Syllabus for M.Sc. Ph.D. Entrance Examination

**M.Sc. Chemistry**
The Syllabus for M.Sc entrance test is based on the existing syllabus of B.Sc. (Hons) in Chemistry under Choice Based Credit System (only core).
Type of question paper in the entrance examination: Multiple Choice Questions (MCQ) with negative marking.

**Ph.D. in Chemistry**
The Syllabus for the Ph.D. entrance test is based on the existing syllabus of M.Sc. in Chemistry as per UGC guidelines.

Type of question paper in the entrance examination: Multiple Choice Questions (MCQ) with negative marking.
Choice Based Credit System (CBCS)

UNIVERSITY OF DELHI

FACULTY OF SCIENCE

UNDERGRADUATE PROGRAMME
(Courses effective from Academic Year 2015-16)

SYLLABUS OF COURSES TO BE OFFERED
Core Courses, Elective Courses & Ability Enhancement Courses

Disclaimer: The CBCS syllabus is uploaded as given by the Faculty concerned to the Academic Council. The same has been approved as it is by the Academic Council on 13.7.2015 and Executive Council on 14.7.2015. Any query may kindly be addressed to the concerned Faculty.

Undergraduate Programme Secretariat
Preamble

The University Grants Commission (UGC) has initiated several measures to bring equity, efficiency and excellence in the Higher Education System of country. The important measures taken to enhance academic standards and quality in higher education include innovation and improvements in curriculum, teaching-learning process, examination and evaluation systems, besides governance and other matters.

The UGC has formulated various regulations and guidelines from time to time to improve the higher education system and maintain minimum standards and quality across the Higher Educational Institutions (HEIs) in India. The academic reforms recommended by the UGC in the recent past have led to overall improvement in the higher education system. However, due to lot of diversity in the system of higher education, there are multiple approaches followed by universities towards examination, evaluation and grading system. While the HEIs must have the flexibility and freedom in designing the examination and evaluation methods that best fits the curriculum, syllabi and teaching–learning methods, there is a need to devise a sensible system for awarding the grades based on the performance of students. Presently the performance of the students is reported using the conventional system of marks secured in the examinations or grades or both. The conversion from marks to letter grades and the letter grades used vary widely across the HEIs in the country. This creates difficulty for the academia and the employers to understand and infer the performance of the students graduating from different universities and colleges based on grades.

The grading system is considered to be better than the conventional marks system and hence it has been followed in the top institutions in India and abroad. So it is desirable to introduce uniform grading system. This will facilitate student mobility across institutions within and across countries and also enable potential employers to assess the performance of students. To bring in the desired uniformity, in grading system and method for computing the cumulative grade point average (CGPA) based on the performance of students in the examinations, the UGC has formulated these guidelines.
CHOICE BASED CREDIT SYSTEM (CBCS):
The CBCS provides an opportunity for the students to choose courses from the prescribed courses comprising core, elective/minor or skill based courses. The courses can be evaluated following the grading system, which is considered to be better than the conventional marks system. Therefore, it is necessary to introduce uniform grading system in the entire higher education in India. This will benefit the students to move across institutions within India to begin with and across countries. The uniform grading system will also enable potential employers in assessing the performance of the candidates. In order to bring uniformity in evaluation system and computation of the Cumulative Grade Point Average (CGPA) based on student’s performance in examinations, the UGC has formulated the guidelines to be followed.

Outline of Choice Based Credit System:

1. **Core Course**: A course, which should compulsorily be studied by a candidate as a core requirement is termed as a Core course.
2. **Elective Course**: Generally a course which can be chosen from a pool of courses and which may be very specific or specialized or advanced or supportive to the discipline/ subject of study or which provides an extended scope or which enables an exposure to some other discipline/subject/domain or nurtures the candidate’s proficiency/skill is called an Elective Course.
   2.1 **Discipline Specific Elective (DSE) Course**: Elective courses may be offered by the main discipline/subject of study is referred to as Discipline Specific Elective. The University/Institute may also offer discipline related Elective courses of interdisciplinary nature (to be offered by main discipline/subject of study).
   2.2 **Dissertation/Project**: An elective course designed to acquire special/advanced knowledge, such as supplement study/support study to a project work, and a candidate studies such a course on his own with an advisory support by a teacher/faculty member is called dissertation/project.
   2.3 **Generic Elective (GE) Course**: An elective course chosen generally from an unrelated discipline/subject, with an intention to seek exposure is called a Generic Elective.
   P.S.: A core course offered in a discipline/subject may be treated as an elective by other discipline/subject and vice versa and such electives may also be referred to as Generic Elective.
3. **Ability Enhancement Courses (AEC)/Competency Improvement Courses/Skill Development Courses/Foundation Course**: The Ability Enhancement (AE) Courses may be of two kinds: AE Compulsory Course (AECC) and AE Elective Course (AEEC). “AECC” courses are the courses based upon the content that leads to Knowledge enhancement. They ((i) Environmental Science, (ii) English/MIL Communication) are mandatory for all disciplines. AEEC courses are value-based and/or skill-based and are aimed at providing hands-on-training, competencies, skills, etc.
   3.1 **AE Compulsory Course (AECC)**: Environmental Science, English Communication/MIL Communication.
   3.2 **AE Elective Course (AEEC)**: These courses may be chosen from a pool of courses designed to provide value-based and/or skill-based instruction.

Project work/Dissertation is considered as a special course involving application of knowledge in solving / analyzing /exploring a real life situation / difficult problem. A Project/Dissertation work would be of 6 credits. A Project/Dissertation work may be given in lieu of a discipline specific elective paper.
Details of courses under B.A (Honors), B.Com (Honors) & B.Sc. (Honors)

<table>
<thead>
<tr>
<th>Course</th>
<th>*Credits</th>
<th>Theory+ Practical</th>
<th>Theory + Tutorial</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I. Core Course</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(14 Papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Core Course Practical / Tutorial*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(14 Papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>II. Elective Course</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(8 Papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1. Discipline Specific Elective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practical/ Tutorial*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 Papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.2. Discipline Specific Elective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practical/ Tutorial*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 Papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.1. Generic Elective/ Interdisciplinary</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 Papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>B.2. Generic Elective</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Practical/ Tutorial*</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(4 Papers)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>• Optional Dissertation or project work in place of one Discipline Specific Elective paper (6 credits) in 6th Semester</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>III. Ability Enhancement Courses</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>1. Ability Enhancement Compulsory</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2 Papers of 2 credit each)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Environmental Science</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>English/MIL Communication</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>2. Ability Enhancement Elective (Skill Based)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(Minimum 2)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>(2 Papers of 2 credit each)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total credit</td>
<td>140</td>
<td></td>
<td>140</td>
</tr>
</tbody>
</table>

Institute should evolve a system/policy about ECA/ General Interest/Hobby/Sports/NCC/NSS/related courses on its own.

* wherever there is a practical there will be no tutorial and vice-versa
# Course Structure (Chemistry-Major)

Details of courses under B.Sc. (Honours)

<table>
<thead>
<tr>
<th>Course</th>
<th>Theory+ Practical</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>I. Core Course Theory (14 Papers)</td>
<td></td>
<td>56</td>
</tr>
<tr>
<td>Core Course Practical (14 Papers)</td>
<td></td>
<td>28</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>84</strong></td>
</tr>
<tr>
<td>II. Elective Course (8 Papers)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>A.1. Discipline Specific Elective (DSE) Theory (4 Papers)</td>
<td>4 × 4=16</td>
<td></td>
</tr>
<tr>
<td>A.2. Discipline Specific Elective (DSE) Practical (4 Papers)</td>
<td>4 × 2=8</td>
<td></td>
</tr>
<tr>
<td>B.1. Generic Elective (GE)/ Interdisciplinary Theory (4 Papers)</td>
<td>4 × 4=16</td>
<td>4 × 5=20</td>
</tr>
<tr>
<td>B.2. Generic Elective (GE) Practical/Tutorial* (4 Papers)</td>
<td>4 × 2=8</td>
<td>4 × 1=4</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td></td>
<td><strong>48</strong></td>
</tr>
</tbody>
</table>

Optional Dissertation or project work in place of one Discipline Specific Elective Paper. (6 credits) in 6th Semester

III. Ability Enhancement Courses (4 Papers)
1. Ability Enhancement Compulsory (2 Papers of 2 credits each)
   - Environmental Science 2 × 2=4
   - English/MIL Communication 2 × 2=4
2. Ability Enhancement Elective (Skill Based) (2 Papers of 2 credits each) (Minimum 2)
   Total: 08

**Total credit**: 140

* Wherever there is a practical there will be no tutorial and vice-versa
<table>
<thead>
<tr>
<th>SEMESTER</th>
<th>COURSE OPTED</th>
<th>COURSE NAME</th>
<th>Credits</th>
</tr>
</thead>
<tbody>
<tr>
<td>I</td>
<td>AEC-I</td>
<td>English Communications/Compulsory Environmental Science</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Core Course-I</td>
<td>Inorganic Chemistry-I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Core Course-I Practical</td>
<td>Inorganic Chemistry-I Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Core Course-II</td>
<td>Physical Chemistry-I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Core Course-II Practical</td>
<td>Physical Chemistry-I Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Generic Elective -1 GE-1</td>
<td>4/5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generic Elective -1 Practical/Tutorial</td>
<td>2/1</td>
<td></td>
</tr>
<tr>
<td>II</td>
<td>AEC-II</td>
<td>Environmental Science</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Core Course-III</td>
<td>Organic Chemistry-I</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Core Course-III Practical</td>
<td>Organic Chemistry-I Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Core Course-IV</td>
<td>Physical Chemistry-II</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Core Course-IV Practical</td>
<td>Physical Chemistry-II Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Generic Elective -2 GE-2</td>
<td>4/5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generic Elective -2 Practical/Tutorial</td>
<td>2/1</td>
<td></td>
</tr>
<tr>
<td>III</td>
<td>Core Course-V</td>
<td>Inorganic Chemistry-II</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Core Course-V Practical</td>
<td>Inorganic Chemistry-II Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Core Course-VI</td>
<td>Organic Chemistry-II</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Core Course-VI Practical</td>
<td>Organic Chemistry-II Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Core Course-VII</td>
<td>Physical Chemistry-III</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Core Course-VII Practical</td>
<td>Physical Chemistry-III Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Skill Enhancement Course -1 SEC-1</td>
<td>2</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generic Elective -3 GE-3</td>
<td>4/5</td>
<td></td>
</tr>
<tr>
<td></td>
<td>Generic Elective -3 Practical/Tutorial</td>
<td>2/1</td>
<td></td>
</tr>
<tr>
<td>IV</td>
<td>Core Course-VIII</td>
<td>Inorganic Chemistry-III</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Course-VIII Practical</td>
<td>Inorganic Chemistry-III Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Core Course-IX</td>
<td>Organic Chemistry-III</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Course-IX Practical</td>
<td>Organic Chemistry-III Lab</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Core Course-X</td>
<td>Physical Chemistry-IV</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Course-X Practical</td>
<td>Physical Chemistry-IV Lab</td>
<td>2</td>
</tr>
<tr>
<td>Course Type</td>
<td>Code</td>
<td>Title</td>
<td>Credits</td>
</tr>
<tr>
<td>-----------------------------</td>
<td>------</td>
<td>--------------------------------------------</td>
<td>---------</td>
</tr>
<tr>
<td>Skill Enhancement Course</td>
<td>-2 SEC</td>
<td>-2</td>
<td></td>
</tr>
<tr>
<td>Generic Elective</td>
<td>GE-4</td>
<td>Generic Elective</td>
<td>4/5</td>
</tr>
<tr>
<td>Generic Elective</td>
<td>Practical</td>
<td>Practical</td>
<td>2/1</td>
</tr>
<tr>
<td>V</td>
<td>-1 DSE</td>
<td>Discipline Specific Elective</td>
<td>4</td>
</tr>
<tr>
<td>Practicals/Tutorials</td>
<td>DSE-1 Lab</td>
<td>Discipline Specific Elective Practical/Tutorial</td>
<td>2</td>
</tr>
<tr>
<td>-2 DSE</td>
<td>DSE-2 Lab</td>
<td>Discipline Specific Elective Practical/Tutorial</td>
<td>2</td>
</tr>
<tr>
<td>VI</td>
<td>-3 DSE</td>
<td>Discipline Specific Elective</td>
<td>4</td>
</tr>
<tr>
<td>Practicals/Tutorials</td>
<td>DSE-3 Lab</td>
<td>Discipline Specific Elective Practical/Tutorial</td>
<td>2</td>
</tr>
<tr>
<td>-4 DSE</td>
<td>DSE-4 Lab</td>
<td>Discipline Specific Elective Practical/Tutorial</td>
<td>2</td>
</tr>
</tbody>
</table>

**Total Credits**: 140

**Core Papers (C): (Credit: 06 each)**

*(4 Lectures/week for Theory and 4 Periods/week for practical)*

1. Inorganic Chemistry I: Atomic Structure & Chemical Bonding (4 + 4)
2. Physical Chemistry I: States of Matter & Ionic Equilibrium (4 + 4)
3. Organic Chemistry I: Basics and Hydrocarbons (4 + 4)
4. Physical Chemistry II: Chemical Thermodynamics and its Applications (4 + 4)
5. Inorganic Chemistry II: s- and p-Block Elements (4 + 4)
7. Physical Chemistry III: Phase Equilibria and Electrochemical Cells (4 + 4)
8. Inorganic Chemistry III: Coordination Chemistry (4 + 4)
10. Physical Chemistry IV: Conductance & Chemical Kinetics (4 + 4)
11. Organic Chemistry IV: Biomolecules (4 + 4)
12. Physical Chemistry V: Quantum Chemistry & Spectroscopy (4 + 4)
13. Inorganic Chemistry IV: Organometallic Chemistry (4 + 4)

**Discipline Specific Elective Papers: (Credit: 06 each) (4 papers to be selected)**

**DSE 1-4**

**DSE 1: Any one of the following**
1. Novel Inorganic Solids (4) + Lab (4)
2. Inorganic Materials of Industrial Importance (4) + Lab (4)

**DSE 2-4: Choose any three of the following**
1. Applications of Computers in Chemistry (4) + Lab (4)
2. Analytical Methods in Chemistry (4) + Lab (4)
3. Molecular Modelling & Drug Design (4) + Lab (4)
4. Polymer Chemistry (4) + Lab (4)
5. Research Methodology for Chemistry (5) + Tutorials (1)
6. Green Chemistry (4) + Lab (4)
7. Industrial Chemicals & Environment (4) + Lab (4)
8. Instrumental Methods of Analysis (4) + Lab (4)
9. Dissertation

**Other Discipline (Four papers of any one discipline)- GE 1 to GE 4**
1. Mathematics (5) + Tut (1)
2. Physics (4) + Lab (4)
3. Economics (5) + Tut (1)
4. Computer Science (4) + Lab (4)

**Skill Enhancement Courses (02 to 04 papers) (Credit: 02 each)- SEC1 to SEC4**

*(Emphasis should be given to Hands on Exercises) (Hands on except for papers 3, 5 and 6)*

1. IT Skills for Chemists
2. Basic Analytical Chemistry
3. Chemical Technology & Society
4. Chemoinformatics
5. Business Skills for Chemists
6. Intellectual Property Rights
7. Analytical Clinical Biochemistry
8. Green Methods in Chemistry
9. Pharmaceutical Chemistry
10. Chemistry of Cosmetics & Perfumes
11. Pesticide Chemistry
12. Fuel Chemistry
Generic Elective Papers (GE) (Minor-Chemistry) (any four) for other Departments/Disciplines: (Credit: 06 each)
1. Atomic Structure, Bonding, General Organic Chemistry & Aliphatic Hydrocarbons (4) + Lab (4)
2. Chemical Energetics, Equilibria & Functional Group Organic Chemistry-I (4) + Lab (4)
4. Chemistry of s- and p-block elements, States of matter and Chemical Kinetics (4) + Lab (4)
5. Chemistry of d-block elements, Quantum Chemistry and Spectroscopy (4) + Lab (4)
6. Organometallics, Bioinorganic chemistry, Polynuclear hydrocarbons and UV, IR Spectroscopy (4) + Lab (4)
7. Molecules of life (4) + Lab (4).

At least two mathematics papers are compulsory for admission for MSc Chemistry in Delhi University.

Discipline (Two Mathematics papers compulsory, two papers of one other discipline may be selected): GE 1 to GE
CORE COURSE (HONOURS IN CHEMISTRY)

SEMESTER I

CHEMISTRY - C I: INORGANIC CHEMISTRY-I
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures


Schrödinger’s wave equation, significance of $\psi$ and $\psi^2$. Quantum numbers and their significance. Normalized and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atom. Radial and angular distribution curves. Shapes of s, p, d and f orbitals.

Pauli’s Exclusion Principle, Hund’s rule of maximum multiplicity, aufbau principle and its limitations.

(14 Lectures)

Periodicity of Elements: Brief discussion of the following properties of the elements, with reference to s & p-block and the trends shown:

(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.

(b) Atomic and ionic radii
(c) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization enthalpy and trends in groups and periods.

(d) Electron gain enthalpy and trends in groups and periods.

(e) Electronegativity, Pauling’s/ Allred Rochow’s scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity.

(16 Lectures)

Chemical Bonding:
(i) Ionic bond: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, Solvation energy.

(ii) Covalent bond: Lewis structure, Valence Bond theory (Heitler-London approach). Energetics of hybridization, equivalent and non-equivalent hybrid orbitals. Bent’s rule,
Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N₂, O₂, C₂, B₂, F₂, CO, NO, and their ions; HCl (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of the following simple molecules and ions containing lone pairs and bond pairs of electrons: H₂O, NH₃, PCl₃, PCl₅, SF₆, ClF₃, I₃, BrF₂⁺, PCl₆⁻, ICl₅⁻ and SO₄²⁻.

Multiple bonding (σ and π bond approach) and bond lengths. Covalent character in ionic compounds, polarizing power and polarizability. Fajan’s rules and consequences of polarization. Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

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

(iv) Weak Chemical Forces: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interaction. Hydrogen bonding (theories of hydrogen bonding, valence bond treatment). Effects of weak chemical forces, melting and boiling points, solubility, energetics of dissolution process.

Reference Books:
- Lee, J.D. Concise Inorganic Chemistry, Pearson Education 2010

Practical C – I Lab: 60 Lectures
(A) Titrimetric Analysis

(i) Calibration and use of apparatus
(ii) Preparation of solutions of titrants of different Molarity/Normality

(B) Acid-Base Titrations
Principles of acid-base titrations to be discussed.
(i) Estimation of sodium carbonate using standardized HCl.
(ii) Estimation of carbonate and hydroxide present together in a mixture.
(iii) Estimation of carbonate and bicarbonate present together in a mixture.
(iv) Estimation of free alkali present in different soaps/detergents
(C) Oxidation-Reduction Titrimetry
Principles of oxidation-reduction titrations (electrode potentials) to be discussed.
(i) Estimation of Fe(II) and oxalic acid using standardized KMnO₄ solution
(ii) Estimation of oxalic acid and sodium oxalate in a given mixture.
(iii) Estimation of Fe(II) with K₂Cr₂O₇ using internal indicator (diphenylamine, N-phenylanthranilic acid) and discussion of external indicator.

Reference Books:
- Vogel, A.I. A Textbook of Quantitative Inorganic Analysis, ELBS.

CHEMISTRY - C II: PHYSICAL CHEMISTRY I
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures
Gaseous state: Kinetic molecular model of a gas: postulates and derivation of the kinetic gas equation; collision frequency; collision diameter; mean free path and viscosity of gases, including their temperature and pressure dependence, relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor, Z, and its variation with pressure and temperature for different gases. Causes of deviation from ideal behaviour. van der Waals equation of state, its derivation and application in explaining real gas behaviour, calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states. (18 Lectures)

Liquid state: Qualitative treatment of the structure of the liquid state; physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases. (6 Lectures)

Solid state: Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg’s law, a simple account of rotating crystal method and
powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl.

(16 Lectures)


(20 Lectures)

**Reference Books:**


**Practical C – II Lab: 60 Lectures**

1. **Surface tension measurements using stalagmometer.**
   
a. Determine the surface tension by (i) drop number (ii) drop weight method.

   b. Study the variation of surface tension with different concentration of detergent solutions. Determine CMC.

2. **Viscosity measurement using Ostwald’s viscometer.**
   
a. Determination of co-efficient of viscosity of an unknown aqueous solution.

   b. Study the variation of co-efficient of viscosity with different concentration of Poly Vinyl Alcohol (PVA) and determine molar of PVA.

   b. Study the variation of viscosity with different concentration of sugar solutions.

3. **Solid State:**
   
a. Indexing of a given powder diffraction pattern of a cubic crystalline system.

4. **pH metry:**
   
a. Study the effect of addition of HCl/NaOH on pH to the solutions of acetic acid, sodium acetate and their mixtures.
b. Preparation of buffer solutions of different pH values i. Sodium acetate-acetic acid ii. Ammonium chloride-ammonium hydroxide

c. pH metric titration of (i) strong acid with strong base, (ii) weak acid with strong base. Determination of dissociation constant of a weak acid.

Any other experiment carried out in the class.

Reference Books:


SEMESTER II

CHEMISTRY - C III: ORGANIC CHEMISTRY I
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

Recapitulation of basics of Organic Chemistry

Hybridization, Shapes of molecules
*Electronic Displacements:* Inductive, electromeric, resonance and mesomeric effects, hyperconjugation Dipole moment; Hydrogen bonding (Applications to be discussed with relevant topics)
Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Types, shape and relative stability of Carbocations, Carbanions, Free radicals and Carbenes. 
Introduction to types of organic reactions: Addition, Elimination and Substitution reactions. 

(6 Lectures)

Stereochemistry:

Fischer,Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: cis–trans , syn-anti and E/Z notations with C.I.P rules.
Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixture and their resolution. Relative and absolute configuration: D/L and R/S designations.  

(18 Lectures)

Chemistry of Aliphatic Hydrocarbons

A. Carbon-Carbon sigma bonds


B. Carbon-Carbon pi bonds:

General methods of preparation, physical and chemical properties of alkenes and alkynes, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations. Electrophilic additions their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroboration- oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation(oxidation). 1,2-and 1,4-addition reactions in conjugated dienes and Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene.

Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions. Hydration to form carbonyl compounds, Alkylation of terminal alkynes.

C. Cycloalkanes and Conformational Analysis

Conformational analysis of alkanes: Relative stability and Energy diagrams. Types of cycloalkanes and their relative stability, Baeyer strain theory: Chair, Boat and Twist boat forms of cyclohexane with energy diagrams; Relative stability of mono substituted cycloalkanes.  

(24 Lectures)

Aromatic Hydrocarbons

Aromaticity: Hückel’s rule, aromatic character of arenes, cyclic carbocations/carbanions and heterocyclic compounds with suitable examples. Electrophilic aromatic substitution: halogenation, nitration, sulphonation and Friedel-Craft’s alkylation/acylation with their mechanism. Directing effects of the groups.

(12 Lectures)

Reference Books:

- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
- Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
Practical C – III Lab: 60 Lectures

1. Checking the calibration of the thermometer
2. Purification of organic compounds by crystallization using the following solvents:
   a. Water
   b. Alcohol
   c. Alcohol-Water
3. Determination of the melting points of unknown organic compounds (Kjeldahl method and electrically heated melting point apparatus)
4. Effect of impurities on the melting point – mixed melting point of two unknown organic compounds
5. Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and capillary method)
6. Chromatography
   a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography
   b. Separation of a mixture of two sugars by ascending paper chromatography
   c. Separation of a mixture of o- and p-nitrophenol or o- and p-aminophenol by thin layer chromatography (TLC)
7. Detection of extra elements
8. Organic Preparations
   (i) Bromination of acetanilide / aniline / phenol
   (ii) Nitration of nitrobenzene / toluene.

Reference Books

CHEMISTRY - C IV: PHYSICAL CHEMISTRY II
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures
Chemical Thermodynamics: Intensive and extensive variables; state and path functions; isolated, closed and open systems.

First law: Concept of heat, Q, work, W, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities, calculations of Q, W, ΔU and ΔH for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Thermochemistry: Heats of reactions: standard states; enthalpy of formation and enthalpy of combustion and its applications; effect of temperature (Kirchhoff’s equations) and pressure on enthalpy of reactions.
**Second Law:** Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics. Calculation of entropy change for reversible and irreversible processes.

**Third Law:** Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules. Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

*(36 Lectures)*

**Systems of Variable Composition:** Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

*(8 Lectures)*

**Chemical Equilibrium:** Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration (Le Chatelier Principle, Quantitatively). Free energy of mixing and spontaneity. equilibrium between ideal gases and a pure condensed phase.

*(8 Lectures)*

**Solutions and Colligative Properties:** Dilute solutions; lowering of vapour pressure, Raoult’s and Henry’s Laws and their applications. Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

*(8 Lectures)*

**Reference Books:**


**Practical C – IV Lab:** **60 Lectures**

**Thermochemistry:**
(a) Determination of heat capacity of a calorimeter for different volumes using (i) change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution of sulphuric acid or enthalpy of neutralization), and (ii) heat gained equal to heat lost by cold water and hot water respectively

(b) Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.

(c) Determination of the enthalpy of ionization of ethanoic acid.

(d) Determination of integral enthalpy (endothermic and exothermic) solution of salts.

(e) Determination of basicity of a diprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also calculate the enthalpy of neutralization of the first step.

(f) Determination of enthalpy of hydration of salt.

(g) Study of the solubility of benzoic acid in water and determination of ∆H.

Any other experiment carried out in the class.

Reference Books:


SEMESTER III

CHEMISTRY - C V: INORGANIC CHEMISTRY II
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

General Principles of Metallurgy

(6 Lectures)
Chemistry of s Block Elements:
(i) General characteristics: melting point, flame colour, reducing nature, diagonal relationships and anomalous behavior of first member of each group.
(ii) Reactions of alkali and alkaline earth metals with oxygen, hydrogen, nitrogen and water.
(iii) Common features such as ease of formation, thermal stability and solubility of the following alkali and alkaline earth metal compounds: hydrides, oxides, peroxides, superoxides, carbonates, nitrates, sulphates.
(iv) Complex formation tendency of s-block elements; structure of the following complexes: crown ethers and cryptates of Group I; basic beryllium acetate, beryllium nitrate, EDTA complexes of calcium and magnesium.
(v) Solutions of alkali metals in liquid ammonia and their properties.

(22 Lectures)

Chemistry of p Block Elements:
Electronic configuration, atomic and ionic size, metallic/non-metallic character, melting point, ionization enthalpy, electron gain enthalpy, electronegativity, Allotropy of C, P, S; inert pair effect, diagonal relationship between B and Si and anomalous behaviour of first member of each group.

(6 lectures)

Structure, bonding and properties: acidic/basic nature, stability, ionic/covalent nature, oxidation/reduction, hydrolysis, action of heat of the following:
- Hydrides: hydrides of Group 13 (only diborane), Group 14, Group 15 (EH$_3$ where E = N, P, As, Sb, Bi), Group 16 and Group 17.
- Oxides: oxides of phosphorus, sulphur and chlorine
- Oxoacids: oxoacids of phosphorus and chlorine; peroxyacids of sulphur
- Halides: halides of silicon and phosphorus

Preparation, properties, structure and uses of the following compounds:
- Borazine
- Silicates, silicones,
- Phosphonitrilic halides {($PNCl_2$)$_n$ where $n$ = 3 and 4}
- Interhalogen and pseudohalogen compounds
- Clathrate compounds of noble gases, xenon fluorides (MO treatment of XeF$_2$).

(26 Lectures)

Reference Books:
- Lee, J.D. Concise Inorganic Chemistry, Pearson Education 2010
Practical C – V Lab: 60 Lectures

(A) Iodo / Iodimetric Titrations

(i) Estimation of Cu(II) and K₂Cr₂O₇ using sodium thiosulphate solution (Iodometrically).
(ii) Estimation of antimony in tartar-ematic iodimetrically

(B) Complexometric titrations using disodium salt of EDTA

(i) Estimation of Mg²⁺, Zn²⁺
(ii) Estimation of Ca²⁺ by substitution method

(C) Inorganic preparations

(i) Cuprous Chloride, Cu₂Cl₂

(ii) Manganese(III) phosphate, MnPO₄.H₂O

(iii) Aluminium potassium sulphate KAl(SO₄)₂·12H₂O (Potash alum) or Chrome alum.

Reference Books:
- Vogel, A.I. A Textbook of Quantitative Inorganic Analysis, ELBS. 1978

CHEMISTRY - C VI: ORGANIC CHEMISTRY II
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures
Chemistry of Halogenated Hydrocarbons:

*Alkyl halides:* Methods of preparation and properties, nucleophilic substitution reactions – S⁻¹, S⁻² and S⁻ił mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.

*Aryl halides:* Preparation (including preparation from diazonium salts) and properties, nucleophilic aromatic substitution; SNAr, Benzyne mechanism.

Relative reactivity of alkyl, allyl, benzyl, vinyl and aryl halides towards nucleophilic substitution reactions.

Organometallic compounds of Mg (Grignard reagent) – Use in synthesis of organic compounds. (16 Lectures)

*Alcohols, Phenols, Ethers and Epoxides:*
Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-BlancReduction; Oxidation of diols by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement;

Phenols: Preparation and properties; Acidity and factors effecting it, Ring substitution reactions, Reimer–Tiemann and Kolbe’s–Schmidt Reactions, Fries and Claisen rearrangements with mechanism;

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and LiAlH₄

(16 Lectures)

Carbonyl Compounds:

Structure, reactivity, preparation and properties;
Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α - substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner,LiAlH₄, NaBH₄, MPV, PDC)

Addition reactions of α, β- unsaturated carbonyl compounds: Michael addition.

Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

(16 Lectures)

Carboxylic Acids and their Derivatives:

General methods of preparation, physical properties and reactions of monocarboxylic acids, effect of substituents on acidic strength. Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids.

Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilicsustitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann- bromamide degradation and Curtius rearrangement.

(12 Lectures)

Reference Books:
• Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

Practical C – VI Lab:  60 Lectures
1. Functional group tests for alcohols, phenols, carbonyl and carboxylic acid group.
2. Organic preparations:
i. Acetylation of one of the following compounds: amines (aniline, o-, m-, p- toluidines and o-, m-, p-anisidine) and phenols (β -naphthol, vanillin, salicylic acid) by any one method:
   a. Using conventional method.
   b. Using green approach

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

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

iv. Selective reduction of meta dinitrobenzene to m-nitroaniline.

v. Hydrolysis of amides and esters.

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

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

viii. Aldol condensation using either conventional or green method.

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

Reference Books:

CHEMISTRY - C VII: PHYSICAL CHEMISTRY III
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures
Phase Equilibria: Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems (H₂O and S), with applications. Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points. Three component systems: triangular plots, water-chloroform-acetic acid system. Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible
liquids (ideal and non ideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs, steam distillation. Nernst distribution law: its derivation and applications.  

**Electrochemical Cells:** Rules of oxidation/reduction of ions based on half-cell potentials, applications of electrolysis in metallurgy and industry. Chemical cells, reversible and irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb2O3 electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation).  

**Surface chemistry:** Physical adsorption, chemisorption, adsorption isotherms (Langmuir and Freundlich). nature of adsorbed state. Qualitative discussion of BET.  

**Reference Books:**

**Practical C – VII Lab: 60 Lectures**

**Phase Equilibria:**
I. Determination of critical solution temperature and composition at CST of the phenol-water system and to study the effect of impurities of sodium chloride and succinic acid on it.
II. Phase equilibria: Construction of the phase diagram using cooling curves or ignition tube method: a. simple eutectic and b. congruently melting systems.
III. Distribution of acetic/benzoic acid between water and chloroform or cyclohexane.
IV. Study the equilibrium of at least one of the following reactions by the distribution method:
   (i) \( I_2 \) (aq) + \( I^- \) (aq) \( \rightarrow \) \( I_3^- \) (aq)
   (ii) \( Cu^{2+} \) (aq) + \( nNH_3 \) \( \rightarrow \) \( Cu(NH_3)_n^{2+} \)

**Potentiometry:**
V. Perform the following potentiometric titrations: i. Strong acid vs. strong base ii. Weak acid vs. strong base iii. Dibasic acid vs. strong base iv. Potassium dichromate vs. Mohr's salt

Reference Books:

permanganate, potassium ferrocyanide, potassium ferricyanide, sodium nitroprusside and sodium cobaltinitrite.

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

**Inorganic Reaction Mechanism**
Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans- effect, theories of trans effect. Thermodynamic and Kinetic stability.

**Reference Books:**

**Practical C – VIII Lab:** 60 Lectures

**Gravimetric Analysis:**
- Estimation of nickel (II) using Dimethylglyoxime (DMG).
- Estimation of copper as CuSCN
- Estimation of iron as Fe₂O₃ by precipitating iron as Fe(OH)₃.
- Estimation of Al(III) by precipitating with oxine and weighing as Al(oxine)₃ (aluminium oxinate).

**Inorganic Preparations:**
- Tetraamminecopper (II) sulphate, [Cu(NH₃)₄]SO₄.H₂O
- Acetylacetonate complexes of Cu²⁺/Fe³⁺
- Tetraamminecarbonatocobalt (III) nitrate
- Potassium tri(oxalato)ferrate(III)

**Properties of Complexes**
- Measurement of 10 Dq by spectrophotometric method
- Verification of spectrochemical series.
- Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

**Reference Book:**
CHEMISTRY - C IX: ORGANIC CHEMISTRY III
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

Nitrogen Containing Functional Groups
Preparation and important reactions of nitro compounds, nitriles and isonitriles.
Amines: Preparation and properties: Effect of substituent and solvent on basicity; Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann’s exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3° amines with Hinsberg reagent and nitrous acid.

Diazonium Salts: Preparation and their synthetic applications. (18 Lectures)

Polynuclear Hydrocarbons
Aromaticity of polynuclear hydrocarbons, structure elucidation of naphthalene; Preparation and properties of naphthalene, phenanthrene and anthracene. (8 Lectures)

Heterocyclic Compounds
Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom; Synthesis, reactions and mechanism of substitution reactions of: Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Indole(Fischer indole synthesis and Madelung synthesis), Quinoline and isoquinoline, (Skraup synthesis, Friedlander’s synthesis, Knorr quinoline synthesis, Doebner-Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction) (22 Lectures)

Alkaloids
Natural occurrence, General structural features, Isolation and their physiological action, Hoffmann’s exhaustive methylation, Emde’s modification; Structure elucidation and synthesis of Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine. (6 Lectures)

Terpenes
Occurrence, classification, isoprene rule; Elucidation of stucture and synthesis of Citral. (6 Lectures)

Reference Books:
• Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
• Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
• Acheson, R.M. Introduction to the Chemistry of Heterocyclic compounds, John Wiley & Sons (1976).

Practical C – IX Lab: 60 Lectures
1. Functional group test for nitro, amine and amide groups.
2. Qualitative analysis of unknown organic compounds containing simple functional groups (alcohols, carboxylic acids, phenols, carbonyl compounds and esters)

Reference Books:

CHEMISTRY - C X: PHYSICAL CHEMISTRY IV
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

(18 Lectures)
Chemical Kinetics: Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions. Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates. (22 Lectures)

Catalysis: Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces. Enzyme catalysis, Michaelis-Menten mechanism, acid-base catalysis. (8 Lectures)

Photochemistry: Characteristics of electromagnetic radiation, Lambert-Beer’s law and its limitations, physical significance of absorption coefficients. Laws, of photochemistry, quantum yield, actinometry, examples of low and high quantum yields, photochemical equilibrium and the differential rate of photochemical reactions, photosensitised reactions, quenching. Role of photochemical 34 reactions in biochemical processes, photostationary states, chemiluminescence. (12 Lectures)

Reference Books:


Practical C – X Lab: 60 Lectures

Conductometry:

I. Determination of cell constant
II. Determination of conductivity, molar conductivity, degree of dissociation and dissociation constant of a weak acid.
III. Perform the following conductometric titrations: i. Strong acid vs. strong base ii. Weak acid vs. strong base iii. Mixture of strong acid and weak acid vs. strong base iv. Strong acid vs. weak base

Chemical Kinetics:
IV. Study the kinetics of the following reactions.
   1. Iodide-persulphate reaction (i) Initial rate method; (ii) Integrated rate method
   2. Acid hydrolysis of methyl acetate with hydrochloric acid.
   3. Saponification of ethyl acetate.
   4. Comparison of the strengths of HCl and H$_2$SO$_4$ by studying kinetics of hydrolysis of methyl acetate.

Reference Books:


SEMESTER V

CHEMISTRY - C XI: ORGANIC CHEMISTRY IV
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

Nucleic Acids
Components of nucleic acids, Nucleosides and nucleotides;

Structure, synthesis and reactions of: Adenine, Guanine, Cytosine, Uracil and Thymine; Structure of polynucleotides (DNA and RNA).

(9 Lectures)

Amino Acids, Peptides and Proteins

Amino acids, Peptides and their classification.

α-Amino Acids - Synthesis, ionic properties and reactions. Zwitterions, pK$_a$ values, isoelectric point and electrophoresis;
Study of peptides: determination of their primary structures-end group analysis, methods of peptide synthesis. Synthesis of peptides using N-protecting, C-protecting and C-activating groups. Solid-phase synthesis; primary, secondary and tertiary structures of proteins, Denaturation

(18 Lectures)

Enzymes

Introduction, classification and characteristics of enzymes. Salient features of active site of enzymes. Mechanism of enzyme action (taking trypsin as example), factors affecting enzyme action, coenzymes and cofactors, specificity of enzyme action (including stereospecificity), enzyme inhibitors and their importance.

(6 Lectures)

Lipids

Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenation of fats and oils, Saponification value, acid value, iodine number. Reversion and rancidity.

(8 Lectures)

Concept of Energy in Biosystems


(7 Lectures)

Pharmaceutical Compounds: Structure and Importance

Classification, structure and therapeutic uses of antipyretics: Paracetamol (with synthesis), Analgesics: Ibuprofen (with synthesis), Antimalarials: Chloroquine (with synthesis). An elementary treatment of Antibiotics and detailed study of chloramphenicol, Medicinal values of curcumin (haldi), azadirachtin (neem), vitamin C and antacid (ranitidine).

(12 Lectures)

Reference Books:


Practical C – XI Lab:  60 Lectures
1. Estimation of glycine by Sorenson’s formalin method.
2. Study of the titration curve of glycine.
4. Study of the action of salivary amylase on starch at optimum conditions.
5. Effect of temperature on the action of salivary amylase.
6. Saponification value of an oil or a fat.
7. Determination of Iodine number of an oil/fat.
8. Isolation and characterization of DNA from onion/ cauliflower/peas.

Reference Books:
• Arthur, I. V. Quantitative Organic Analysis, Pearson.

CHEMISTRY - C XII: PHYSICAL CHEMISTRY V
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures
Quantum Chemistry: Postulates of quantum mechanics, quantum mechanical operators and commutation rules, Schrödinger equation and its application to free particle and “particle-in-a-box” (rigorous treatment), quantization of energy levels, zero-point energy and Heisenberg Uncertainty principle; wave functions, probability distribution functions, nodal properties, Extension to two and three dimensional boxes, separation of variables, degeneracy.

Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wave functions. Vibrational energy of diatomic molecules and zero-point energy.


Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus. Setting up of Schrödinger equation for many-electron atoms (He, Li). Need for approximation methods. Statement of variation theorem and application to simple systems (particle-in-a-box, harmonic oscillator, hydrogen atom).

Chemical bonding: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H₂⁺. Bonding and antibonding orbitals. Qualitative extension to H₂. Comparison of LCAO-MO and VB treatments of H₂ (only wave functions, detailed solution not
required) and their limitations. Refinements of the two approaches (Configuration Interaction for MO, ionic terms in VB). Qualitative description of LCAO-MO treatment of homonuclear and heteronuclear diatomic molecules (HF, LiH).

(30 Lectures)

**Molecular Spectroscopy:** Interaction of electromagnetic radiation with molecules and various types of spectra; Born Oppenheimer approximation.

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

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies.

Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.

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


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

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

(30 Lectures)

**Reference Books:**

Practical C – XII Lab: 60 Lectures

Colorimetry:

I. Verify Lambert-Beer’s law and determine the concentration of CuSO₄/KMnO₄/K₂Cr₂O₇ in a solution of unknown concentration.

II. Determine the concentrations of KMnO₄ and K₂Cr₂O₇ in a mixture.

III. Study the kinetics of iodination of propanone in acidic medium.

IV. Determine the amount of iron present in a sample using 1, 10-phenanthroline.

V. Determine the dissociation constant of an indicator (phenolphthalein).

VI. Study the kinetics of interaction of crystal violet/phenolphthalein with sodium hydroxide.

VII. Analysis of the given vibration-rotation spectrum of HCl(g)

Adsorption

VIII. Verify the Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.

UV/Visible spectroscopy:

I. Study the 200-500 nm absorbance spectra of KMnO₄ and K₂Cr₂O₇ (in 0.1 M H₂SO₄) and determine the λ_max values. Calculate the energies of the two transitions in different units (J molecule⁻¹, kJ mol⁻¹, cm⁻¹, eV).

II. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of K₂Cr₂O₇.

III. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.

Reference Books:


CHEMISTRY - C XIII: INORGANIC CHEMISTRY IV
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures
Theoretical Principles in Qualitative Analysis (H₂S Scheme)

Basic principles involved in analysis of cations and anions. Solubility products, common ion effect. Principles involved in separation of cations into groups and choice of group reagents. Interfering anions (fluoride, borate, oxalate and phosphate) and need to remove them after Group II.

(12 Lectures)

Organometallic Compounds
Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands.
Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. \(\pi\)-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding.
Zeise’s salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls.
Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds.
Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.

(26 Lectures)

Bioinorganic Chemistry:
Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on the distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxypeptidase. Excess and deficiency of some trace metals. Toxicity of metal ions (Hg, Pb, Cd and As), reasons for toxicity, Use of chelating agents in medicine, Cisplatin as an anti-cancer drug.

Iron and its application in bio-systems, Haemoglobin, Myoglobin; Storage and transfer of iron.

(14 Lectures)
Catalysis by Organometallic Compounds

Study of the following industrial processes and their mechanism:
1. Alkene hydrogenation (Wilkinson’s Catalyst)
2. Synthetic gasoline (Fischer Tropsch reaction)
3. Polymerisation of ethene using Ziegler-Natta catalyst

(8 Lectures)

Reference Books:
- Vogel, A.I. Qualitative Inorganic Analysis, Longman, 1972
- Cotton, F.A., Wilkinson, G., & Gaus, P.L. Basic Inorganic Chemistry 3rd Ed.; Wiley India,
- Sharpe, A.G. Inorganic Chemistry, 4th Indian Reprint (Pearson Education) 2005
- Purcell, K.F. & Kotz, J.C., Inorganic Chemistry, W.B. Saunders Co. 1977

Practical C – XIII Lab: 60 Lectures

Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested:

\[ \text{CO}_3^{2-}, \text{NO}_3^-, \text{S}^{2-}, \text{SO}_3^{2-}, \text{S}_2\text{O}_3^{2-}, \text{CH}_3\text{COO}^-, \text{F}^-, \text{Cl}^-, \text{Br}^-, \Gamma, \text{NO}_3^-, \text{BO}_3^{3-}, \text{C}_2\text{H}_2\text{O}_4^{2-}, \text{PO}_4^{3-}, \text{NH}_4^+, \text{K}^+, \text{Pb}^{2+}, \text{Cu}^{2+}, \text{Cd}^{2+}, \text{Bi}^{3+}, \text{Sn}^{2+}, \text{Sb}^{3+}, \text{Fe}^{3+}, \text{Al}^{3+}, \text{Cr}^{3+}, \text{Zn}^{2+}, \text{Mn}^{2+}, \text{Co}^{2+}, \text{Ni}^{2+}, \text{Ba}^{2+}, \text{Sr}^{2+}, \text{Ca}^{2+}, \]
Mg$^{2+}$
Mixtures should preferably contain one interfering anion, or insoluble component (BaSO$_4$, SrSO$_4$, PbSO$_4$, CaF$_2$ or Al$_2$O$_3$) or combination of anions e.g. CO$_3^{2-}$ and SO$_3^{2-}$, NO$_2^-$ and NO$_3^-$, Cl$^-$ and Br$^-$, Cl$^-$ and I$^-$, Br$^-$ and I$^-$, NO$_3^-$ and Br$^-$, NO$_3^-$ and I$^-$.
Spot tests should be done whenever possible.

Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:
   i. Ni (II) and Co (II)
   ii. Cu(II) and Cd(II)

Reference Books:
   - Vogel’s Qualitative Inorganic Analysis, Revised by G. Svehla.
   - Vogel, A.I. A Textbook of Quantitative Analysis, ELBS. 1986

---

CHEMISTRY - C XIV: ORGANIC CHEMISTRY V
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures
Organic Spectroscopy

General principles Introduction to absorption and emission spectroscopy.

UV Spectroscopy: Types of electronic transitions, $\lambda_{\text{max}}$, Chromophores and Auxochromes, Bathochromic and Hypsochromic shifts, Intensity of absorption; Application of Woodward Rules for calculation of $\lambda_{\text{max}}$ for the following systems: $\alpha,\beta$-unsaturated aldehydes, ketones, carboxylic acids and esters; Conjugated dienes: alicyclic, homoannular and heteroannular; Extended conjugated systems (aldehydes, ketones and dienes); distinction between cis and trans isomers.

IR Spectroscopy: Fundamental and non-fundamental molecular vibrations; IR absorption positions of O, N and S containing functional groups; Effect of H-bonding, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in functional group analysis.

NMR Spectroscopy: Basic principles of Proton Magnetic Resonance, chemical shift and factors influencing it; Spin – Spin coupling and coupling constant; Anisotropic effects in alkene, alkyne, aldehydes and aromatics, Interpretation of NMR spectra of simple compounds.

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

Occurrence, classification and their biological importance.

Monosaccharides: Constitution and absolute configuration of glucose and fructose, epimers and anomers, mutarotation, determination of ring size of glucose and fructose, Haworth projections and conformational structures; Interconversions of aldoses and ketoses; Killiani- Fischer synthesis and Ruff degradation;
Disaccharides – Structure elucidation of maltose, lactose and sucrose.
Polysaccharides – Elementary treatment of starch, cellulose and glycogen.

Dyes

Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing;

Synthesis and applications of: Azo dyes – Methyl orange; Triphenyl methane dyes - Malachite green and Rosaniline ; Phthalein Dyes – Phenolphthalein; Natural dyes – structure elucidation and synthesis of Alizarin and Indigotin; Edible Dyes with examples.

Polymers

Introduction and classification including di-block, tri-block and amphiphilic polymers;

Polymerisation reactions -Addition and condensation -Mechanism of cationic, anionic and free radical addition polymerization; Metalloocene-based Ziegler-Natta polymerisation of alkenes; Preparation and applications of plastics – thermosetting (phenol-formaldehyde, Polyurethanes) and thermosoftening (PVC, polythene);

Fabrics – natural and synthetic (acrylic, polyamido, polyester); Rubbers – natural and synthetic: Buna-S, Chloroprene and Neoprene; Vulcanization; Polymer additives; Introduction to; Biodegradable and conducting polymers with examples.

Reference Books:
• Billmeyer, F. W. Textbook of Polymer Science, John Wiley & Sons, Inc.
• Finar, I. L. Organic Chemistry (Volume 2: Stereochemistry and the Chemistry of Natural Products), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
Practical C – XIV Lab: 60 Lectures
1. Extraction of caffeine from tea leaves.
2. Preparation of urea formaldehyde resin.
3. Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, e.g. salicylic acid, cinnamic acid, nitrophenols etc.
4. Identification of simple organic compounds by IR spectroscopy and NMR spectroscopy (Spectra to be provided).
5. Preparation of methyl orange.

Reference Books:

Chemistry Discipline Elective Courses

CHEMISTRY-DSE 1: Choose any one of the following:

CHEMISTRY-DSE: NOVEL INORGANIC SOLIDS
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

Synthesis and modification of inorganic solids:


Inorganic solids of technological importance:
Solid electrolytes – Cationic, anionic, mixed Inorganic pigments – coloured solids, white and black pigments.

One-dimensional metals, molecular magnets, inorganic liquid crystals.

Nanomaterials:
Overview of nanostructures and nanomaterials: classification.


Introduction to engineering materials for mechanical construction:
Composition, mechanical and fabricating characteristics and applications of various types of cast irons, plain carbon and alloy steels, copper, aluminum and their alloys like duralumin, brasses and bronzes cutting tool materials, super alloys thermoplastics, thermosets and composite materials.

Composite materials:
Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix
composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

(10 Lectures)

Speciality polymers:


(10 Lectures)

Reference Books:

- Atkins, Peter, Overton, Tina, Rourke, Jonathan, Weller, Mark and Armstrong, Fraser

-----------------------------------------------------------------------------------------------------------

CHEMISTRY PRACTICAL - DSE LAB: NOVEL INORGANIC SOLIDS
60 Lectures

1. Determination of cation exchange method
2. Determination of total difference of solids.
3. Synthesis of hydrogel by co-precipitation method.

Reference Book:


-----------------------------------------------------------------------------------------------------------

CHEMISTRY-DSE: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures
(Compulsory elective)
Silicate Industries
Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

Cermics: Brief introduction to types of ceramics. Superconducting and semiconducting oxides, fullerenes, carbon nanotubes and carbon fibre.

Cements: Manufacture of cement and the setting process, quick setting cements. (16 Lectures)

Fertilizers:
Different types of fertilizers (N, P and K). Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates, superphosphate of lime. (8 Lectures)

Surface Coatings:

Batteries:
Working of the following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell. (10 Lectures)

Catalysis:
General principles and properties of catalysts, homogenous catalysis (catalytic steps and examples) and heterogenous catalysis (catalytic steps and examples) and their industrial applications, Deactivation or regeneration of catalysts.

Application of zeolites as catalysts. (6 Lectures)

Chemical explosives:
Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX). Introduction to rocket propellants. (6 Lectures)

Reference Books:
- Felder, R. M. and Rousseau, R.W., Elementary Principles of Chemical Processes, Wiley
PRACTICALS-DSE LAB: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE
60 Lectures

1. Determination of free acidity in ammonium sulphate fertilizer.
2. Estimation of Calcium in Calcium ammonium nitrate fertilizer.
3. Estimation of phosphoric acid in superphosphate fertilizer.
4. Electroless metallic coatings on ceramic and plastic material.
5. Determination of composition of dolomite (by complexometric titration).
6. Analysis of (Cu, Ni); (Cu, Zn ) in alloy or synthetic samples.
8. Preparation of pigment (zinc oxide).

Reference Books:

- Jain, P. C. and Jain, M. Engineering Chemistry, Dhanpat Rai & Sons, Delhi 2005
CHEMISTRY-DSE 2-4: Choose any three of the following:
CHEMISTRY-DSE: APPLICATIONS OF COMPUTERS IN CHEMISTRY
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

- **Basic Computer system (in brief)** - Hardware and Software; Input devices, Storage devices, Output devices, Central Processing Unit (Control Unit and Arithmetic Logic Unit); Number system (Binary, Octal and Hexadecimal Operating System); Computer Codes (BCD and ASCII); Numeric/String constants and variables. Operating Systems (DOS, WINDOWS, and Linux); Software languages: Low level and High Level languages (Machine language, Assembly language; QBASIC, FORTRAN and C++); Software Products (Office, chemsketch, scilab, matlab, hyperchem, etc.), internet application.

- **Use of Programming Language for solving problems in Chemistry**
  Computer Programming Language- QBASIC, (for solving some of the basic and in turn complicated chemistry problems). QB4 version of QBASIC can be used.

  **Programming Language – QBASIC; Commands:**  INPUT and PRINT Commands; GOTO, If, ELSEIF, THEN and END IF Commands; FOR and NEXT Commands; Library Functions (ABS, ASC, CHR$, EXP, INT, LOG, RND, SQR, TAB and trigonometric Functions), DIM, READ, DATA, REM, RESTORE, DEF FNR, GOSUB, RETURN, SCREEN, VIEW, WINDOW, LINE, CIRCLE, LOCATE, PSET Commands.

  Simple programs using above mentioned commands.

  QBASIC programs for Chemistry problems - Example: plotting van der Waal Isotherms (Simple Problem, available in general text books) and observe whether van der Waal gas equation is valid at temperatures lower than critical temperature where we require to solve a cubic equation and calculation of area under the curves (Complicated Problem, not available in general text books).

  Solution of quadratic equation, polynomial equations (formula, iteration and Newton – Raphson methods, binary bisection and Regula Falsi); Numerical differential, Numerical integration (Trapezoidal rule), Simultaneous equations, Matrix addition and multiplication, Statistical analysis.

  (40 Lecture)

- **Use of Software Products**
Computer Software like Scilab, Excel, etc to solve some of the plotting or calculation problems.

**Basic idea of Molecular Modelling using software like chemsketch, arguslab and Accelerys JDraw etc for geometry optimization and potential energy surface (local and global minima) (15 lecture)**

**Practical: 60 Periods**

- **Computer programs using QBASIC based on numerical methods**
  
  1. Roots of equations: (e.g. volume of gas using van der Waals equation and comparison with ideal gas, pH of a weak acid).
  2. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).
  3. Numerical integration (e.g. entropy/enthalpy change from heat capacity data).
  4. Probability distributions (gas kinetic theory) and mean values.
  5. Matrix operations.
  6. Graphic programs related to Chemistry problems. e.g. van der Waals isotherm, Compressibility versus pressure curves, Maxwell distribution curves, concentration-time graph, pH metric titration curve, conductometric titration curves, Lambert Beer’s law graph, s, p, d orbital shapes, radial distribution curves, etc.

- **Use of Software Products**
  
  1. Computer Software like Scilab and Excel, etc for data handling and manipulation.
  2. Simple exercises using molecular visualization software like Chemskech, Arguslab and Accelerys JDraw, geometry optimization and potential energy surface of molecules like carbon dioxide, water, ethane, cyclohexane and benzene (local and global minima)

**Reference Books:**


CHEMISTRY-DSE: ANALYTICAL METHODS IN CHEMISTRY (Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

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

Optical methods of analysis:(5 Lectures)


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

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers.

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

(25 Lectures)

Thermal methods of analysis:
Theory of thermogravimetry (TG), basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.

(5 Lectures)

Electroanalytical methods:
Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. Techniques used for the determination of $pK_a$ values.

(10 Lectures)

Separation techniques:

Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions.

Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and non-aqueous media.


(15 Lectures)

Reference Books:

(a) Separation of mixtures

(i) Paper chromatographic separation of Co\(^{2+}\) and Ni\(^{2+}\).

(ii) Separation and identification of the amino acids present in the given mixture by paper chromatography. Reporting the Rf values.

II. Solvent Extractions:

(i) To separate a mixture of Ni\(^{2+}\) & Fe\(^{2+}\) by complexation with DMG and extracting the Ni\(^{2+}\)-DMG complex in chloroform, and determine its concentration by spectrophotometry.

Analysis of soil:

(i) Determination of pH of soil. 
(ii) Total soluble salt
(iii) Estimation of calcium, magnesium
(iv) Qualitative detection of nitrate, phosphate

Ion exchange:

(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.

(ii) Separation of amino acids from organic acids by ion exchange chromatography.

III Spectrophotometry

Verification of Lambert-Beer’s law and determination of concentration of a coloured species (CuSO\(_4\), KMnO\(_4\))

Reference Books:

CHEMISTRY-DSE: MOLECULAR MODELLING & DRUG DESIGN
(Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

Introduction to Molecular Modelling:

Force Fields:

Energy Minimization and Computer Simulation:

Molecular Dynamics & Monte Carlo Simulation:

Structure Prediction and Drug Design:

Reference Books:
PRACTICAL- DSE LAB: MOLECULAR MODELLING & DRUG DESIGN
60 Lectures
i. Compare the optimized C-C bond lengths in ethane, ethene, ethyne and benzene. Visualize the molecular orbitals of the ethane σ bonds and ethene, ethyne, benzene and pyridine π bonds.

ii. (a) Perform a conformational analysis of butane. (b) Determine the enthalpy of isomerization of cis and trans 2-butene.

iii. Visualize the electron density and electrostatic potential maps for LiH, HF, N2, NO and CO and comment. Relate to the dipole moments. Animate the vibrations of these molecules.

iv. (a) Relate the charge on the hydrogen atom in hydrogen halides with their acid character. (b) Compare the basicities of the nitrogen atoms in ammonia, methylamine, dimethylamine and trimethylamine.

v. (a) Compare the shapes of the molecules: 1-butanol, 2-butanol, 2-methyl-1-propanol, and 2-methyl-2-propanol. Note the dipole moment of each molecule. (b) Show how the shapes affect the trend in boiling points: (118 °C, 100 °C, 108 °C, 82 °C, respectively).

vi. Build and minimize organic compounds of your choice containing the following functional groups. Note the dipole moment of each compound: (a) alkyl halide (b) aldehyde (c) ketone (d) amine (e) ether (f) nitrile (g) thiol (h) carboxylic acid (i) ester (j) amide.

vii. (a) Determine the heat of hydration of ethylene. (b) Compute the resonance energy of benzene by comparison of its enthalpy of hydrogenation with that of cyclohexene.

viii. Arrange 1-hexene, 2-methyl-2-pentene, (E)-3-methyl-2-pentene, (Z)-3-methyl-2-pentene, and 2,3-dimethyl-2-butene in order of increasing stability.

ix. (a) Compare the optimized bond angles H2O, H2S, H2Se. (b) Compare the HAH bond angles for the second row dihydrides and compare with the results from qualitative MO theory.

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

Reference Books:

CHEMISTRY-DSE: POLYMER CHEMISTRY
(Credits: Theory-06, Practicals-02)

Theory: 60 Lectures
Introduction and history of polymeric materials:
Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.

(4 Lectures)

Functionality and its importance:

(8 Lectures)

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

(8 lectures)

Crystallization and crystallinity:
Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point.

(4 Lectures)

Nature and structure of polymers-Structure Property relationships.

(2 Lectures)

Determination of molecular weight of polymers \((M_n, M_w, \text{etc})\) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.

(8 Lectures)

Glass transition temperature \((T_g)\) and determination of \(T_g\), Free volume theory, WLF equation, Factors affecting glass transition temperature \((T_g)\).

(8 Lectures)

Polymer Solution – Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures.

(8 Lectures)

Properties of Polymers (Physical, thermal, Flow & Mechanical Properties).
Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydiienes, Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly(p-phenylene sulphide polypyrrole, polythiophene)].

(10 Lectures)

Reference Books:
- Seymour’s Polymer Chemistry, Marcel Dekker, Inc.

CHEMISTRY PRACTICAL - DSE LAB: POLYMER CHEMISTRY
60 Lectures
Polymer synthesis
1. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) / Methyl Acrylate (MA) / Acrylic acid (AA).
   a. Purification of monomer
   b. Polymerization using benzoyl peroxide (BPO) / 2,2’-azo-bis-isobutylonitrile (AIBN)
2. Preparation of nylon 6/6
   1. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
      a. Preparation of IPC
      b. Purification of IPC
      c. Interfacial polymerization
   3. Redox polymerization of acrylamide
   4. Precipitation polymerization of acrylonitrile
   5. Preparation of urea-formaldehyde resin
   6. Preparations of novalac resin/resold resin.
   7. Microscale Emulsion Polymerization of Poly(methylacrylate).

**Polymer characterization**
1. Determination of molecular weight by viscometry:
   (a) Polyacrylamide-aq.NaNO2 solution
   (b) (Poly vinyl propyldine (PVP) in water
2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of “head-to-head” monomer linkages in the polymer.
3. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG) (OH group).
5. Determination of hydroxyl number of a polymer using colorimetric method.

**Polymer analysis**
1. Estimation of the amount of HCHO in the given solution by sodium sulphite method
2. Instrumental Techniques
3. IR studies of polymers
4. DSC analysis of polymers
5. Preparation of polyacrylamide and its electrophoresis
   *at least 7 experiments to be carried out.

**Reference Books:**
- Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed.
CHEMISTRY-DSE: RESEARCH METHODOLOGY FOR CHEMISTRY
(Credits: Theory-05, Tutorials-01)

Theory: 75 Lectures

Literature Survey:
Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples.

Information Technology and Library Resources: The Internet and World Wide Web. Internet resources for chemistry. Finding and citing published information. (20 Lectures)

Methods of Scientific Research and Writing Scientific Papers:
Reporting practical and project work. Writing literature surveys and reviews. Organizing a poster display. Giving an oral presentation. Writing scientific papers – justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work. Writing ethics. Avoiding plagiarism. (20 Lectures)

Chemical Safety and Ethical Handling of Chemicals:
Safe working procedure and protective environment, protective apparel, emergency procedure and first aid, laboratory ventilation. Safe storage and use of hazardous chemicals, procedure for working with substances that pose hazards, flammable or explosive hazards, procedures for working with gases at pressures above or below atmospheric – safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals, procedure for laboratory disposal of explosives, identification, verification and segregation of laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals. (12 Lectures)

Data Analysis
The Investigative Approach: Making and Recording Measurements. SI Units and their use. Scientific method and design of experiments.
Electronics
Basic fundamentals of electronic circuits and their components used in circuits of common instruments like spectrophotometers, typical circuits involving operational amplifiers for electrochemical instruments. Elementary aspects of digital electronics.

(10 Lectures)

Reference Books:
- OSU safety manual 1.01.

CHEMISTRY-DSE: GREEN CHEMISTRY (Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

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

(4 Lectures)

Principles of Green Chemistry and Designing a Chemical synthesis

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

- Designing a Green Synthesis using these principles; Prevention of Waste/ byproducts; maximum incorporation of the materials used in the process into the final products, Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions.
- Prevention/ minimization of hazardous/toxic products reducing toxicity risk = (function) hazard x exposure; waste or pollution prevention hierarchy
- Green solvents—super critical fluids, water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents and how to compare greenness of solvents
- Energy requirements for reactions – alternative sources of energy: use of microwaves
and ultrasonic energy

- Selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups;
- Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, bio catalysis, asymmetric catalysis and photo catalysis.
- Prevention of chemical accidents designing greener processes, inherent safer design, principle of ISD “What you don’t have cannot harm you”, greener alternative to Bhopal Gas Tragedy (safer route to carbaryl) and Flixborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation.
- Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

(30 Lectures)

Examples of Green Synthesis/ Reactions and some real world cases

1. Green Synthesis of the following compounds: adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis)
2. Microwave assisted reactions in water: Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols; microwave assisted reactions in organic solvents Diels-Alder reaction and Decarboxylation reaction
3. Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)
5. Designing of Environmentally safe marine antifoulant.
7. An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.
8. Healthier Fats and oil by Green Chemistry: Enzymatic Inter esterification for production of no Trans-Fats and Oils
9. Development of Fully Recyclable Carpet: Cradle to Cradle Carpeting

(16 Lectures)

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

(10 Lecture)

Reference Books:
• Matlack, A.S. *Introduction to Green Chemistry*, Marcel Dekker, 2001

-------------------------------------------------------------------------------------------------------

CHEMISTRY PRACTICAL - DSE LAB: GREEN CHEMISTRY
60 Lectures

1. Safer starting materials

Preparation and characterization of nano particles of gold using tea leaves.

1. Using renewable resources

Preparation and characterization of biodiesel from vegetable oil/waste cooking oil

3. Avoiding waste

Principle of atom economy.

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

Preparation of propene by two methods can be studied

(I) \[ \text{Triethylamine ion + OH} \rightarrow \text{propene + trimethylpropene + water} \]
\[ \text{H}_2\text{SO}_4/\text{H}_2\text{O} \]

(II) \[ \text{1-propanol} \rightarrow \text{propene + water} \]

The other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy.
4. Use of enzymes as catalysts

Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide

Alternative Green solvents

6. Extraction of D-limonene from orange peel using liquid CO$_2$ prepared from dry ice.

7. Mechanochemical solvent free synthesis of azomethines

Alternative sources of energy

8. Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).

9. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Reference Books:

- Kirchoff, M. and Ryan, M.A. *Greener approaches to undergraduate chemistry experiment*. American Chemical Society, Washington DC, 2002
- Ryan, M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC, 2002
- Cann, M.C. and Connelly, M. E. *Real world cases in Green Chemistry*, American Chemical Society, 2008
- Cann, M. C. and Thomas, P. *Real world cases in Green Chemistry*, American Chemical Society, 2008

---

**CHEMISTRY-DSE: INDUSTRIAL CHEMICALS AND ENVIRONMENT**
(Credits: Theory-04, Practicals-02)

**Theory:** 60 Lectures
Industrial Gases and Inorganic Chemicals
Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene.

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

(10 Lectures)

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

(4 Lectures)

Environment and its segments

Water Pollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems. Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc.
Sludge disposal. Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

(30 Lectures)

Energy & Environment
Sources of energy: Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.
Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

(10 Lectures)

Biocatalysis
Introduction to biocatalysis: Importance in “Green Chemistry” and Chemical Industry.

(6 Lectures)

Reference Books:
Delhi.


CHEMISTRY PRACTICAL - DSE LAB: INDUSTRIAL CHEMICALS & ENVIRONMENT

60 Lectures

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD)
3. Determination of Biological Oxygen Demand (BOD)
4. Percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by simple titration method (AgNO$_3$ and potassium chromate).
6. Estimation of total alkalinity of water samples (CO$_3^{2-}$, HCO$_3^-$) using double titration method.
8. Study of some of the common bio-indicators of pollution.
10. Preparation of borax/ boric acid.

*Reference Books:*

---

CHEMISTRY-DSE: INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS

(Credits: Theory-04, Practicals-02)

**Theory: 60 Lectures**

*Introduction to spectroscopic methods of analysis:*

Recap of the spectroscopic methods covered in detail in the core chemistry syllabus: Treatment of analytical data, including error analysis. Classification of analytical methods and the types of instrumental methods. Consideration of electromagnetic radiation.
Molecular spectroscopy:

Infrared spectroscopy:
Interactions with molecules: absorption and scattering. Means of excitation (light sources), separation of spectrum (wavelength dispersion, time resolution), detection of the signal (heat, differential detection), interpretation of spectrum (qualitative, mixtures, resolution), advantages of Fourier Transform (FTIR). Samples and results expected. Applications: Issues of quality assurance and quality control, Special problems for portable instrumentation and rapid detection. UV-Visible/ Near IR – emission, absorption, fluorescence and photoacoustic. Excitation sources (lasers, time resolution), wavelength dispersion (gratings, prisms, interference filters, laser, placement of sample relative to dispersion, resolution), Detection of signal (photocells, photomultipliers, diode arrays, sensitivity and S/N), Single and Double Beam instruments, Interpretation (quantification, mixtures, absorption vs. fluorescence and the use of time, photoacoustic, fluorescent tags).

Separation techniques

Chromatography: Gas chromatography, liquid chromatography, supercritical fluids, Importance of column technology (packing, capillaries), Separation based on increasing number of factors (volatility, solubility, interactions with stationary phase, size, electrical field), Detection: simple vs. specific (gas and liquid), Detection as a means of further analysis (use of tags and coupling to IR and MS), Electrophoresis (plates and capillary) and use with DNA analysis.

Mass spectroscopy:
Making the gaseous molecule into an ion (electron impact, chemical ionization), Making liquids and solids into ions (electrospray, electrical discharge, laser desorption, fast atom bombardment), Separation of ions on basis of mass to charge ratio, Magnetic, Time of flight, Electric quadrupole. Resolution, time and multiple separations, Detection and interpretation (how this is linked to excitation).

Elemental analysis:
Mass spectrometry (electrical discharges).
Atomic spectroscopy: Atomic absorption, Atomic emission, and Atomic fluorescence. Excitation and getting sample into gas phase (flames, electrical discharges, plasmas), Wavelength separation and resolution (dependence on technique), Detection of radiation (simultaneous/scanning, signal noise), Interpretation (errors due to molecular and ionic species, matrix effects, other interferences).

NMR spectroscopy: Principle, Instrumentation, Factors affecting chemical shift, Spincoupling, Applications.

Electroanalytical Methods: Potentiometry & Voltammetry

Radiochemical Methods

X-ray analysis and electron spectroscopy (surface analysis)

Reference books:
- Instrumental Methods of Analysis, 7th ed, Willard, Merritt, Dean, Settle.
- P.W. Atkins: Physical Chemistry.
- G.W. Castellan: Physical Chemistry.
- C.N. Banwell: Fundamentals of Molecular Spectroscopy.
- W.J. Moore: Physical Chemistry.

**PRACTICALS-DSE LAB: INSTRUMENTAL METHODS OF CHEMICAL ANALYSIS**

**60 Lectures**

1. Safety Practices in the Chemistry Laboratory
2. Determination of the isoelectric pH of a protein.
3. Titration curve of an amino acid.
4. Determination of the void volume of a gel filtration column.
5. Determination of a Mixture of Cobalt and Nickel (UV/Vis spec.)
6. Study of Electronic Transitions in Organic Molecules (i.e., acetone in water)
7. IR Absorption Spectra (Study of Aldehydes and Ketones)
8. Determination of Calcium, Iron, and Copper in Food by Atomic Absorption
9. Quantitative Analysis of Mixtures by Gas Chromatography (i.e., chloroform and carbon tetrachloride)
10. Separation of Carbohydrates by HPLC
11. Determination of Caffeine in Beverages by HPLC
12. Potentiometric Titration of a Chloride-Iodide Mixture
13. Cyclic Voltammetry of the Ferrocyanide/Ferricyanide Couple
14. Nuclear Magnetic Resonance
15. Use of fluorescence to do “presumptive tests” to identify blood or other body fluids.
16. Use of “presumptive tests” for anthrax or cocaine
17. Collection, preservation, and control of blood evidence being used for DNA testing
18. Use of capillary electrophoresis with laser fluorescence detection for nuclear DNA (Y chromosome only or multiple chromosome)
19. Use of sequencing for the analysis of mitochondrial DNA
20. Laboratory analysis to confirm anthrax or cocaine
21. Detection in the field and confirmation in the laboratory of flammable accelerants or explosives
22. Detection of illegal drugs or steroids in athletes
23. Detection of pollutants or illegal dumping
24. Fibre analysis

*At least 10 experiments to be performed.*

**Reference Books:**

- Instrumental Methods of Analysis, 7th ed, Willard, Merritt, Dean, Settle.
Skill Enhancement Course (any four) (Credit: 02 each)- SEC1 to SEC4

IT SKILLS FOR CHEMISTS (Credits: 02)
(Hands on Exercises: 60 Lectures)

Mathematics

Fundamentals, mathematical functions, polynomial expressions, logarithms, the exponential function, units of a measurement, interconversion of units, constants and variables, equation of a straight line, plotting graphs.

Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities.


Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms). Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).

Numerical integration (Trapezoidal and Simpson’s rule, e.g. entropy/enthalpy change from heat capacity data).

Computer programming:

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

BASIC programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson’s rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

HANDS ON

Introductory writing activities: Introduction to word processor and structure drawing (ChemSketch) software. Incorporating chemical structures, chemical equations, expressions from
chemistry (e.g. Maxwell-Boltzmann distribution law, Bragg’s law, van der Waals equation, etc.) into word processing documents.

Handling numeric data: Spreadsheet software (Excel), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs. Incorporating tables and graphs into word processing documents. Simple calculations, plotting graphs using a spreadsheet (Planck’s distribution law, radial distribution curves for hydrogenic orbitals, gas kinetic theory- Maxwell-Boltzmann distribution curves as function of temperature and molecular weight), spectral data, pressure-volume curves of van der Waals gas (van der Waals isotherms), data from phase equilibria studies. Graphical solution of equations.

Numeric modelling: Simulation of pH metric titration curves. Excel functions LINEST and Least Squares. Numerical curve fitting, linear regression (rate constants from concentration- time data, molar extinction coefficients from absorbance data), numerical differentiation (e.g. handling data from potentiometric and pH metric titrations, pKa of weak acid), integration (e.g. entropy/enthalpy change from heat capacity data).


Presentation: Presentation graphics

Reference Books:

- Levie, R. de, How to use Excel in analytical chemistry and in general scientific data analysis,

-------------------------------------------------------------------------------------------------------

BASIC ANALYTICAL CHEMISTRY (Credits: 02)  
(Hands on Exercises: 60 Lectures)

Introduction: Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. Presentation of experimental data and results, from the point of view of significant figures.
Analysis of soil: Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators

a. Determination of pH of soil samples.
b. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

Analysis of water: Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods.

a. Determination of pH, acidity and alkalinity of a water sample.
b. Determination of dissolved oxygen (DO) of a water sample.

Chromatography: Definition, general introduction on principles of chromatography, paper chromatography, TLC etc.

Paper chromatographic separation of mixture of metal ion (Ni$^{2+}$ and Co$^{2+}$).

Ion-exchange: Column, ion-exchange chromatography etc.
Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

Suggested Applications (Any one):

a. To study the use of phenolphthalein in trap cases.
b. To analyze arson accelerants.
c. To carry out analysis of gasoline.

Suggested Instrumental demonstrations:

a. Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.
b. Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.
c. Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drink.

Reference Books:
CHEMICAL TECHNOLOGY & SOCIETY (Credits: 02)

(Hands on Exercises: 60 Lectures)

Chemical Technology

Basic principles of distillation, solvent extraction, solid-liquid leaching and liquid-liquid extraction, separation by absorption and adsorption. An introduction into the scope of different types of equipment needed in chemical technology, including reactors, distillation columns, extruders, pumps, mills, emulgators. Scaling up operations in chemical industry. Introduction to clean technology.

Society

Exploration of societal and technological issues from a chemical perspective. Chemical and scientific literacy as a means to better understand topics like air and water (and the trace materials found in them that are referred to as pollutants); energy from natural sources (i.e. solar and renewable forms), from fossil fuels and from nuclear fission; materials like plastics and polymers and their natural analogues, proteins and nucleic acids, and molecular reactivity and interconversions from simple examples like combustion to complex instances like genetic engineering and the manufacture of drugs.

Reference Book:

John W. Hill, Terry W. McCreary & Doris K. Kolb, Chemistry for changing times 13th Ed.

-------------------------------------------------------------------------------------------------------

CHEMOINFORMATICS (Credits: 02)

(Hands on Exercises: 60 Lectures)

Introduction to Chemoinformatics: History and evolution of chemoinformatics, Use of chemoinformatics, Prospects of chemoinformatics, Molecular Modelling and Structure elucidation.

Representation of molecules and chemical reactions: Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and Sdfiles, Libraries and toolkits, Different electronic effects, Reaction classification.
Searching chemical structures: Full structure search, sub-structure search, basic ideas, similarity search, three dimensional search methods, basics of computation of physical and chemical data and structure descriptors, data visualization.

Applications: Prediction of Properties of Compounds; Linear Free Energy Relations; Quantitative Structure-Property Relations; Descriptor Analysis; Model Building; Modeling Toxicity; Structure-Spectra correlations; Prediction of NMR, IR and Mass spectra; Computer Assisted Structure elucidations; Computer Assisted Synthesis Design, Introduction to drug design; Target Identification and Validation; Lead Finding and Optimization; Analysis of HTS data; Virtual Screening; Design of Combinatorial Libraries; Ligand-Based and Structure Based Drug design; Application of Chemoinformatics in Drug Design.

Hands-on Exercises

Reference Books:


-------------------------------------------------------------------------------------------------------

BUSINESS SKILLS FOR CHEMISTS (Credits: 02)

Theory: 30 Lectures

Business Basics
Key business concepts: Business plans, market need, project management and routes to market.

Chemistry in Industry
Current challenges and opportunities for the chemistry-using industries, role of chemistry in India and global economies.

Making money

Financial aspects of business with case studies

Intellectual property

Concept of intellectual property, patents.

References:
www.rsc.org

-------------------------------------------------------------------------------------------------------

INTELLECTUAL PROPERTY RIGHTS (IPR) (Credits: 02)

Theory: 30 Lectures

In this era of liberalization and globalization, the perception about science and its practices has undergone dramatic change. The importance of protecting the scientific discoveries, with commercial potential or the
intellectual property rights is being discussed at all levels – statutory, administrative, and judicial. With India ratifying the WTO agreement, it has become obligatory on its part to follow a minimum acceptable standard for protection and enforcement of intellectual property rights. The purpose of this course is to apprise the students about the multifaceted dimensions of this issue.

**Introduction to Intellectual Property:**

Historical Perspective, Different Types of IP, Importance of protecting IP.

**Copyrights**

Introduction, How to obtain, Differences from Patents.

**Trade Marks**

Introduction, How to obtain, Different types of marks – Collective marks, certification marks, service marks, Trade names, etc.

Differences from Designs.

**Patents**

Historical Perspective, Basic and associated right, WIPO, PCT system, Traditional Knowledge, Patents and Healthcare – balancing promoting innovation with public health, Software patents and their importance for India.

Geographical Indications

Definition, rules for registration, prevention of illegal exploitation, importance to India.

**Industrial Designs**

Definition, How to obtain, features, International design registration.

Layout design of integrated circuits

Circuit Boards, Integrated Chips, Importance for electronic industry.

**Trade Secrets**

Introduction and Historical Perspectives, Scope of Protection, Risks involved and legal aspects of Trade Secret Protection.

**Different International agreements**

(a) Word Trade Organization (WTO):

(i) General Agreement on Tariffs & Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement

(ii) General Agreement on Trade related Services (GATS)
(iii) Madrid Protocol
(iv) Berne Convention
(v) Budapest Treaty
(b) Paris Convention

WIPO and TRIPS, IPR and Plant Breeders Rights, IPR and Biodiversity


Reference Books:


• Jayashree Watal, Intellectual property rights in the WTO and developing countries,

Oxford University Press, Oxford.

-------------------------------------------------------------------------------------------------------------------------

-------------------------------------------------------------------------------------------------------------------------

ANALYTICAL CLINICAL BIOCHEMISTRY (Credits: 02)

(Hands on Exercises: 60 Lectures)

Basic understanding of the structures, properties and functions of carbohydrates, lipids and proteins:

Review of concepts studied in the core course:

Carbohydrates: Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle.

Isolation and characterization of polysachharides.
Proteins: Classification, biological importance; Primary and secondary and tertiary structures of proteins: α-helix and β-pleated sheets, Isolation, characterization, denaturation of proteins.

Enzymes: Nomenclature, Characteristics (mention of Ribozymes), Classification; Active site, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme inhibitors, Introduction to Biocatalysis: Importance in “Green Chemistry” and Chemical Industry.

Lipids: Classification. Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications.

Lipoproteins.

Properties, functions and biochemical functions of steroid hormones.

Biochemistry of peptide hormones.

Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy.

Enzymes: Nomenclature, classification, effect of pH, temperature on enzyme activity, enzyme inhibition.

Biochemistry of disease: A diagnostic approach by blood/ urine analysis.


**Practicals**

Identification and estimation of the following:

1. Carbohydrates – qualitative and quantitative.
2. Lipids – qualitative.
3. Determination of the iodine number of oil.
4. Determination of the saponification number of oil.
5. Determination of cholesterol using Liebermann- Burchard reaction.
7. Isolation of protein.
8. Determination of protein by the Biuret reaction.
9. Determination of nucleic acids

Reference Books:

• T.G. Cooper: Tool of Biochemistry.
• Keith Wilson and John Walker: Practical Biochemistry.
• Alan H Gowenlock: Varley’s Practical Clinical Biochemistry.
• Thomas M. Devlin: Textbook of Biochemistry.
• Jeremy M. Berg, John L Tymoczko, Lubert Stryer: Biochemistry.
• A.L. Lehninger: Biochemistry.
• O. Mikes, R.A. Chalmers: Laboratory Handbook of Chromatographic Methods.

---

GREEN METHODS IN CHEMISTRY (Credits: 02)

(Hands on Exercises: 60 Lectures)

Theory and Hands-on Experiments

Introduction: Definitions of Green Chemistry. Brief introduction of twelve principles of Green Chemistry, with examples, special emphasis on atom economy, reducing toxicity, green solvents, Green Chemistry and catalysis and alternative sources of energy, Green energy and sustainability

The following Real world Cases in Green Chemistry should be discussed:

1. Surfactants for Carbon Dioxide – replacing smog producing and ozone depleting solvents with CO₂ for precision cleaning and dry cleaning of garments.
2. Designing of Environmentally safe marine antifoulant.
4. An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.

PRACTICALS

1. Preparation and characterization of biodiesel from vegetable oil.
2. Extraction of D-limonene from orange peel using liquid CO₂ prepared from dry ice.
3. Mechanochemical solvent free synthesis of azomethine.
4 Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper(II)

Reference Books:

7. Wealth from waste: A green method to produce biodiesel from waste cooking oil and generation of useful products from waste further generated “A social Awareness Project” Indu Tucker Sidhwani, Geeta Saini, Sushmita Chowdhury, Dimple Garg, Malovika, Nidhi Garg, Delhi University Journal of Undergraduate Research and Innovation, Vol1, Issue 1, Feb 2015. ISSN: 2395-2334.

-------------------------------------------------------------------------------------------------------

PHARMACEUTICAL CHEMISTRY (Credits: 02)

(Hands on Exercises: 60 Lectures)

Drugs & Pharmaceuticals

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

Fermentation

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

Practicals
1. Preparation of Aspirin and its analysis.

2. Preparation of magnesium bisilicate (Antacid).

Reference Books:


---------------------------

CHEMISTRY OF COSMETICS & PERFUMES (Credits: 02)

(Hands on Exercises: 60 Lectures)

A general study including preparation and uses of the following: Hair dye, hair spray, shampoo, suntan lotions, face powder, lipsticks, talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants and artificial flavours. Essential oils and their importance in cosmetic industries with reference to Eugenol, Geraniol, sandalwood oil, eucalyptus, rose oil, 2-phenyl ethyl alcohol, Jasmone, Civetone, Muscone.

Practicals

1. Preparation of talcum powder.
2. Preparation of shampoo.
3. Preparation of enamels.
4. Preparation of hair remover.
5. Preparation of face cream.
6. Preparation of nail polish and nail polish remover.

Reference Books:


----------------------------------------

PESTICIDE CHEMISTRY (Credits: 02)
(Hands on Exercises: 60 Lectures)

General introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides, structure activity relationship, synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene,); Organophosphates (Malathion, Parathion ); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor).

Practicals

1To calculate acidity/alkalinity in given sample of pesticide formulations as per BIS specifications.

2Preparation of simple organophosphates, phosphonates and thiophosphates

Reference Book:

• R. Cremlyn: Pesticides, John Wiley.

------------------------------

FUEL CHEMISTRY (Credits: 02)

(Hands on Exercises: 60 Lectures)

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

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

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

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

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

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

Reference Books:

• E. Stocchi: Industrial Chemistry, Vol -I, Ellis Horwood Ltd. UK.
Generic Elective Papers (GE) (Minor-Chemistry) (any four) for other Departments/Disciplines: (Credit: 06 each)

ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC (Credits: Theory-4, Practicals-2)

THEORY Lectures: 60
Section A: Inorganic Chemistry-1 (30 Periods)

What is Quantum mechanics? Time independent Schrodinger equation and meaning of various terms in it. Significance of ψ and ψ², Schrödinger equation for hydrogen atom. Radial and angular parts of the hydgenic wavefunctions (atomic orbitals) and their variations for 1s, 2s, 2p, 3s, 3p and 3d orbitals (Only graphical representation). Radial and angular nodes and their significance. Radial distribution functions and the concept of the most probable distance with special reference to 1s and 2s atomic orbitals. Significance of quantum numbers, orbital angular momentum and quantum numbers ml and ms. Shapes of s, p and d atomic orbitals, nodal planes. Discovery of spin, spin quantum number (s) and magnetic spin quantum number (ms).

Rules for filling electrons in various orbitals, Electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

(14 Lectures)

Chemical Bonding and Molecular Structure

Ionic Bonding: General characteristics of ionic bonding. Energy considerations in ionic bonding, lattice energy and solvation energy and their importance in the context of stability and solubility of ionic compounds. Statement of Born-Landé equation for calculation of lattice energy (no derivation), Born-Haber cycle and its applications, polarizing power and polarizability. Fajan’s rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Covalent bonding: VB Approach: Shapes of some inorganic molecules and ions on the basis of VSEPR (H2O, NH3, PCl5, SF6, ClF3, SF4) and hybridization with suitable examples of linear, trigonal planar, square planar, tetrahedral, trigonal bipyramidal and octahedral arrangements. Concept of resonance and resonating structures in various inorganic and organic compounds. MO Approach: Rules for the LCAO method, bonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, nonbonding combination of orbitals, MO treatment of homonuclear diatomic molecules of 1st and 2nd periods (including idea of s-p mixing) and heteronuclear diatomic molecules such as CO, NO and NO⁺.

(16 Lectures)

Section B: Organic Chemistry-1 (30 Lectures)
Fundamentals of Organic Chemistry

Reaction intermediates: Carbocations, Carbanions and free radicals. Electrophiles and nucleophiles

Aromaticity: Benzenoids and Hückel’s rule.

(8 Lectures)

Stereochemistry

Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and Meso compounds). Threeo and erythro; D and L; cis - trans nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and E / Z Nomenclature (for upto two C=C systems).

(10 Lectures)

Aliphatic Hydrocarbons

Functional group approach for the following reactions (preparations physical property & chemical reactions) to be studied with mechanism in context to their structure.


Alkenes: Preparation: Elimination reactions: Dehydration of alcohols and dehydrohalogenation of alkyl halides (Saytzeff’s rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alk. KMnO4) and trans-addition (bromine), Addition of HX (Markownikoff’s and anti-Markownikoff’s addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration-oxidation.

Alkynes: Preparation: Acetylene from CaC2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides. Reactions: formation of metal acetylides and acidity of alkynes, addition of bromine and alkaline KMnO4, ozonolysis and oxidation with hot alk. KMnO4. Hydration to form carbonyl compounds

(12 Lectures)

Reference Books:
• J. D. Lee: A new Concise Inorganic Chemistry, E L. B. S.17
CHEMISTRY LAB: ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONS
60 Lectures

Section A: Inorganic Chemistry - Volumetric Analysis

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.

2. Estimation of oxalic acid by titrating it with KMnO₄.

3. Estimation of water of crystallization in Mohr’s salt by titrating with KMnO₄.

4. Estimation of Fe (II) ions by titrating it with K₂Cr₂O₇ using internal indicator.

5. Estimation of Cu (II) ions iodometrically using Na₂S₂O₃.

Section B: Organic Chemistry

1. Purification of OC by crystallisation (from water and alcohol) and distillation.

2. Criteria of purity: Determination of Mpt/Bpt

3. Detection of extra elements (N, S, Cl, Br, I) in organic compounds

4. Separation of mixtures by Chromatography: Measure the Rf value in each case (combination of two compounds to be given)

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

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

Reference Books:

• Vogel’s Qualitative Inorganic Analysis, A.I. Vogel, Prentice Hall, 7th Edition.
CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY I
(Credits: Theory-4, Practicals-2)

THEORY: Lectures: 60

Section A: Physical Chemistry-1 (30 Lectures)

Chemical Energetics

Review of thermodynamics and the Laws of Thermodynamics.

Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature – Kirchhoff’s equation.

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

(10 Lectures)

Chemical Equilibrium:

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between $G$ and $G_0$, Le Chatelier’s principle. Relationships between $K_p$, $K_c$ and $K_x$ for reactions involving ideal gases.

(8 Lectures)

Ionic Equilibria:

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect. Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

(12 Lectures)
Section B: Organic Chemistry-2 (30 Lectures)
Functional group approach for the following reactions (preparations physical properties and Chemical reactions) to be studied in context to their structure with mechanism.

Aromatic hydrocarbons

\textit{Preparation} (benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid.


(8 Lectures)

Alkyl and Aryl Halides

Alkyl Halides

\textit{Preparation}: from alkenes and alcohols.

\textit{Reactions}: Types of Nucleophilic Substitution (S\textsubscript{N}1, S\textsubscript{N}2 and S\textsubscript{N}i) reactions, hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson’s ether synthesis: Elimination vs substitution.

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

\textit{Reactions} (Chlorobenzene): Aromatic electrophilic and nucleophilic substitution (replacement by – OH group) and effect of nitro substituent. Benzyne Mechanism: \textit{KNH}_2/\textit{NH}_3 (or \textit{NaNH}_2/\textit{NH}_3).

Relative reactivity of alkyl, allyl, benzyl, vinyl and aryl halides towards Nucleophilic substitution reactions.

(8 Lectures)

Alcohols, Phenols and Ethers

Alcohols: \textit{Preparation}: Preparation of 1\textsubscript{o}, 2\textsubscript{o} and 3\textsubscript{o} alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters.

\textit{Reactions}: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. \textit{KMnO}_4, acidic dichromate, conc. \textit{HNO}_3), factors affecting acidity, Oppeneauer oxidation

\textit{Diols}: oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols: (Phenol case) \textit{Preparation}: Cumene hydroperoxide method, from diazonium salts. \textit{Reactions}: Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer-
Tiemann Reaction, Gattermann-Koch Reaction, Houben–Hoesch Condensation, Schotten – Baumann Reaction. acidity and factors affecting

**Ethers (aliphatic and aromatic).**
Preparation: Williamson ether synthesis.
**Reactions:** Cleavage of ethers with HI

**Aldehydes and ketones (aliphatic and aromatic):**

*Preparation:* from acid chlorides and from nitriles.


*(14 Lectures)*

**Reference Books:**

**CHEMISTRY LAB: CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL ORGANIC CHEMISTRY**

**60 Lectures**

*Section A: Physical Chemistry*

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

*Ionic equilibria* pH measurements
a) Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH-meter.
b) Preparation of buffer solutions:
(i) Sodium acetate-acetic acid
(ii) Ammonium chloride-ammonium hydroxide
Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

Section B: Organic Chemistry
1. Preparations: Mechanism of various reactions involved to be discussed. Recrystallisation, determination of melting point and calculation of quantitative yields to be done.
   (a) Bromination of Phenol/Aniline
   (b) Benzoylation of amines/phenols
   (c) Oxime and 2,4 dinitrophenylhydrazone of aldehyde/ketone
2. Systematic Qualitative organic analyses of organic compounds possessing monofunctional groups (Alcohols, Phenols, Carbonyl,-COOH) and preparation of one suitable derivative.

Reference Books:
- B.D. Khosla, Senior Practical Physical Chemistry, R. Chand & Co.

SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL GROUP ORGANICCHEMISTRY-II
(Credits: Theory-4, Practicals-2)

THEORY: Lectures: 60

Section A: Physical Chemistry-2 (30 Lectures)

Solutions
Phase Equilibrium

Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation and its importance in phase equilibria. Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, FeCl₃-H₂O and Na-K only).

Conductance

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch law of independent migration of ions.


Electrochemistry


Calculation of equilibrium constant from EMF data. Concentration cells with transference and without transference. Liquid junction potential and salt bridge.

pH determination using hydrogen electrode and quinhydrone electrode.

Potentiometric titrations -qualitative treatment (acid-base and oxidation-reduction only).

Section B: Organic Chemistry-3 (30 Lectures)

Functional group approach for the following reactions (preparations Physical Property & Chemicals reactions) to be studied in context to their structure with mechanism.

Carboxylic acids and their derivatives

Carboxylic acids (aliphatic and aromatic)

*Preparation:* Acidic and Alkaline hydrolysis of esters.

*Reactions:* Hell – Vohlard - Zelinsky Reaction, Acidity of carboxylic acid, effect of substitution on acid strength.

Carboxylic acid derivatives (aliphatic):
**Preparation:** Acid chlorides, Anhydrides, Esters and Amides from acids and their interconversion.

**Reactions:** Relative reactivity of acid derivatives towards nucleophiles, Reformatsky Reaction, Perkin condensation.

(6 Lectures)

**Amines and Diazonium Salts**

Amines (Aliphatic and Aromatic):

**Preparation:** from alkyl halides, Gabriel’s Phthalamide synthesis, Hofmann Bromamide reaction.

**Reactions:** Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, reaction with HNO₂, Schotten – Baumann Reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation basic character of amines.

(6 Lectures)

**Diazonium salts:** **Preparation:** from aromatic amines.

**Reactions:** conversion to benzene, phenol, dyes.

(6 Lectures)

**Amino Acids, Peptides and Proteins:**

Zwitterion, Isoelectric point and Electrophoresis

**Preparation of Amino Acids:** Strecker synthesis using Gabriel’s phthalamide synthesis.

**Reactions of Amino acids:** ester of –COOH group, acetylation of –NH₂ group, complexation with Cu²⁺ ions, ninhydrin test.

Overview of Primary, Secondary, Tertiary and Quaternary Structure of proteins.

Determination of Primary structure of Peptides by degradation Edmann degradation (N-terminal) and C-terminal (thiodyantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (upto dipeptides) by N-protection (t-butyloxycarbonyl and phthaloyl) & C-activating groups and Merrifield solid-phase synthesis.

(10 Lectures)

**Carbohydrates:** Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disacharrides (sucrose, cellobiose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation.

(8 Lectures)

**Reference Books:**

Chemistry Lab: Solutions, Phase Equilibrium, Conductance, Electrochemistry & Biomolecules

60 Lectures

Section A: Physical Chemistry

Distribution

Study of the equilibrium of one of the following reactions by the distribution method:

\[ \text{I}_2(\text{aq}) \text{ + I}^- (\text{aq}) \rightarrow \text{I}_3^- (\text{aq}) \]

\[ \text{Cu}^{2+}(\text{aq}) + x \text{NH}_2(\text{aq}) \rightarrow [\text{Cu(NH}_3)_x]^{2+} \]

Phase equilibria

a) Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.
b) Determination of the critical solution temperature and composition of the phenol water system and study of the effect of impurities on it.
c) Study of the variation of mutual solubility temperature with concentration for the phenol water system and determination of the critical solubility temperature.

Conductance

I. Determination of cell constant
II. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
III. Perform the following conductometric titrations:
   i. Strong acid vs. strong base
   ii. Weak acid vs. strong base

Potentiometry

Perform the following potentiometric titrations:
   i. Strong acid vs. strong base
ii. Weak acid vs. strong base
iii. Potassium dichromate vs. Mohr's salt

Section B: Organic Chemistry

I Systematic Qualitative Organic Analysis of Organic Compounds possessing monofunctional groups (amide, nitro, amines, Hydrocorbans, Halo Hydrocorbans) and preparation of one derivative.

II

1. Determination of the concentration of glycine solution by formylation method
2. Action of salivary amylase on starch
3. Differentiation between a reducing and nonreducing sugar

Reference Books:
• B.D. Khosla: Senior Practical Physical Chemistry, R. Chand & Co.

CHEMISTRY OF S- AND P-BLOCK ELEMENTS, STATES OF MATTER & CHEMICAL KINETICS
(Credits: Theory-4, Practicals-2)

THEORY: Lectures: 60
General Principles of Metallurgy

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon as reducing agent.

Hydrometallurgy with reference to cyanide process for silver and gold, Methods of purification of metals (Al, Pb, Ti, Fe, Cu, Ni, Zn): electrolytic, oxidative refining, van Arkel-de Boer process and Mond’s process.

(4 Lectures)

s- and p-Block Elements
Periodicity in \( s \)- and \( p \)-block elements with respect to electronic configuration, atomic and ionic size, ionization enthalpy, electronegativity (Pauling, Mulliken, and Alfred-Rochow scales). Allotropy in C, S, and P.

Oxidation states with reference to elements in unusual and rare oxidation states like carbides and nitrides), inert pair effect, diagonal relationship and anomalous behaviour of first member of each group.

Compounds of \( s \)- and \( p \)-Block Elements

Diborane and concept of multicentre bonding

Structure, bonding and their important properties like oxidation/reduction, acidic/basic nature of the following compounds and their applications in industrial and environmental chemistry.

Hydrides of nitrogen (\( \text{NH}_3, \text{N}_2\text{H}_4, \text{N}_3\text{H}, \text{NH}_2\text{OH} \)) Oxoacids of P, S and Cl. Halides and oxohalides: \( \text{PCl}_3, \text{PCl}_5, \text{SOCl}_2 \) and \( \text{SO}_2\text{Cl}_2 \)

\textbf{(26 Lectures)}

\textit{Section B: Physical Chemistry-3 (30 Lectures)}

\textbf{Kinetic Theory of Gases}

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation.

Deviation of real gases from ideal behaviour, compressibility factor, causes of deviation. van der Waals equation of state for real gases. Boyle temperature (derivation not required). Critical phenomena, critical constants and their calculation from van der Waals equation. Andrews isotherms of \( \text{CO}_2 \).

Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance.

Temperature dependence of these distributions. Most probable, average and root mean square velocities (no derivation). Collision cross section, collision number, collision frequency, collision diameter and mean free path of molecules. Viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only).

\textbf{Liquids}

Surface tension and its determination using stalagmometer. Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer. Effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only)

\textbf{Solids}

Forms of solids. Symmetry elements, unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of Crystallography - Law of constancy of interfacial angles,

Chemical Kinetics


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

Reference Books:

- J. D. Lee: *A New Concise Inorganic Chemistry*, E.L.B.S.

CHEMISTRY LAB: CHEMISTRY OF s- AND p-BLOCK ELEMENTS, STATES OF MATTER & CHEMICAL KINETICS

60 Lectures

Section A: Inorganic Chemistry

Semi-micro qualitative analysis of mixtures using H₂S or any other scheme- not more than four ionic species (two anions and two cations and excluding insoluble salts) out of the following:

Cations : NH₄⁺, Pb²⁺, Bi³⁺, Cu²⁺, Fe³⁺, Al³⁺, Co²⁺, Ni²⁺, Mn²⁺, Zn²⁺, Ba²⁺, Sr²⁺, Ca²⁺, K⁺

Anions : CO₃²⁻, S²⁻, SO₃²⁻, NO₃⁻, CH₃COO⁻, Cl⁻, Br⁻, I⁻, NO₃⁻, SO₄²⁻, PO₄³⁻, BO₃³⁻, C₂O₄²⁻, F⁻

(Spot tests should be carried out wherever feasible)

Section B: Physical Chemistry

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

a) Determination of the surface tension of a liquid or a dilute solution using a stalagmometer.
b) Study of the variation of surface tension of a detergent solution with concentration.

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

a) Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald’s viscometer.
b) Study of the variation of viscosity of an aqueous solution with concentration of solute.

(III) Chemical Kinetics

Study the kinetics of the following reactions.
1. Initial rate method: Iodide-persulphate reaction
2. Integrated rate method:
a. Acid hydrolysis of methyl acetate with hydrochloric acid.
b. Saponification of ethyl acetate.
c. Compare the strengths of HCl and H2SO4 by studying kinetics of hydrolysis of methyl acetate

Reference Books:
- A.I. Vogel, Qualitative Inorganic Analysis, Prentice Hall, 7th Edn.
- B.D. Khosla, Senior Practical Physical Chemistry, R. Chand & Co.

GE: CHEMISTRY OF d-BLOCK ELEMENTS, QUANTUM CHEMISTRY & SPECTROSCOPY

(Credits: Theory-04, Practical-02)

Theory: 60 Lectures

Section A: Inorganic Chemistry-3 (30 Lectures) Transition Elements (3d series)
General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu.

Lanthanoids and actinoids: Electronic configurations, oxidation states, colour, magnetic properties, lanthanide contraction, separation of lanthanides (ion exchange method only).

(12 Lectures)

Coordination Chemistry

Drawbacks of VBT. IUPAC system of nomenclature.

(8 Lectures)

Crystal Field Theory
Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D. Spectrochemical series. Comparison of CFSE for $O_h$ and $T_d$ complexes, Tetragonal distortion of octahedral geometry.

Jahn-Teller distortion, Square planar coordination.  

(10 Lectures)

Section B: Physical Chemistry-4 (30 Lectures) Quantum Chemistry & Spectroscopy


Postulates of quantum mechanics, quantum mechanical operators.

Free particle. Particle in a 1-D box (complete solution), quantization, normalization of wavefunctions, concept of zero-point energy.

Rotational Motion: Schrödinger equation of a rigid rotator and brief discussion of its results (solution not required). Quantization of rotational energy levels.

Microwave (pure rotational) spectra of diatomic molecules. Selection rules. Structural information derived from rotational spectroscopy.

Vibrational Motion: Schrödinger equation of a linear harmonic oscillator and brief discussion of its results (solution not required). Quantization of vibrational energy levels. Selection rules, IR spectra of diatomic molecules. Structural information derived from vibrational spectra. Vibrations of polyatomic molecules. Group frequencies. Effect of hydrogen bonding (inter- and intramolecular) and substitution on vibrational frequencies.


(24 Lectures)

Photochemistry


(6 Lectures)

Reference Books:
• J. D. Lee: A New Concise Inorganic Chemistry, E.L.B.S.

**GE LAB**
**60 Lectures**
Section A: Inorganic Chemistry

1. Estimation of the amount of nickel present in a given solution as bis(dimethylglyoximato) nickel(II) or aluminium as oxinate in a given solution gravimetrically.
2. Estimation of (i) Mg$^{2+}$ or (ii) Zn$^{2+}$ by complexometric titrations using EDTA.
3. Estimation of total hardness of a given sample of water by complexometric titration.
4. Determination of the composition of the Fe$^{3+}$ - salicylic acid complex / Fe$^{2+}$ - phenanthroline complex in solution by Job’s method.

**Section B: Physical Chemistry**

UV/Visible spectroscopy

I. Study the 200-500 nm absorbance spectra of KMnO$_4$ and K$_2$Cr$_2$O$_7$ (in 0.1 M H$_2$SO$_4$) and determine the $\lambda_{\text{max}}$ values. Calculate the energies of the two transitions in different units (J molecule$^{-1}$, kJ mol$^{-1}$, cm$^{-1}$, eV).
II. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of K$_2$Cr$_2$O$_7$.
III. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.

Colorimetry

I. Verify Lambert-Beer’s law and determine the concentration of CuSO$_4$/KMnO$_4$/K$_2$Cr$_2$O$_7$ in a solution of unknown concentration
II. Analyse the given vibration-rotation spectrum of HCl(g)

**Reference Books:**
• A.I. Vogel, Qualitative Inorganic Analysis, Prentice Hall, 7th Edn.
• A.I. Vogel, Quantitative Chemical Analysis, Prentice Hall, 6th Edn.
GE: ORGANOMETALLICS, BIOINORGANIC CHEMISTRY, POLYNUCLEAR HYDROCARBONS AND UV, IR SPECTROSCOPY (Credits: Theory-04, Practicals-02)

Theory: 60 Lectures

Section A: Inorganic Chemistry-4 (30 Lectures)

Chemistry of 3d metals
Oxidation states displayed by Cr, Fe, Co, Ni and Co.

A study of the following compounds (including preparation and important properties);

Peroxocompounds of Cr, K₂Cr₂O₇, KMnO₄, K₄[Fe(CN)₆], K₃[Fe(CN)₆], sodium nitroprusside, [Co(NH₃)₆]Cl₃, Na₃[Co(NO₂)₆].

(6 Lectures)

Organometallic Compounds
Definition and Classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p and multicentre bonds). Structures of methyl lithium, Zeise’s salt and ferrocene. EAN rule as applied to carboxyls. Preparation, structure, bonding and properties of mononuclear and polynuclear carboxyls of 3d metals. p-acceptor behaviour of carbon monoxide. Synergic effects (VB approach)- (MO diagram of CO can be referred to for synergic effect to IR frequencies).

(12 Lectures)

Bio-Inorganic Chemistry
A brief introduction to bio-inorganic chemistry. Role of metal ions present in biological systems with special reference to Na⁺ K⁺ and Mg²⁺ ions: Na/K pump; Role of Mg²⁺ ions in energy production and chlorophyll. Role of iron in oxygen transport, haemoglobin, myoglobin, storage and transport of iron.

(12 Lectures)

Section B: Organic Chemistry-4 (30 Lectures) Polynuclear and heteronuclear aromatic compounds:
Structure elucidation of naphthalene, preparation and properties of naphthalene and anthracene. Properties of the following compounds with reference to electrophilic and nucleophilic substitution: Furan, Pyrrole, Thiophene, and Pyridine.

(12 Lectures)

Active methylene compounds:
Preparation: Claisen ester condensation. Keto-enol tautomerism.
Reactions: Synthetic uses of ethylacetoacetate (preparation of non-heteromolecules having upto 6 carbon).

(6 Lectures)

Application of Spectroscopy to Simple Organic Molecules
Application of visible, ultraviolet and Infrared spectroscopy in organic molecules. Electromagnetic radiations, electronic transitions, $\lambda_{\text{max}}$ & $\varepsilon_{\text{max}}$, chromophore, auxochrome, bathochromic and hypsochromic shifts. Application of electronic spectroscopy and Woodward rules for calculating $l_{\text{max}}$ of conjugated dienes and $\alpha,\beta$ – unsaturated compounds.

Infrared radiation and types of molecular vibrations, functional group and fingerprint region. IR spectra of alkanes, alkenes and simple alcohols (inter and intramolecular hydrogen bonding), aldehydes, ketones, carboxylic acids and their derivatives (effect of substitution on >C=O stretching absorptions).

(12 Lectures)

Reference Books:
- J.D. Lee: A New Concise Inorganic Chemistry, E.L.B.S.

GE LAB
60 Lectures

Section A: Inorganic Chemistry
1. Separation of mixtures by chromatography: Measure the $R_f$ value in each case. (Combination of two ions to be given)

   Paper chromatographic separation of Fe$^{3+}$, Al$^{3+}$ and Cr$^{3+}$ or

   Paper chromatographic separation of Ni$^{2+}$, Co$^{2+}$, Mn$^{2+}$ and Zn$^{2+}$

2. Preparation of any two of the following complexes and measurement of their conductivity: (i) tetraamminecarbonatocobalt (III) nitrate
   (ii) tetraamminecopper (II) sulphate
   (iii) potassium trioxalatoferrate (III) trihydrate

Compare the conductance of the complexes with that of M/1000 solution of NaCl, MgCl$_2$ and
LiCl₃.

Section B: Organic Chemistry
Systematic Qualitative Organic Analysis of Organic Compounds possessing monofunctional groups (-COOH, alcoholic, phenolic, carbohydrates, aldehydic, ketonic, amide, nitro, amines) and preparation of one derivative.

*Reference Books:*

**GE: MOLECULES OF LIFE**
*(Credits: Theory-04, Practicals-02)*

**Theory: 60 Lectures**

**Unit 1: Carbohydrates** (10 Periods)
Classification of carbohydrates, reducing and non reducing sugars, General Properties of Glucose and Fructose, their open chain structure. Epimers, mutarotation and anomers. Determination of configuration of Glucose (Fischer proof). Cyclic structure of glucose. Haworth projections. Cyclic structure of fructose. Linkage between monosachharides, structure of disacharrides (sucrose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation.

**Unit 2: Amino Acids, Peptides and Proteins** (12 Periods)
Classification of Amino Acids, Zwitterion structure and Isoelectric point. Overview of Primary, Secondary, Tertiary and Quaternary structure of proteins. Determination of primary structure of peptides, determination of N-terminal amino acid (by DNFB and Edman method) and C-terminal amino acid (by thiohydantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (upto dipeptides) by N-protection (tbutyloxycarbonyl and phthaloyl) & C-activating groups and Merrifield solid phase synthesis.

**Unit 3: Enzymes and correlation with drug action** (12 Periods)
Mechanism of enzyme action, factors affecting enzyme action, Coenzymes and cofactors and their role in biological reactions, Specificity of enzyme action(Including stereospecifity), Enzyme inhibitors and their importance, phenomenon of inhibition(Competitive and Non competitive inhibition including allosteric inhibition). Drug action-receptor theory. Structure – activity relationships of drug molecules, binding role of –OH group, –NH₂ group, double bond and aromatic ring.

**Unit 4: Nucleic Acids** (10 Periods)
Components of Nucleic acids: Adenine, guanine, thymine and Cytosine (Structure only), other components of nucleic acids, Nucleosides and nucleotides (nomenclature), Structure of polynucleotides; Structure of DNA (Watson-Crick model) and RNA(types of RNA), Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation.
Unit 5: Lipids (8 Periods)
Introduction to lipids, classification.
Oils and fats: Common fatty acids present in oils and fats, Omega fatty acids, Trans fats, Hydrogenation, Saponification value, Iodine number.
Biological importance of triglycerides, phospholipids, glycolipids, and steroids (cholesterol).

Unit 6: Concept of Energy in Biosystems (8 Periods)

Reference Book:
- Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).

GE LAB
60 Lectures
1. Separation of amino acids by paper chromatography
2. To determine the concentration of glycine solution by formylation method.
3. Study of titration curve of glycine
4. Action of salivary amylase on starch
5. Effect of temperature on the action of salivary amylase on starch.
6. To determine the saponification value of an oil/fat.
7. To determine the iodine value of an oil/fat
8. Differentiate between a reducing/ nonreducing sugar.
9. Extraction of DNA from onion/cauliflower
10. To synthesize aspirin by acetylation of salicylic acid and compare it with the ingredient of an aspirin tablet by TLC.

Reference Books:
References Books:

Inorganic Chemistry

• Lee, J. D., A New Concise Inorganic Chemistry, ELBS, 1991
• Atkins, Peter, Overton, Tina, Rourke, Jonathan, Weller, Mark and Armstrong, Fraser

Physical Chemistry

• Levine, Ira N., Physical Chemistry 6e, McGraw-Hill Education, 2008

Organic Chemistry

• McMurry, John, Introduction to Organic Chemistry, Cengage Learning, 2011

Instrumental Chemistry

• Skoog, Douglas A., Holler, F. James, Crouch, Stanley R, Principles of Instrumental Analysis, 6e, Cengage Learning, 2006

General Chemistry

• Kotz, J.C., Treichel, P.M., Townsend, John, General Chemistry, Cengage Learning, 2009
• Goldberg, David E., 3000 Solved Problems in Chemistry, Schaum's outlines, 2011