preparation of: (i) *p*-nitroacetanilide from acetanilide, (ii) *t*-butyl chloride from *t*-butyl alcohol,(iii)*p*-nitrophenylamine from *p*-nitro-acetanilide.

**2.** Identification of organic compounds containing mono and bifunctional groups: (a) Detection of elements (N. S and halogen) in organic compounds, (b) Solubility test with water (hot and cold), 5% aqueous sodium hydrogen carbonate, sodium hydroxide, hydrochloric acid and conc. sulphuric acid, (c) Detection of functional group, (d) Derivatives/Specific test, (e) Determination of melting point, mixed melting point/boiling point, (f) Name and structure, the following organic compounds will be considered for identification: 1-butanol, 2-butanol, 2-methyl-2-propanol, phenol, propanone, acetophenone, benzophenone, methanal, ethanal, benzaldehyde, methanoic acid, ethanoic acid, benzoic acid, phenylamine, phenyl-methylamine, diphenylamine, nitrobenzene, 1-nitronaphthalene, 1-naphthol, 2-naphlthol, 1-naphthylamine, chlorobenzene, dichlorobenzene, urea, thiourea, naphthalene and anthracene,*p*-nitroaniline, *o*-nitroaniline, *o*-hydroxybenzoic acid, *p*-hydroxybenzoic acid,*o*-nitrobenzoic acid, *p*-nitrobenzoic and *m*-nitrobenzoic acids.

**3.** Detection of sugars and amino acids by paper and thin layer chromatography (TLC).

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Handle the simple apparatus/equipments safely.
(ii) Understand how to prepare different compounds mentioned in the content in the laboratory.
(iii) Understand how to work up with the products.
(iv) Check the purity of the products using various physico-chemical parameters like melting temperature, boiling temperature, etc.
(v) Purify the impure or crude solid as well as the liquid products by different chemical methods.

**Books Recommended**

1. A Textbook of Practical Organic Chemistry, A. I. Vogel.
2. A Handbook of Organic Analysis, H. T. Clarke

**CM 241 Chemistry of the Elements (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Aware the fundamentals of the chemistry of the main group elements, transition elements and their compounds.
(ii) Define metallurgy and how to extract metal from its ores.
(iii) Impart knowledge on the coordination compounds, their bonding models, structures, and applications.
(iv) Acquaint with the significant of noble gases.
(v) Discuss the fundamentals of radioactive decay, nuclear reactions, nuclear reactors, etc.

**Course Content**

1. **Chemistry of the Representative Elements:** Chemistry of alkali and alkaline earth metals, chemistry of elements of Gr IIIA-VIIA with particular reference to B and Al, C and Si, N and P, O and S and chemistry of the halogens.

2. **Metallurgy of Some Selected Elements:** Occurrence and extraction of Mg, Al, Cr, Fe, Ni, Cu, Au, Zn, Sn and Pb.

3. **The First Transition Series and the Lanthanides:** The metals and their oxidation states,aqueous chemistry, chemistry of their oxides and halides, lanthanides and actinides - their occurrence and isolation, general features, oxidation states, oxides and hydroxides, aquo ions and oxo salts.

4. **Coordination Chemistry:** Coordination compounds, ligands, coordination number, nomenclature, structures of complex compounds: Werner's primary and secondary valency concept, Sidwick's electronic concept, valence bond theory, stability of coordination compounds, isomerism in coordination compounds, coordination compounds in biological systems.

5. **Inert Gases:** Occurrence and isolation, chemistry of xenon and other noble gases, and their application.

6. **Elements of Radiochemistry:** Discovery of radioactivity, natural and artificial radioactivity, concept of half life and average life of radioelements, radioactive decay, isotopes and their uses, nuclear reactions, nuclear reactors - working principle and uses.

**Learning Objectives**

Upon completion of this course, the students will be able to

(i) Explain the chemistry of alkaline and alkaline earth metals and preparations and uses of their compounds.
(ii) Know the principles of extract different metals from their ores.
(iii) Understand about the chemistry ofmain and inner transition elements in the periodic table and their compounds.

(iv) Express the chemistry of coordination compounds and their uses in various aspects of life.
(v) Statethe chemistry of inert gases andtheir uses.
(vi) Know the properties of an atomic nucleus that make it unstable and undergo nuclear decay.

**Books Recommended**

1. Concise Inorganic Chemistry, J. D. Lee.
2. Modern Inorganic Chemistry, R. D. Madan.
3. Basic Inorganic Chemistry, F. A. Cotton, G. Wilkinson and P. L. Gaus.
4. Introduction to Modern Inorganic Chemistry, S. Z. Haider.
5. Chemistry, S. S. Zumdahl.

**CM 242 Materials Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to
(i) Know the chemistry of the field of materials.
(ii) Understand the structure, properties, processing and performance of materials systems.
(iii) Explain the differences in properties of different materials, including metals, alloys, ceramics, polymers and composites.
(iv) Describe the properties of materials to microstructure.

**Course Content**

1. **Introduction to Material Science:** Solid state reaction, general principles, crystallization from solutions and melts, glasses and gels, vapour phase transport methods, preparation of thin films, growing single crystals, high pressure and hydrothermal methods.

2. **Chemistry of Materials:** Thin layers, molecular sieves, extended inorganic solids, superlattice reactants, semiconductors, superconductors, optical materials, ceramics, polymer composites, aspects to materials related activity, importance of materials science, development of advanced-performance materials, chemistry of silicon and germanium - extraction, purification, physical and chemical properties, important compounds of silicon and germanium, silicates, classification of silicates, silicates in technology.

3. **High-conductivity, Solid Polymeric Electrolytes:** Conductivity of simple salt-polyether systems, processing polymeric electrolytes, categories of polymeric electrolytes, copolymers, polymer blends, polymers with inert fillers, plasticized systems.

4. **Molecular Magnets:** Magnetic behaviour, structure and magnetic properties of electron donor and acceptor salts, models for molecules based magnetic materials, high spin molecules, room temperature polymeric magnet.

5. **Catalytic Materials:** Materials used as catalysts, forms of catalytic materials, constituents of catalyst particles, preparation of catalytic materials, polymer supported catalysts, catalytic membranes.

6. **Oxide Superconductors:** Nature of oxide superconductors, metastability, theories of superconductivity, applications of oxide superconductors.

7. **Inorganic Biomaterials:** Biomaterials to repair the body, interfacial instability, bioceramics, porous implants.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(v) Gain ideas on the basic properties, characteristics and constituents of composite materials.
(vi) Apply knowledge of the structure, properties, performance, and processing of materials to solve complex engineering problems.
(vii) Apply the basic principles of material selection to specific application.

**Books Recommended**

1. Solid State Chemistry and Its Applications, A. R. West.
2. Inorganic Solids, D. M. Adams.
3. An Introduction to Crystal Chemistry, R. C. Evans.
4. Materials Chemistry, L. V. Interrante, L. A. Casper and A. B. Ellis edited.
5. Advances in Chemistry Series 245, American Chemical Society, Washington, DC 1995.

**CML 243 Quantitative Inorganic Analysis (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Make distinction between qualitative and quantitative chemical analysis.
(ii) Application of statistical methods for the evaluation of laboratory data.
(iii) Methods for calibration and sampling applied to quantitative analysis.
(iv) Understand the analytical methods based on different types of titrations and separations at an introductory level.

**Course Content**

1. **Measurement and Significant Figures in Data Collection and Processing:** Introduction to an analytical balance, significant figures, rounding off, etc., determination of the density of water at room temperature and at a temperature between 60-70$^{o}$C, determination of the density of ethanol at room temperature, determination of the volume and mass of one drop of water and of one drop of ethanol, determination of the volume of a piece of stone.

2. **Accuracy, Precision and Error in Mass and Volume Measurements:** Introduction to accuracy, precision, error, propagation of errors, etc., weighing the small nails supplied using an analytical balance, calibrating a 10.0 mL pipette, application of statistics in evaluating the weighing data and the volume data, comparing the precision obtained in the measurement of mass and volume.

3. **Titrimetric or Volumetric Analysis:** Principle, types of volumetric analysis,

(i) *Neutralization Method:* Standardization of sodium hydroxide solution using a solution of oxalic acid as a primary standard titrant, standardization of hydrochloric acid using standard sodium hydroxide solution, determination of carbonate in washing soda using phenolphthalein end point, determination of bicarbonate in baking powder using methyl orange end point, determination of Vitamin C in a Vitamin C tablet, determination of acetic acid in vinegar, determination of acetylsalicylic acid in aspirin, determination of total acid in lemon juice.

(ii) *Oxidation–Reduction Method:* Standardization of potassium permanganate using standard oxalic acid solution, determination of Fe(II) using standard permanganate solution, determination of Fe(II) using potassium dichromate solution as primary standard titrant, determination of Fe(III) using dichromate solution.

(iii) *Iodometric Method:* Standardization of sodium thiosulphate solution using standard dichromate solution, iodometric determination of copper, iodometric determination of Fe(III) using $Cu_2I_2$ as catalyst, determination of available chlorine in bleaching powder.

(iv) *Precipitation Method:* Preparation of standard silver nitrate solution, standardization of ammonium or potassium thiocyanate solution, determination of chloride by Volhard's method.

4. **Gravimetric Analysis:** Determination of nickel as dimethylglyoximate, sulfate as barium sulfate.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Identify, properly use, and care for equipment and supplies used in analytical laboratory.
(ii) Do statistical analysis and evaluate repeatability of obtained results.
(iii) Perform accurate and precise analysis in the field of analytical chemistry.
(iv) Perform quantitative analysis of known standards as well as unknown samples.
(v) Design and carry out scientific experiments as well as accurately record and analyze the results of scientific experiments.

**Books Recommended**

1. A Textbook of Quantitative Inorganic Analysis, A. I. Vogel, $3^{rd}/4^{th}$ edition.
2. Fundamentals of Analytical Chemistry, D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch.

**CM 251Basic Analytical Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Familiar with some validation parameters used in analytical methods.
(ii) Impart knowledge on sampling and dealing with the sample for analysis.
(iii) Give general idea on different reactions equilibrium and application of these reactions for quantitative estimation of various species.
(iv) Deal with the knowledge of chemical separation and their application for quantitative determination by both gravimetric and solvent extraction methods.
(v) Discuss about the complexometric method and some instrumental techniques for quantitative determination of different chemical species.

**Course Content**

1. **Basic Concepts in Analytical Chemistry:** Background aspects, classical and modern concepts of analytical detection and quantification, sensitivity, selectivity, specificity, dilution limit, concentration etc. of chemical reactions, sampling and sample preparation for quantitative analysis.

2. **Chemical Equilibria:** Acid-base equilibria and buffers in analytical chemistry, chemical equilibria in solution, complexation and equilibria, oxidation-reduction reactions in chemical analysis.

3. **Separation Methods:** Precipitation and coprecipitation phenomena, group chemistry for qualitative analysis, solvent extraction, ion-

exchange separation and chromatographic methods, paper and thin layer chromatography.

4. **Complexometric Titrations:** Complexing reagents such as EDTA, NTA, etc., organic reagents in analytical chemistry, metal indicators and their characteristics, limitations of complexometric measurements.
5. **Instrumental Methods of Chemical Analysis:** Molecular spectroscopic methods, atomic spectroscopic methods - atomic absorption and emission, potentiometric analysis.
6. **Errors in Analytical Measurements:** The significant figure convention, accuracy, precision, mean deviation, standard deviation, errors,types of errors, treatment of analytical results, sensitivity and detection limit of an instrument, quality assurance and quality control of analytical results.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Understand some validation parameters used in analytical methods.
(ii) Collect representative sample and preserve for quantitative analysis.
(iii) Describe the various separation methods, their basis and potential use.
(iv) Apply skills in complexometric titration procedure and instrumental methods in analytical inorganic chemistry.
(v) Calculate averages, percent deviations, standard deviation and other statistical data pertaining to measurements.

**Books Recommended**


1. Analytical Chemistry Principles, J. H. Kennedy.
2. Fundamentals of Analytical Chemistry, D. A. Skoog, D. M. West, F. J. Holler and S. R. Crouch.
3. Instrumental Methods of Analysis, H. W. Willard, L. L. Merritt Jr., J. A. Dean and F. A. Settle Jr.
4. Analytical Chemistry, G. D. Christian.
5. Modern Methods of Chemical Analysis, R. L. Pecsok, L. D. Shields, T. Cairns and L. G. McWilliam.
6. A Textbook of Quantitative Inorganic Analysis, A. I. Vogel.


**CM 261 Environmental Chemistry (2 Credits)**

**Learning Objectives**

The learning objectives of this course are to

(i) Impart knowledge of main segments of earth environment and fundamental chemical processes related to problem in these segments.
(ii) Describe the sources, fates and environmental impacts of PCBs, CFCs, and pesticides, air particulate matters, etc.
(iii) Describe the sources, distribution, health effects and remediation of heavy metal pollution.
(iv) Discuss the chemistry of water environment, different types of water pollutants and different water quality parameters and measuring techniques of important parameters like DO, BOD, COD, pH, Eh, hardness, etc.
(v) Explain why chemistry is an integral activity for addressing social, economic, and environmental problems.

**Course Content**

1. **Basic Concepts of Environmental Chemistry and Its Scope:** Fundamental components and structure of the environment: lithosphere, hydrosphere, atmosphere and biosphere and their natural chemical compositions, structure of the biosphere, classification of environmental pollutants - natural and manmade, physical, chemical and biological.

2. **Chemical Pollutants and the Environment:** Nature of chemical pollutants in air, water and soil, primary and secondary pollutants in the atmosphere, acid rain, heavy metals, nutrients (S, N and P), VOCs, PCBs, CFCs, pesticides, etc., oxides of N, S and C, air particulate matters, smog formation, photochemical pollutants.

3. **Sources of Solid Wastes and the Associated Chemical Pollutants:** Municipal, agricultural, and industrial solid wastes, toxic organic micro-pollutants, heavy metals such as arsenic,lead, cadmium, mercury, etc., waste incineration, emission and residues.

4. **Chemistry of Environmental Pollutants:** Chemical equilibria in aquatic environments, interactions of metals, metal oxides and hydroxides, sulfides and carbonates and metal organics in natural waters, physico-chemical processes governing the composition of the atmosphere and natural waters.

5. **Biological Effects of Chemical Pollutants:** Chemical toxicity in biological systems, discussions with specific effects related to overburden of toxic chemicals.

6. **Analytical Chemistry of Chemical Pollutants:** Collection of environmental samples, and measurements of important parameters such as BOD, COD, DO, $E_h$, pH and temperature for water quality assessments, potentiometric and complexometric analysis of water

quality (hardness, nitrate, ammonia, etc.), analysis of gases like $N_2O$, $NO_x$ and $SO_x$ in the atmosphere.

7. **Environmental Impacts:** Greenhouse effect and climate change, marine pollution and its impact on marine resources.

8. **Regulatory Laws:** Clean air act, drinking water standard, food additives and radiation protection laws.

**Learning Outcomes**

Upon completion of this course, the students will be able to

(i) Know the main components and structures of earth environment and impact of various pollutants on dynamic equilibria between these components.
(ii) Acquaint with the chemistry of air environment, different types of air pollutants and their sources, different analytical techniques for measuring air pollutants.
(iii) Understand types of water pollutants, their sources, and fates, and the purpose of water treatment processes.
(iv) Understand of the basic principal of the greenhouse effect, the sources and sinks of the family of greenhouse gases and their implication for climate change.
(v) Discuss environmental regulations and policy.

**Books Recommended**

1. Environmental Chemistry, A. K. De.
2. Environmental Chemistry, S. E. Manahan.
3. Environmental Toxicology, M. Satake, Y Mido, M. S. Sethi, S. A. Iqbal, H. Yasuhisa and S. Taguchi.
4. Air Quality, T. Godish.
5. Fundamental Concepts of Environmental Chemistry, G. S. Sodhi.