

CURRICULUM
FOR
BS CHEMISTRY
(4 Year Program)



Fall 2025 and onwards

(HEC Curriculum 2025, aligned with HEC Policy-2023)

**Department of Chemistry,
Shaheed Benazir Bhutto University,
Sheringal, Dir (Upper), Khyber Pakhtunkhwa, Pakistan.**

Office of the Registrar
SHAHEED BENAZIR BHUTTO UNIVERSITY
SHERINGAL, DIR UPPER, KHYBER PAKHTUNKHAWA, PAKISTAN

Ref. No.SBBU/Acad/Ntf/24-/222

Dated: 13.06.2024.



Notification

In pursuance of powers conferred upon him under Section (32.3), of Chapter 32 “**Constitution, Functions and Powers of Authorities of the University Statutes 2022**”, the Vice-Chancellor is pleased to nominate and approve the following as members of the Board of Studies of the department of Chemistry, of the University for a Period of three years with immediate effect.

| Section | Name and Designation | Appointing Authority |
|-------------|---|------------------------|
| 32.3(2)(i) | Dr. Abdul Khaliq Jan (Chairman/ Associate Professor in department of Chemistry) | By virtue of his Chair |
| 32.3(2)(ii) | i). Dr. Saira Nayab (Assistant Professor in department of Chemistry) ii). Dr. Noor Rahman (Assistant Professor in department of Chemistry) iii). Dr. Kashif Raza (Lecturer in department of Chemistry) iv). Dr. Muhammad Tariq (Lecturer in department of Chemistry) | Vice Chancellor |
| 32.3(2)(iv) | i) . Dr. Khair Zaman (Professor, department of Chemistry, (AWKUM) ii). Dr. Rasul Khan (Associate Professor, Institute of Chemical Sciences, UOP) iii).Dr. Mumtaz (Associate Professor, department of Chemistry, UOM) | Vice Chancellor |
| 32.3(2)(v) | i. Mr. Muhammad Sabir Khan (Associate Professor, Department of Chemistry, GPGC Chitral) ii. Mr. Muhammad Wahab (Lecturer, Department of Chemistry, GDC Wari) | Vice Chancellor |

Deputy Registrar (Acads)

Copy for Information to:

1. PS to Vice Chancellor
2. PS to Registrar
3. Treasurer
4. Controller of Examinations
5. Director Teaching/Admissions
6. Director QEC
- ✓ 7. HoD Concerned Department
8. All Members Concerned
9. Record File

Deputy Registrar (Acads)

Curriculum Contributed by Faculty Department of Chemistry SBBU

1) Dr. Abdul khaliq Jan (Chairman Chemistry)

2) Dr. Saira Nayab (Assistant Professor)

3) Dr. Noor Rehman (Assistant Professor)

4) Dr. Farman Ali Khan (Assistant Professor)

5) Dr. Irfan Ullah (Assistant Professor)

6) Dr. Nasruddin (Lecturer)

7) Dr. Muhammad Kashif Raza (Lecturer)

8) Dr. Muhammad Tariq (Lecturer)

9) Dr. Muhammad Naveed Khan (Lecturer)

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Introduction

The curriculum serves as a comprehensive blueprint for the teaching-learning process that students must navigate to achieve specific academic objectives. This encompasses clearly defined prior learning requirements, program objectives, scheme of studies, and course learning outcomes. As knowledge rapidly evolves and new fields emerge, it is crucial to continually develop and revise curricula to ensure they remain current, relevant, and impactful. As mandated by its law through Clause 10-1 (a), (l), (s), and (v), the Higher Education Commission (HEC) of Pakistan has been developing and periodically updating curricula through its National Curriculum Revision Committees (NCRCs). These committees are generally composed of subject matter experts, researchers, and representatives from accreditation bodies, professional councils, and industry stakeholders. In response to the evolving needs, HEC has undertaken the task to develop robust standards for the curricula of degree programs in Chemistry at levels 5, 6 and 7 of the National Qualifications Framework. These standards are meticulously structured in accordance with the HEC's Undergraduate Education Policy V 1.1 (2023) and Graduate Education Policy (2023), ensuring alignment with both national priorities and international educational standards. The degree programs in Chemistry are designed to equip students with advanced theoretical knowledge and practical skills, fostering innovation and research to address the evolving challenges in the field of Chemistry. These curricular standards, developed by subject experts from across the country, aim to enhance graduates' competencies, enabling them to contribute effectively to national scientific, industrial, and environmental needs. With the support of universities in implementing these standards, HEC envisions a future where Pakistani graduates in Chemistry lead advancements in chemical research, industrial applications, and policy development, driving innovation in pharmaceuticals, materials science, energy, and environmental sustainability, both nationally and internationally.

PROGRAM STRUCTURE

| | |
|---|--|
| Minimum Credit Hours | 139 (137+2) Max allowed 144 |
| General Education | 32+2 Credit hours (13+2 courses) |
| Discipline Related Courses / Major | 81 Credit hours (27 courses) |
| Interdisciplinary / Allied Courses | 18 Credit hours (06 courses) |
| Internship | 03 Credit hours |
| Capstone | 03 Credit hours |
| Program Duration | Minimum: 4 years (8 regular semesters) Maximum: 6 years (12 regular semesters) The maximum limit is further extendable in accordance with HEC semester rules |
| Semester Duration | 16-18 weeks for regular semesters (1-2 weeks for examination) 8-9 weeks for summer semesters (1 week for examination) |
| Course Load (per semester) | 15-18 credit hours for regular semesters Up-to 8 credit hours for summer semesters (for remedial/deficiency/failure/repetition courses only) |
| 3 Credit Hours (Theory) | 3 classes (1 hour each) OR 2 classes (1.5 hour each) OR 1 class (3 hours) per week throughout the semester |
| 1 Credit Hours (Lab / Field Work) | 1 credit hour in laboratory or practical work / project requires lab contact of 3 hours per week throughout the semester |

COURSE CODES AND COURSE TITLES

| Year - I | | | |
|-------------------------------|---|---------------------|-------------------|
| SEMESTER 1 | | | |
| Course Code | Course Title | Credit Hours | Category |
| CHEM-301 | Fundamentals of Chemistry | 3 (2-1) | Major |
| CHEM-331 | Principles of Biochemistry | 3 (2-1) | Interdisciplinary |
| GEN-341 | Quantitative Reasoning – I* | 3 (3-0) | General Education |
| GEN-371 | Natural Science (Physics)** | 3 (2-1) | General Education |
| GEN-321 | Functional English* | 3 (3-0) | General Education |
| GEN-311 | Applications of Information and Communication Technology* | 3 (2-1) | General Education |
| TOTAL CREDIT HOURS: 18 | | | |
| Year - I | | | |
| SEMESTER 2 | | | |
| CHEM-301 | Principles of Organic Chemistry | 3 (2-1) | Major |
| CHEM-391 | Principles of Inorganic Chemistry | 3 (2-1) | Major |
| CHEM-321 | Principles of Physical Chemistry | 3 (2-1) | Major |
| GEN-342 | Quantitative Reasoning – II** | 3 (3-0) | General Education |
| GEN-322 | Expository Writing* | 3 (3-0) | General Education |
| GEN-361 | Pakistan Studies* | 2 (2-0) | General Education |
| GEN-331 | Understanding of Quran – I | 1 (0-1) | General Education |
| TOTAL CREDIT HOURS: 18 | | | |
| Year - II | | | |
| SEMESTER 3 | | | |
| CHEM-421 | Principles of Analytical Chemistry | 3 (2-1) | Major |
| CHEM-421 | Principles of Polymer Chemistry | 3 (2-1) | Major |

| | | | |
|------------------------|--|---------|-------------------|
| CHEM-402 | Introduction to Nano-Chemistry | 3 (2-1) | Major |
| GEN-462 | Ideology and constitution of Pakistan* | 2 (2-0) | General Education |
| GEN-432 | Understanding of Quran – II | 1 (0-1) | General Education |
| GEN-433 | Islamic Studies* (Ethics for non-Muslim students) | 2 (2-0) | General Education |
| GEN-434 | Arts and humanities (Seerat Ul Nabi)*** | 2 (2-0) | General Education |
| TOTAL CREDIT HOURS: 16 | | | |
| Year - II | | | |
| SEMESTER 4 | | | |
| CHEM-461 | Forensic Chemistry | 3 (2-1) | Major |
| CHEM-481 | Industrial Chemistry | 3 (2-1) | Major |
| CHEM-451 | Environmental Chemistry | 3 (2-1) | Major |
| CHEM-411 | Pharmaceutical Chemistry | 3 (2-1) | Major |
| GEN-481 | Social Sciences****/ Sociology/ Human Rights/ Social Anthropology | 2 (2-0) | General Education |
| GEN-482 | Civics & Community Engagement* | 2 (2-0) | General Education |
| GEN-451 | Entrepreneurship* | 2 (2-0) | General Education |
| TOTAL CREDIT HOURS: 18 | | | |
| Year – III | | | |
| SEMESTER 5 | | | |
| CHEM-502 | Advanced Organic Chemistry | 3 (2-1) | Major |
| CHEM-592 | Advanced Inorganic Chemistry | 3 (2-1) | Major |
| CHEM-522 | Advanced Physical Chemistry | 3 (3-0) | Major |
| CHEM-522 | Advanced Analytical Chemistry | 3 (2-1) | Major |
| CHEM-541 | Soil Chemistry | 3 (2-1) | Major |
| CHEM-541 | Computational Chemistry | 3 (2-1) | Major |
| TOTAL CREDIT HOURS: 18 | | | |

| Specializations | | | |
|------------------------|---------------------------------------|---------|-------------------|
| Year – III | | | |
| SEMESTER 6 | | | |
| CHEM-511 | Agricultural Chemistry | 3 (2-1) | Major |
| CHEM-5-- | Elective – I***** | 3 (3-0) | Major |
| CHEM-5-- | Elective – II***** | 3 (3-0) | Major |
| CHEM-501 | Scientific Writing & Research Methods | 3 (3-0) | Interdisciplinary |
| GEN-540 | Statistics for Chemists | 3 (3-0) | Interdisciplinary |
| CHEM-500 | Internship | 3 | Internship |
| TOTAL CREDIT HOURS: 18 | | | |
| Year – IV | | | |
| SEMESTER 7 | | | |
| CHEM-601 | Chemical Safety & Risk Management | 3 (3-0) | Major |
| CHEM-6-- | Elective – III***** | 3 (3-0) | Major |
| CHEM-6-- | Elective – IV***** | 3 (3-0) | Major |
| CHEM-6-- | Elective – V***** | 3 (3-0) | Major |
| CHEM-602 | Materials Science***** | 3 (2-1) | Interdisciplinary |
| CHEM-671 | Fuel Chemistry | 3(2-1) | Major |
| TOTAL CREDIT HOURS: 18 | | | |
| Year – IV | | | |
| SEMESTER 8 | | | |
| CHEM-6-- | Elective – VI***** | 3 (3-0) | Major |
| CHEM-6-- | Elective – VII***** | 3 (3-0) | Major |
| CHEM-603 | AI in Chemistry***** | 3 (2-1) | Interdisciplinary |

| | | | |
|------------------------|-----------------------------|---------|-------------------|
| CHEM-604 | Quality Control & Assurance | 3 (2-1) | Interdisciplinary |
| CHEM-600 | Capstone | 3 | Capstone |
| TOTAL CREDIT HOURS: 15 | | | |

SPECIALIZATION: ANALYTICAL CHEMISTRY

Elective Courses

| | | | |
|-------------------|---|---------|-------|
| SEMESTER 6 | | | |
| CHEM-523 | Atomic Spectroscopy | 3 (3-0) | Major |
| CHEM-524 | Separation Techniques in Analytical Chemistry | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-625 | Molecular Spectroscopy | 3 (3-0) | Major |
| CHEM-627 | Advanced Chromatography | 3 (3-0) | Major |
| CHEM-628 | Quality Control & Quality Assurance Analysis | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-629 | Sample Preparation | 3 (3-0) | Major |
| CHEM-620 | Electroanalytical Techniques | 3 (3-0) | Major |

**Specialization Biochemistry
Elective courses**

| | | | |
|-------------------|--|---------|-------|
| SEMESTER 6 | | | |
| CHEM-531 | Advanced Molecular Biological Techniques | 3 (3-0) | Major |
| CHEM-533 | Clinical Biochemistry | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-634 | Endocrinology | 3 (3-0) | Major |

| | | | |
|-------------------|---------------------------------|---------|-------|
| CHEM-635 | Enzymology & Catalysis | 3 (3-0) | Major |
| CHEM-639 | Metabolic Pathways & Regulation | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-630 | Molecular Immunology | 3 (3-0) | Major |
| CHEM-632 | Nucleic Acid Chemistry | 3 (3-0) | Major |

SPCILIAZATION: INDUSTRIAL CHEMISTRY

Elective Courses

| | | | |
|-------------------|--|---------|-------|
| SEMESTER 6 | | | |
| CHEM-582 | Process Chemistry & Industrial Catalysis | 3 (3-0) | Major |
| CHEM-583 | Industrial Water Treatment | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-684 | Cosmetics Industry | 3 (3-0) | Major |
| CHEM-685 | Petroleum Chemistry | 3 (3-0) | Major |
| CHEM-686 | Industrial Electrochemistry | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-687 | Industrial Waste Treatment & Pollution Control | 3 (3-0) | Major |
| CHEM-689 | Corrosion Science & Protection | 3 (3-0) | Major |

SPECIALIZATION: ORGANIC CHEMISTRY

Elective Courses

| | | | |
|-------------------|-----------------------------|---------|-------|
| SEMESTER 6 | | | |
| CHEM-503 | Stereochemistry | 3 (3-0) | Major |
| CHEM-504 | Synthetic Organic Chemistry | 3 (3-0) | Major |

| SEMESTER 7 | | | |
|-------------------|---------------------------|---------|-------|
| CHEM-605 | Heterocyclic Chemistry | 3 (3-0) | Major |
| CHEM-606 | Reactive Intermediates | 3 (3-0) | Major |
| CHEM-607 | Organic Spectroscopy | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-608 | Natural Product Chemistry | 3 (3-0) | Major |
| CHEM-609 | Organic Electronics | 3 (3-0) | Major |

SPECIALIZATION: INORGANIC CHEMISTRY

Elective Courses

| SEMESTER 6 | | | |
|-------------------|------------------------------|---------|-------|
| CHEM-593 | Coordination Compounds | 3 (3-0) | Major |
| CHEM-594 | Inorganic Reaction Mechanism | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-695 | Inorganic Polymers | 3 (3-0) | Major |
| CHEM-696 | Organometallics | 3 (3-0) | Major |
| CHEM-697 | Group Theory | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-698 | Bio-Inorganic Chemistry | 3 (3-0) | Major |
| CHEM-699 | Radio And Nuclear Chemistry | 3 (3-0) | Major |

SPECIALIZATION: PHYSICAL CHEMISTRY

Elective Courses

| SEMESTER 6 | | | |
|-------------------|------------------------|---------|-------|
| CHEM-523 | Colloids & Surfactants | 3 (3-0) | Major |
| CHEM-524 | Materials Science | 3 (3-0) | Major |

| SEMESTER 7 | | | |
|-------------------|--------------------------------|---------|-------|
| CHEM-625 | Physical Chemistry of Polymers | 3 (3-0) | Major |
| CHEM-626 | Surface Chemistry | 3 (3-0) | Major |
| CHEM-627 | Chemical Thermodynamics | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-628 | Nuclear & Radiation Chemistry | 3 (3-0) | Major |
| CHEM-629 | Photochemistry | 3 (3-0) | Major |

* HEC designed model courses for general education may be adopted by the university.

** The university / department may offer any course in the broader category of “Natural Sciences” which should have relevance to the purpose of the degree program.

*** The university / offering department may offer any course in the broader category of “Arts and Humanities” including but not limited to a course of regional or international language such as Chinese, Arabic, French, Spanish etc. or any other course such as Philosophy, History etc.

**** The university / department may offer any course in the broader category of “Social Sciences” including but not limited to a course of Economics, Anthropology, Education, International Relations etc.

***** Read in conjunction with guidance given on “Standard Nomenclature”, the university / department may offer any 7 courses from either the general pool of electives or from within one of the specializations keeping in view availability of academic, human and infrastructural resources. Credit combination (reflecting balance of theory and lab / field work) may be arranged in accordance with the nature of the course.

***** These interdisciplinary courses are optional and designed to enhance students' academic breadth. The concerned department is encouraged to offer these courses subject to availability of required faculty, academic, and technical resources. If the required resources are not available, the department may substitute them with other relevant courses that are aligned with academic objectives and institutional capacity.

Internship: Internship of 3 credit hours is a mandatory degree award requirement for Bachelor of Science in Chemistry. Internship of 6 to 8

weeks (preferably undertaken during semester or summer break) must be graded by a faculty member in collaboration with the supervisor in the field. This requirement cannot be substituted with additional course work, capstone or any project work.

Capstone: It is a mandatory degree award requirement of 3 credit hours for Bachelor of Science in Chemistry. The capstone is a multifaceted body of work that serves as a culminating academic and intellectual experience for students. It must be supervised and graded by a faculty member as per the protocols prescribed by the concerned department. This requirement cannot be substituted with additional course work or internship.

Course Code.

(1) Alphabet: CHEM= Chemistry, GEN=General

(2) Digit: For chemistry: 1st Digit= year, 2nd Digit= Area, 3rd Digit= level/number

(If 2nd digit for particular area i.e organic, inorganic exceeds 9 then **0**, **1** and **2** and so on will be written while if third digit for subject within an area exceeds 9 then the digit will be bold underlined and italic i.e **0**, **1** and **2** and so on.).

Regarding codes for Optional courses within a specialization the first digit representing year can be assigned while offering that particular course in a particular semester like 6th, 7th or 8th semester, while second digit will be related to that particular specialization and third digit for course withing that specialty.

(3) Digit: General: 1st Digit= year, 2nd Digit= Other Departments of SBBU in alphabetic order, 3rd Digit= level/number

For other Departments. General Subjects. 1st Digit= year, 2nd Digit= Area,

| | |
|--------------------|------------------------------|
| Computer Science | GEN-010 (alphabetical order) |
| English | GEN-020 (alphabetical order) |
| Islamyat | GEN-030 (alphabetical order) |
| Maths | GEN-040 (alphabetical order) |
| Management Science | GEN-050 (alphabetical order) |
| Pak Studies | GEN-060 (alphabetical order) |
| Sciences (General) | GEN-070 (alphabetical order) |
| Sociology | GEN-080 (alphabetical order) |
| Zoology | GEN-090 (alphabetical order) |

| Year – I | | | |
|------------------------|--|--------------|-------------------|
| SEMESTER 1 | | | |
| Course Code | Course Title | Credit Hours | Category |
| CHEM-301 | Fundamentals of Chemistry | 3 (2-1) | Major |
| CHEM-331 | Principles of Biochemistry | 3 (2-1) | Interdisciplinary |
| GEN-341 | Quantitative Reasoning – I | 3 (3-0) | General Education |
| GEN-371 | Natural Science | 3 (2-1) | General Education |
| GEN-321 | Functional English | 3 (3-0) | General Education |
| GEN-311 | Applications of Information and Communication Technology | 3 (2-1) | General Education |
| TOTAL CREDIT HOURS: 18 | | | |

SEMESTER 1

| CHEM-301 | Fundamentals of Chemistry | 3 (2-1) | Major |
|--|---------------------------|---------|-------|
| Course Contents | | | |
| Chemistry & Advanced Stoichiometry. Application of stoichiometric principles to solve quantitative problems in complex chemical systems, including limiting reactant analysis, reaction yield prediction, and mass relationships in redox processes. | | | |
| Atomic Structure & Periodic Relationships Quantum mechanical model of the atom and its role in explaining electronic structure, periodic trends, and chemical reactivity. Analysis of atomic radius, ionization energy, and electronegativity to predict elemental behavior. | | | |
| Chemical Bonding & Molecular Properties Theories of chemical bonding including valence bond theory and molecular orbital theory for diatomic molecules. Prediction of molecular structure, hybridization, and intermolecular forces to explain physical properties and molecular behavior. | | | |
| Principles of Chemical Equilibrium Concepts of dynamic equilibrium, equilibrium constants, and the reaction quotient. Application of Le-Chatelier's principle to predict shifts in equilibrium systems and discuss factors affecting reaction spontaneity. | | | |

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

- Understand complex chemical reactions, including redox and acid-base reactions, and apply advanced stoichiometric principles to solve quantitative problems.
- Explore and explain chemical bonding theories in-depth, such as hybridization, molecular orbital theory, and intermolecular forces, to predict molecular structure and behavior.
- Integrate thermodynamic and kinetic principles to evaluate energy changes, reaction spontaneity, and reaction mechanisms in diverse chemical processes.

Relevant Experiments

Experiments will be conducted based on the theory topics and subject to the availability of resources. The following is a suggested list of possible experiments.

1. Laboratory Safety, Basic Operations, and Data Handling: Introduce proper use of balances, Bunsen burners, and glassware by accurately preparing a specific volume of different solutions.
2. Determination of density and application of Significant Figures
3. Separation of a Mixture using physical properties
4. Determination of the Empirical Formula of a Compound
5. Gravimetric analysis of a limiting reactant
6. Volumetric Analysis: Acid-Base Titration: solution preparation, standardization and determination of unknown acid contents.
7. Flame tests and observation of atomic emission spectra for various metal salts.
8. Paper Chromatography: Separation and identification of metal cations
9. Investigation of ionic and covalent compounds by observing melting points, electrical conductivity, and solubility.
10. Molecular Model Building: Application of VSEPR Theory
11. Synthesis and analysis of a coordination compound: Synthesis and purification of tetraamminecopper(II) sulfate monohydrate, $[\text{Cu}(\text{NH}_3)_4] \text{SO}_4 \cdot \text{H}_2\text{O}$, via recrystallization
12. Exploring chemical equilibrium and Le Chatelier's Principle

Recommended Books

1. Brown, T. L., LeMay, H. E., Bursten, B. E., Murphy, C. J., Woodward, P. M., Stoltzfus, M. W., *Chemistry: The Central Science*, 15th ed., Pearson Education, (2023).
2. Zumdahl, S. S., Zumdahl, S. A., DeCoste, D. J., *Chemistry*, 11th ed., Cengage Learning, (2023).
3. Petrucci, R. H., Herring, F. G., Madura, J. D., Bissonnette, C., *General Chemistry: Principles and Modern Applications*, 12th ed., Pearson Canada, (2023).
4. Skoog, D. A., West, P. M., Holler, F. J., Crouch, S. R., *Fundamentals of Analytical Chemistry*, 9th ed., Brooks Cole Publishing Company, (2013).
5. Christian, G. D., *Analytical Chemistry*. 6th ed., John-Wiley & Sons, New York, (2006).
6. Harris, D. C., *Quantitative Chemical Analysis*, 8th ed., W. H. Freeman and Company, New York, USA, (2011).
7. Atkins, P., Jones, L., Laverman, L., *Chemical Principles: The Quest for Insight*, 8th ed., W. H. Freeman and Company, (2023).
8. Chang, R., Goldsby, K. A., *Chemistry*, 13th ed., McGraw-Hill Education, (2018).

9. McQuarrie, D. A., Rock, P. A., Gallogly, E. B., *General Chemistry*, 4th ed., University Science Books, (2010).
10. Silberberg, M. S., Amateis, P., *Chemistry: The Molecular Nature of Matter and Change*, 9th ed., McGraw-Hill Education, (2021).
11. Moore, J. W., Stanitski, C. L., Jurs, P. C., *Chemistry: The Molecular Science*, 5th ed., Cengage Learning, (2014)

| CHEM-331 | Principles of Biochemistry | 3 (2-1) | Interdisciplinary |
|---|----------------------------|---------|-------------------|
| <p>Course Contents</p> <p>Introduction to Biochemistry</p> <p>Brief introduction to the scope and history of Biochemistry. Molecular logic of the living organism. Cell structures and their functions. Origin and nature of biomolecules.</p> <p>Carbohydrates</p> <p>Definition, classification, chemistry. Biological functions of starch, glycogen, cellulose and cell wall polysaccharides, acid mucopolysaccharides and proteoglycans. Biological importance of carbohydrates.</p> <p>Lipids</p> <p>Definition and classification of lipids. Chemistry and biological importance of fatty acids, waxes, glycerides, phospholipids, sphingolipids, glycolipids, sterols and prostaglandins. Biological importance of lipids.</p> <p>Proteins</p> <p>Chemistry and classification of Amino acids. Proteins; their classification. Primary, secondary, tertiary and quaternary structure of proteins. Denaturation of proteins. Protein sequencing. Biological importance of carbohydrates.</p> <p>Nucleic Acids</p> <p>Chemical composition, structure and biological significance of nucleic acids. Isolation and separation of Nucleic acids. Introduction to recombinant DNA technology.</p> <p>Course Learning Outcomes:</p> <p>By the end of this course, the students will be able to:</p> <ul style="list-style-type: none"> • Explain biochemical principles underlying the structure and function of biomolecules. | | | |

- Analyze metabolic pathways and their relevance to cellular function and human health.
- Evaluate the applications of biochemistry in fields such as medicine, agriculture, and biotechnology etc.

Recommended Books

1. Nelson, D. L.; Cox, M. N., Lehninger principles of biochemistry, 4th ed. Worth Publisher, New York, 2004.
2. Murray, R. K.; Mayes P. A.; Granner, D. K.; and Rodwell, V. W., Harper's Biochemistry, Appleton & Lange, 2000.
3. West, W. R.; Todd, H. S., Text Book of Biochemistry, 4th ed. Macmillan, London, 1968.
4. Voet, D.; Voet J. G., Biochemistry, 3rd ed. John Wiley & Sons, New York, 2004.
5. Zubay, G., Biochemistry, 4th ed. Macmillan Publishing Co, 1999.
6. www.bio.mtu.edu/campbell/401sch1.html

Practical work:

Identification of carbohydrates, Identification of reducing sugars through Fehling test and tollen,s test, Identification of starch Iodine test, Measuring blood sugar level through glucometer, Sugar inversion through polarimeter/Measuring optical activity, Calibration of micropipette, Autoclaving, Identification of Proteins and Lipids and any other based on lab facilities available.

Course Learning outcomes:

The students will be able to:

- Identify and analyze carbohydrates, proteins, and lipids using biochemical tests and instruments like glucometers and polarimeters.
- Operate and calibrate essential lab equipment including micropipettes and autoclaves with precision and safety.
- Interpret experimental results and adapt procedures based on available lab resources to ensure reliable outcomes.

Recommended Books

1. Boyer, R. F. (2012). *Biochemistry laboratory: Modern theory and techniques* (2nd ed.). Pearson Education.

2. Wilson, K., & Walker, J. (Eds.). (2018). *Principles and techniques of biochemistry and molecular biology* (8th ed.). Cambridge University Press.
3. Switzer, R. L., & Garrity, L. F. (1999). *Experimental biochemistry* (3rd ed.). W.H. Freeman.
4. Robyt, J. F., & White, B. J. (1990). *Biochemical techniques: Theory and practice* (2nd ed.). Waveland Press.
5. Bishop, M. L., Fody, E. P., & Schoeff, L. E. (2022). *Clinical chemistry: Principles, techniques, and correlations* (9th ed.). Wolters Kluwer.

| Year – I | | | |
|-------------------------------|-----------------------------------|---------|-------------------|
| SEMESTER 2 | | | |
| CHEM-301 | Principles of Organic Chemistry | 3 (2-1) | Major |
| CHEM-391 | Principles of Inorganic Chemistry | 3 (2-1) | Major |
| CHEM-321 | Principles of Physical Chemistry | 3 (2-1) | Major |
| GEN-342 | Quantitative Reasoning – II | 3 (3-0) | General Education |
| GEN-322 | Expository Writing | 3 (3-0) | General Education |
| GEN-361 | Pakistan Studies | 2 (2-0) | General Education |
| GEN-331 | Understanding of Quran – I | 1 (0-1) | General Education |
| TOTAL CREDIT HOURS: 17 | | | |

| CHEM-301 | Principles of Organic Chemistry | 3 (2-1) | Major |
|--|---------------------------------|---------|-------|
| Course Contents | | | |
| Atomic structure, covalent bonding and hybridization, molecular shapes, hydrogen bonding, inductive effect, Lewis structures, resonance, hyperconjugation, structural isomerism, geometrical isomerism (Tamoxifen, Maleic acid & Fumaric acid), aromaticity. Nomenclature of organic compounds including bicyclo and spiro compounds, electrophile, nucleophile, and leaving group, preparation of alkanes (Corey- House synthesis & Wurtz reaction), alkenes (Hofmann elimination), alcohols (Reduction of carbonyl compounds), carbonyl compounds (Ozonolysis of alkenes), carboxylic acids (Hydrolysis of nitriles and esters). Reaction mechanisms (Curved arrow notation & structure activity relationships) including electrophilic-addition (Addition of HX and water to alkenes and alkynes), electrophilic aromatic substitution (Halogenation, alkylation, and acylation of benzene and phenol), nucleophilic substitution (S _N 1 | | | |

and S_N2 reactions of R-X to form R-OH), elimination (Dehydrohalogenation of R-X & dehydration of alcohols), nucleophilic-addition (Addition of ammonia derivatives to carbonyl compounds), rearrangement (Pinacol-Pinacolone). Introduction to polymers, addition polymerization (Preparation of polystyrene) and condensation polymerization (Preparation of nylon-6,6).

Course Learning Outcomes

By the end of this course, the students will be able to:

- Explain fundamental principles of organic chemistry, including structure, bonding, and functional groups.
- Understand the reaction mechanisms and synthesis of organic molecules relevant to pharmaceuticals and polymers etc.
- Apply organic chemistry principles in laboratory settings with emphasis on safety, precision, and efficiency.

Relevant Experiments

Personal protective equipment (PPE), safe handling and disposal of chemicals, and familiarization with glassware. Identification of functional groups such as alkenes, alcohols, aldehydes, ketones, and carboxylic acids. Determination of melting and boiling points, crystallization, distillation, and chromatography. Preparation of aspirin, oxime, hydrazone, benzanilide, and soap etc.

Recommended Books

1. Klein, D. R. (2020). *Organic Chemistry* (4th ed.). John Wiley & Sons. ISBN: 978- 1-119-65959-4.
2. Bruice, P. Y. (2024). *Organic Chemistry* (9th ed.). Pearson. ISBN-13: 9780138223731.
3. Karty, J. (2021). *Organic Chemistry: Principles and Mechanisms* (3rd ed.). W. W. Norton & Company, New York, USA. ISBN: 978-0-393-87764-9
4. Brown, W., Iverson, B., Anslyn, E., & Foote, C. (2017). *Organic Chemistry* (8th ed.). Cengage Learning, Boston, USA. ISBN-13: 978-1305580350.
5. Solomons, T.W. G., Fryhle, C. B., & Snyder, S. A. (2016). *Organic Chemistry* (12th ed.). John Wiley & Sons. ISBN: 978-1-119-07725-1.
6. Caron, S. (Ed.). (2020). *Practical synthetic organic chemistry: Reactions, principles, and techniques* (2nd ed.). John Wiley & Sons. ISBN: 978-1-119- 44885-3.
7. Gilbert, J. C., & Martin, S. F. (2015). *Experimental organic chemistry: A miniscale and microscale approach* (6th ed.). Cengage Learning, Boston, USA. ISBN-13: 978-1305080461.
8. Pavia, D. L., Lampman, G. M., Kriz, G. S., & Engel, R. G. (2017). *A microscale approach to organic laboratory techniques* (6th ed.). Cengage Learning, Boston, USA. ISBN: 978-1305968349.

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|--|--|----------------|--------------|
| CHEM-391 | PRINCIPLES OF INORGANIC CHEMISTRY | 3 (2-1) | Major |
| Course Content | | | |
| Chemical Bonding | | | |
| Types of chemical bonding, ionic and covalent bonding, localized bond approach, theories of chemical bonding, valence bond theory (VBT), hybridization and resonance, prediction of molecular shapes using Valence Shell Electron Pair Repulsion (VSEPR) model, molecular orbital theory (MOT) applied to diatomic molecules, delocalized approach to bonding, bonding in electron deficient compounds, hydrogen bonding. | | | |
| Acids and Bases | | | |
| Brief concepts of acids and bases including soft and hard acids and bases (SHAB), concept of relative strength of acids and bases, significance of pH, pKa, pKb and buffer solutions, theory of indicators, solubility, solubility product, common ion effect and their industrial applications. | | | |
| s and p-Block Elements | | | |
| Physical and chemical properties of s and p-block elements with emphasis on some representative compounds, inter-halogens, pseudo-halogens and polyhalides. | | | |
| Course Learning Outcomes | | | |
| Upon successful completion of this course, students will be able to: | | | |
| <ul style="list-style-type: none"> • Understand fundamental bonding types and modern theories to predict molecular shapes, hybridization, and electron behavior in compounds. • Learn acid-base equilibria, and solubility principles (K_{sp}, buffers) to solve practical problems in industrial and laboratory settings. • Learn trends in physical/chemical properties of p-block elements, and their reactive behaviors to rationalize real-world uses and environmental impacts. | | | |
| Experimental Work | | | |
| <ol style="list-style-type: none"> 1. Lab safety and good laboratory practices, knowledge about material safety data sheets (MSD). Disposal of chemical waste and first-aid practices. 2. Green Chemistry principles (e.g., use of a less hazardous chemical; minimization of wastes. 3. Qualitative analysis of salt mixtures. 4. Preparation of primary standard solution and standardization of acid and alkali solutions. 5. Acid- base titrations. 6. Preparation of Buffer solution. 7. Redox titrations. 8. Preparation and standardization of potassium permanganate solution and its use for the determination of purity of commercial potassium oxalate or oxalic acid. 9. Preparation and standardization of sodium thiosulfate solution and its use in determination of copper in a given sample. 10. Gravimetric analysis. | | | |

11. Determination of barium in a given sample, determination of chloride in a given solution.

Recommended Books

1. Shriver, D. F., Atkins, P. W., Langford, C. H., *Inorganic Chemistry*, 5th ed., Oxford University Press, (2010).
2. Cotton, F. A. and Wilkinson, G., *Advanced Inorganic Chemistry*, 6th ed., John-Wiley & Sons, New York, (2007).
3. Huheey, J. E., *Inorganic Chemistry: Principles of Structure and Reactivity*, 4th ed., Pearson, (1997).
4. House, J. E., *Inorganic Chemistry*, Academic Press. USA, (2008).
5. Rayner-Canham, G., & Overton, T., *Descriptive Inorganic Chemistry*, 6th ed., W.H. Freeman, (2018).
6. Chaudhary S. U., *Ilmi Textbook of Inorganic Chemistry*, Ilmi Kitab Khana, Lahore, (2013).
7. Catherine E. House crdft, Alan G. Sharpe, *Inorganic Chemistry*, 5th ed., Prentice Hall, (2018).
8. Kathleen A. H., James E. H., *Descriptive Inorganic Chemistry*, 2nd ed., Brooks Cole, (2010).
9. Miessler, G. L., Fischer, P. J., Tarr, D. A., *Inorganic Chemistry*, 6th ed., Pearson Education, (2022)
10. Rodgers, G. E., *Descriptive Inorganic, Coordination, and Solid-State Chemistry*, 3rd ed., Brooks Cole, (2012).

| CHEM-321 | Principles of Physical Chemistry | 3 (2-1) | Major |
|--|----------------------------------|---------|-------|
| <p>Course Learning Outcomes</p> <p>Chemical Thermodynamics: Fundamentals of thermodynamics, thermodynamic properties, relation used in thermodynamics, free energy, enthalpy, entropy, heat capacities and their dependence on temperature, pressure and volume, laws of thermodynamics and their applications.</p> <p>Chemical Kinetics: The rates of reactions, rate law and rate equation, order of reaction. Zero, first, second and third order reactions, Methods for determination of order of reactions (integration, half-life, initial rate, and graphical methods), Activation energy,</p> <p>Quantum Mechanics: Basic concepts of quantum mechanics, Quantum mechanical treatment (Schrodinger wave equation), Atomic structure, atomic models, line spectra of elements, Quantum numbers, Operators, types of operators, eigen function, eigen values and eigen value equation, wave and particle nature of matter, Debroglie hypothesis, Heisenberg uncertainty principle</p> <p>Experimental Work</p> <ol style="list-style-type: none"> 1. Determination of viscosity and refractive index of liquids. 2. Determination of percent composition of liquid solutions viscometrically. 3. Determination of refractive index and molar refractivity. 4. Determination of surface tension by stalagmometer. 5. Determination of viscosity by Ostwald viscometer. 6. Determination of conductance of a solution by conductometer. 7. Determination of percent composition of liquid solutions by refractive index measurements. 8. Determination of heat of solution by solubility method. 9. Determination of heat of neutralization of an acid with a base. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. McQuarrie, D. A. and Simon, J. D., Physical Chemistry – A Molecular Approach, 1st ed., University Science Books, (1997). 2. Atkins, P. and Paula, J. D., Atkin's Physical Chemistry, 9th ed., Oxford University Press, (2010). 3. Shoemaker, D., Experiments in Physical Chemistry, 8th ed., McGraw Hill Publishing Company Limited, (2003). 4. Silbey, R., Alberty, R. and Bawendi, M., Physical Chemistry, 4th ed., (2005). 5. Glasstone, S., Textbook of Physical Chemistry, Macmillan London (1960). 6. James, A. M., Prichard, F. E., Practical Physical Chemistry, 3rd ed., Longman Group Limited, New York, (1974). 7. Chaudhary, S. U., Ilmi Textbook of Physical Chemistry, 2nd ed., Ilmi Kitab Khana, Lahore, (2013). | | | |

8. Atkins, P., Jones, L., Chemical Principles: The Quest for Insight, 5th ed., W. H. Freeman, New York, (2010).
9. Linder, B., Elementary Physical Chemistry, World Scientific Publishing Co. Pvt. Ltd., (2011).
10. Davis, W. M., Dykstra, C. E., Physical Chemistry: A Modern Introduction, 2nd ed., CRC Press, (2011).

| Year - II | | | |
|------------------------|---|---------|-------------------|
| SEMESTER 3 | | | |
| CHEM-421 | Principles of Analytical Chemistry | 3 (2-1) | Major |
| CHEM-421 | Principles of Polymer Chemistry | 3 (2-1) | Major |
| CHEM-402 | Introduction to Nano-chemistry | 3 (2-1) | Major |
| GEN-462 | Ideology and constitution of Pakistan | 2 (2-0) | General Education |
| GEN-432 | Understanding of Quran – II | 1 (0-1) | General Education |
| GEN-433 | Islamic Studies (Ethics for non-Muslim students) | 2 (2-0) | General Education |
| GEN-434 | Seerat UI Nabi | 2 (2-0) | General Education |
| TOTAL CREDIT HOURS: 16 | | | |

| CHEM-421 | Principles of Analytical Chemistry | 3 (2-1) | Major |
|---|------------------------------------|---------|-------|
| Course Contents | | | |
| Fundamental Concepts of Analytical Chemistry | | | |
| Introduction to quantitative and qualitative analysis. Principles and applications of classical analytical techniques including gravimetric, volumetric, and complexometric methods. Stoichiometric calculations for various titration types (acid-base, redox, precipitation) to determine analyte concentrations. Theory of mass action and chemical equilibrium as the basis for analytical methods. | | | |
| Chemometrics for Data Interpretation | | | |
| Application of statistical methods to interpret analytical data and ensure reliability. Techniques include significance tests, analysis of variance (ANOVA), and least squares regression for calibration. Management of errors, outliers, and uncertainty to support scientific and industrial decision-making. | | | |

Quality Assurance and Control Protocols

Implementation of quality control (QC) and quality assurance (QA) systems in analytical laboratories. Use of QC tools and ISO standards to validate methods for environmental monitoring, food safety, and other industrial sectors. Principles of calibration and monitoring to maintain analytical standards.

Course Learning Outcomes

Upon successful completion of this course, students will be able to:

- Describe fundamental analytical techniques for quantitative and qualitative analysis.
- Apply analytical methods to chemical testing in various sectors, such as environmental monitoring and food safety etc.
- Interpret data from analytical experiments to support scientific research and industrial standards.

Experimental Work

Experiments will be conducted based on the theory topics and subject to the availability of resources. The following is a suggested list of possible experiments.

1. Laboratory Safety and good laboratory practices, knowledge about material safety data sheets (MSDS).
2. Disposal of chemical waste and first-aid practices.
3. Sampling and sample preparation for solid and liquid analytes.
4. Preparation of primary standard solutions and introduction to stoichiometric calculations.
5. Standardization of HCl and Introduction to Indicators for acid base titration.
6. Standardization of a sodium hydroxide solution using potassium hydrogen phthalate (KHP) primary standard.
7. Determination of total alkalinity in a water sample by acid-base titration.
8. Determination of the amount of aspirin in a tablet using back-titration.
9. Determining the accuracy of a method.
10. Determination of Water of Hydration in a Salt by gravimetric analysis.
11. Analysis of an Unknown Carbonate Mixture by pH meter.
12. Determination of acetic acid in vinegar using both titration and a pH probe.
13. Application of statistical analysis (mean, standard deviation, Q-test) to class titration data.
14. Determination of Vitamin C (Ascorbic Acid) in fruit juice by redox titration.
15. Determination of Water Hardness by complexometric titration.

Recommended Books

1. Skoog, D. A., West, P. M., Holler, F. J., Crouch, S. R., Fundamentals of Analytical Chemistry, 9th ed., Brooks Cole Publishing Company, (2013).
2. Christian, G. D., Analytical Chemistry. 6th ed., John-Wiley & Sons, New York, (2006).
3. Harris, D. C., Quantitative Chemical Analysis, 8th ed., W. H. Freeman and Company, New York, USA, (2011).
4. Mitra A., Fundamentals of Quality Control and Improvement, 3rd ed., John-Wiley & Sons, (2008).

5. Miller, J. N., & Miller, J. C. *Statistics and chemometrics for analytical chemistry*. Pearson education, (2018).
6. Rouessac, F., Rouessac, A., *Chemical Analysis: Modern Instrumentation Methods and Techniques*, 2nd ed., John Wiley & Sons, (2007).
7. Bruno, T. J., Svoronos, P. D. N., *Handbook of Basic Tables for Chemical Analysis*, 4th ed., CRC Press, (2021).
8. Prichard, E., Barwick, V., *Quality Assurance in Analytical Chemistry*, John Wiley & Sons, (2007).

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|--|--|----------------|--------------|
| CHEM-421 | Principles of Polymer Chemistry | 3 (2-1) | Major |
| <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <p>Explain the chemistry of polymerization and the properties of synthetic and natural polymers.</p> <p>Analyze the molecular structure of polymers and their mechanical, thermal, and chemical behaviors.</p> <p>Evaluate applications of polymers in biomedical devices, packaging, and electronics etc.</p> <p>Course contents:</p> <p>Introduction to Polymers, Classification of polymers, crystalline structures, semicrystalline nature and amorphous polymers, applications of polymer, physical aspects of polymers, averages, number average and weight average. Polymer solutions and blends, characteristics of polymer solutions, self-aggregation and micellization.</p> <p>Recommended Books:</p> <ol style="list-style-type: none"> 1. Sperling, L. H. <i>Introduction to Physical Polymer Science</i>, 4th ed., Wiley-Interscience, New York, USA, (2006). 2. Boyd, R. H. and Phillips, P. J., <i>The Science of Polymer Molecules</i>, Cambridge, UK, (1993). 3. Odian, G., <i>Principles of Polymerization</i>, 4th ed., Wiley Interscience, (2004). 4. Carraher Jr, C. E., <i>Carraher's, Polymer Chemistry</i>, 8th ed., CRC Press, Inc., (2010). 5. Ravve, A., <i>Principles of Polymer Chemistry</i>, 3rd ed., Springer, (2012). 6. Stevens, M. P., <i>Polymer Chemistry: An Introduction</i>, 3rd ed., Oxford University Press, (1998). | | | |

7. Allcock, H., Lampe, F. and Mark, J., *Contemporary Polymer Chemistry*, 3rd ed., Prentice Hall, (2003).
8. Flory, J., *Principles of Polymer Chemistry*, Cornell University Press (1953).
9. Painter P.C. and Coleman M.M., *Fundamental of Polymer Science*, 2nd ed., CRC Press (1997).
10. Carraher C.E., *Polymer Chemistry*, 6th ed., Marcel Dekker (2003). 3. Young R.J., *Introduction to Polymers*, Chapman and Hall Ltd. (1981).
11. Stevens M.P., *Polymer Chemistry: An Introduction*, Oxford University Press (1999).
12. Sperling L.H., *Introduction to Physical Polymer Science*, 4th ed., Wiley Interscience (2006).

Practicals:

Course Learning Outcomes

The course will provide the practical grounds for the verification of fundamental principles of polymer chemistry and applications of these principles. In addition it will enable the students to apply these practical methods in other branches of chemistry. Students will also learn the advanced techniques like XRD and UV-visible for characterization of materials.

Course Contents:

Extraction of biopolymer and their characterization.

Biopolymers interaction with surfactants and their characterization

Determination of molecular weight of a polymer by viscosity method.

Measurement of IR spectra of simple compound and their interpretation.

| CHEM-402 | Introduction to Nano-chemistry | 3 (2-1) | Major |
|---|--------------------------------|---------|-------|
| <p>Course Contents</p> <p>Nanomaterials, Classification of nanomaterials, metal oxides, sulfides, nitrides, fullerenes, graphenes, graphite, diamond, activated carbon, pyrolytic carbon, structure and bonding in nanomaterials. Nanostructure-dependent properties: electrical, magnetic, optical and catalytic. Synthesis, characterization and functionalization of nanomaterials for advanced applications</p> <p>Course Learning Outcomes</p> <p>Upon successful completion of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Learn about nanomaterials, their different types, structural variabilities | | | |

2. Learn about different properties associated with nanomaterial as compared to their bulk counterparts.
3. Learn about the synthetic and characterization methods used in production of nanomaterial.

Relevant Experiments

1. Synthesis of Metallic nanoparticles and their characterization using FTIR and UV-visible spectroscopy.
2. Synthesis of metal oxide nanoparticles and their characterization using FTIR and XRD techniques.
3. Synthesis of Ferrite nanoparticles and their characterization using different techniques.
4. Measurement of FTIR spectra of simple compound and their interpretation.
5. Measurement of UV-visible spectra of simple compound and their interpretation.

Recommended Books

1. K.J. Klabundle, R.M. Richards, Nanoscale Materials in Chemistry, John Wiley & Sons, Inc., New York, 2nd edition, (2009).
2. A.A. Moosa, Carbon Nanotubes: Synthesis and Applications, Dar Djlal Publishing, Amman, Jordan (2012).
3. G. A. Ozin, A. C. Arsenault, L. Cademartiri, Nanochemistry: A Chemical Approach to Nanomaterials, Royal Society of Chemistry (2009).

| Year - II | | | |
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| SEMESTER 4 | | | |
| CHEM-461 | Forensic Chemistry | 3 (2-1) | Major |
| CHEM-481 | Industrial Chemistry | 3 (2-1) | Major |
| CHEM-451 | Environmental Chemistry | 3 (2-1) | Major |
| CHEM-411 | Pharmaceutical Chemistry | 3 (2-1) | Major |
| GEN-481 | Social Sciences | 2 (2-0) | General Education |
| GEN-482 | Civics & Community Engagement | 2 (2-0) | General Education |
| GEN-451 | Entrepreneurship and Economic Development | 2 (2-0) | General Education |
| TOTAL CREDIT HOURS: 18 | | | |

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|---|---------------------------|---------|--------------|
| CHEM-461 | Forensic Chemistry | 3 (2-1) | Major |
| <p>Course Contents</p> <p>Introduction to forensic chemistry, role in justice system, ethical issues; analytical techniques: chromatography (TLC, GC, HPLC), spectroscopy (UV-Vis, IR, AAS), microscopy; crime scene and evidence handling: management, collection, preservation, chain of custody; drugs and narcotics: classification, spot and confirmatory tests; poisons and toxicology: types and detection in biological samples; fire and explosive analysis: combustion chemistry, arson, explosives; forensic serology and DNA analysis: blood and body fluids, stains, bloodstain interpretation, genetic markers, DNA profiling, parentage testing; trace evidence and document examination: hair, fibers, glass, soil, paints, inks, dyes, forgery detection, handwriting analysis; industrial, environmental and food forensics: pesticides, adulterants, pollutants.</p> <p>Course Learning Outcomes</p> <p>Upon successful completion of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Understand fundamentals of forensic chemistry and crime scene analysis. 2. Apply chemical and laboratory methods for forensic evidence analysis. 3. Identify and analyze drugs, toxins, explosives, DNA, fluids, and trace evidence. 4. Simulate forensic testing using laboratory techniques. 5. Recognize legal and ethical responsibilities in forensic practice. <p>Relevant Experiments</p> <ol style="list-style-type: none"> 1. Lab orientation, safety, and chain of custody. 2. Presumptive and confirmatory blood tests. 3. Chromatography for drugs, inks, and dyes. 4. Identification of powders and alcohol analysis. 5. Flame test for metals, fiber and soil analysis. 6. Forgery and adulteration detection. 7. Spot tests for poisons. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Bell, S. (2022). Forensic chemistry. CRC Press. 2. Elkins, K. M. (2018). Introduction to forensic chemistry. CRC Press. 3. Siegel, J. A. (Ed.). (2015). <i>Forensic chemistry: fundamentals and applications</i>. John Wiley & Sons. 4. Newton, D. E. (2007). Forensic chemistry. Infobase Publishing. | | | |

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| CHEM-481 | Industrial Chemistry | 3 (2-1) | Major |
| Course Contents | | | |

Fundamentals of Chemical Industry. Introduction to unit operations such as heat transfer, evaporation, distillation, size reduction, screening, and filtration, steam production and scale removal. Cracking and distillation of various petroleum fractions. Industrial manufacturing of sulfuric acid, nitric acid, hydrochloric acid, caustic soda and polymers. Impact of industrial processes on the economic growth, environmental sustainability and social welfare. Principles and benefits of circular economy.

Optional Activity: To enhance students' applied understanding of industrial chemistry, an optional, however highly recommended **industrial tour** may be arranged to chemical industries/educational institutions. The arrangement of this tour will depend on financial feasibility and resources. Where visits are not possible, alternative enrichment activities will be provided, including industrial case studies, virtual plant visits, or invited lectures by industry/educational professionals.

Course Learning Outcomes

By the end of this course, the students will be able to:

Describe the principles and processes of industrial chemistry, including manufacturing chemicals, petrochemicals, and polymers etc.

Apply knowledge of process optimization, catalysis, and reaction engineering in industrial chemical production.

Assess the impact of industrial chemical processes on economic growth, environmental sustainability, and social welfare.

Relevant Experiments

Laboratory work illustrating topics covered in the lectures of the course.

Recommended Books:

1. Benvenuto, M.A. (2024). *De Gruyter Textbook of Industrial Chemistry* (2nd ed.). Walter de Gruyter Publisher. ISBN: 9783110671063.
2. Srinivasan, V., Rekha, S., & Sudhakar, K. (2018). *Engineering Chemistry*. Pearson India Education Services Pvt. Ltd. ISBN: 9789353066178.
3. Maheswaramma, K.S., & Chugh, M. *Engineering Chemistry*. Pearson India Education Services Pvt. Ltd. ISBN: 9788131774519.
4. Sharma, J. (2012). *Applied Industrial Chemistry*. Arise Publishers and Distributors. ISBN: 9789381031179
5. Kent, J.A. (2007). *Kent and Riegel's Handbook of Industrial Chemistry and Biotechnology*. Springer Publisher. ISBN: 9781461442592.

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|---|--------------------------------|----------------|--------------|
| CHEM-451 | Environmental Chemistry | 3 (2-1) | Major |
| <p>Course Contents</p> <p>Introduction to environmental chemistry and its importance. Overview of atmosphere, hydrosphere, and lithosphere. Chemical processes occurring in different environmental compartments and their implications for the environment. Key challenges of the pollution highlighted in some famous multilateral environmental agreements (MEAs), effects of transport pollution, industrial activities, solid waste management on ecosystem and human health, their mitigation measures and sustainable approach regarding their management in the light of sustainable development goals.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <p>Explain chemical processes occurring in the atmosphere, hydrosphere, and lithosphere and their implications for the environment.</p> <p>Analyze sources, fate, and transport of pollutants, with a focus on chemical impacts on ecosystems and human health.</p> <p>Evaluate strategies for pollution control and sustainable practices in environmental management.</p> <p>Relevant Experiments</p> <p>Laboratory work illustrating topics covered in the lectures of the course.</p> <p>Recommended books</p> <ol style="list-style-type: none"> 1. Manahan, S.E. (2022). <i>Environmental Chemistry</i> (11th ed.). CRC Press, Taylor & Francis Group. ISBN: 9780367558871 2. Girard, J.E. (2013). <i>Principles of Environmental Chemistry</i> (3rd ed.). Jones and Bartlett Publishers. ISBN: 9781449693527 3. Baird, C. (2012). <i>Environmental Chemistry</i> (5th ed.). W.H. Freeman & Company. ISBN: 9781429277044 4. Holloway, A.M., & Wayne, R.P. (2010). <i>Atmospheric Chemistry</i> (1st ed.). Royal Society of Chemistry. ISBN: 9781847558077 5. Harrison, R.M., Monks, P., Farmer, J.G., Graham, M.C., Mora, S.J., Pulford, I., & Hulsal, C. (2007). <i>Principles of Environmental Chemistry</i>. Royal Society of Chemistry. ISBN: 9780854043712. | | | |

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|---|--------------------------|---------|-------|
| CHEM-411 | Pharmaceutical Chemistry | 3 (2-1) | Major |
| <p>Course Contents</p> <p>Introduction to medicinal chemistry. Drug and medicine: difference and customary use. Drug discovery and development. Rational drug design and synthesis. Physicochemical properties in relation to biological action and drug transport. Pharmacodynamics (drug action) and Pharmacokinetics. Modes and sites of drug action. Routes of drug administration, absorption, distribution, metabolism and excretion. Bioavailability, toxicity, safety and therapeutic index of drugs. Drug-receptor interactions. Drug formulations. Active ingredients and excipients. Quality control and assurance. Good Manufacturing Practices (GMP).</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Explain fundamental concepts in pharmaceutical chemistry, including drug design and synthesis, physico-chemical properties of drugs, and their interactions with biological systems. 2. Analyze the principles of drug action, absorption, distribution, metabolism, excretion and toxicity to understand drug efficacy and safety. 3. Design, develop and investigate pharmaceutical compounds, emphasizing quality control and assurance. <p>Relevant Experiments</p> <p>Performance of weight-variation, friability, disintegration and dissolution tests on solid dosage forms. Assays (UV methods) of marketed drug molecules like ofloxacin, cetirizine dihydrochloride, esomeprazole magnesium, and pantoprazole sodium etc.</p> <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Jain, K. & Yadav, A. K. (2025). <i>Advances in Pharmaceutical Product Development</i>. Springer Nature Singapore. ISBN: 978-9-81-979229-0. 2. Rosa, J. M. C. (2024). <i>Pharmaceutical Chemistry: Drug Design and Action</i> (2nd ed.). De Gruyter Textbook Series. ISBN: 978-3-11-131654-3. 3. Patrick, G. L. (2023). <i>An Introduction to Medicinal Chemistry</i> (7th ed.). Oxford University Press. ISBN: 978-0-19-886666-4. 4. Watson, D. J. (2011). <i>Pharmaceutical Chemistry</i> (1st ed.). Elsevier Health Sciences. ISBN: 978-0-443-07232-1. 5. Sriram, D. & Yogeewari, P. (2010). <i>Medicinal Chemistry</i> (2nd ed.). Dorling Kindersley (India) Pvt. Ltd. ISBN: 978-81-317-3144-4. 6. Hanson, J. R. (2019). <i>Chemistry and Medicine; An Introductory Text</i>. Royal Society of Chemistry, UK. ISBN: 978-0854046454. 7. Wilson, C. O. (2011). <i>Wilson and Gisvold's Textbook of Organic Medicinal and</i> | | | |

Pharmaceutical Chemistry. (12th ed.; J. M. Beale Jr., & J. H. Block, Eds.). Lippincott Williams & Wilkins, Philadelphia, USA. ISBN: 978-0-7817-7929-6.

8. Dharuman, J. (2024). *Chemistry of Synthetic Drugs*. (3rd ed.). AITBS Publishers and Distributors, New Delhi, India. ISBN: 978-8-17-473337-5.
9. Current Literature and Reviews.

| Year - III | | | |
|-------------------------------|-------------------------------|---------|-------|
| SEMESTER 5 | | | |
| CHEM-502 | Advanced Organic Chemistry | 3 (2-1) | Major |
| CHEM-592 | Advanced Inorganic Chemistry | 3 (2-1) | Major |
| CHEM-522 | Advanced Physical Chemistry | 3 (3-0) | Major |
| CHEM-522 | Advanced Analytical Chemistry | 3 (2-1) | Major |
| CHEM-541 | Soil Chemistry | 3 (2-1) | Major |
| CHEM-541 | Computational Chemistry | 3 (2-1) | Major |
| TOTAL CREDIT HOURS: 18 | | | |

| CHEM-502 | Advanced Organic Chemistry | 3 (2-1) | Major |
|--|-----------------------------------|----------------|--------------|
| Course Contents | | | |
| Introduction and importance of organic synthesis. stereospecific and stereoselective organic reactions (kinetic <i>vs</i> thermodynamic control, conformation effects, stereoelectronic effects). methods of c-c, c-o & c-n bond formation. Stereoselective oxidations, epoxidations and reductions. ylides in c-c bond formation. other methods like cycloaddition and pericyclic reactions. multistep organic synthesis (mainly c-c, c- o & c-n). Biomedical and industrial applications of polymers depending on the structure. | | | |
| Course Learning Outcomes | | | |
| By the end of this course, the students will be able to: | | | |
| <ol style="list-style-type: none"> 1. Explain reaction mechanisms, stereochemistry, and the synthesis of organic molecules. 2. Apply synthetic methods to design complex organic compounds relevant to pharmaceuticals and polymers. 3. Design organic synthesis with an emphasis on research and industrial | | | |

applications.

Relevant Experiments

Synthesis of aspirin, parabens, and substituted benzene. reduction of nitrobenzene, sulfonation of aniline, oxidation of benzaldehyde, synthesis of cyclohexanone from cyclohexanol. Synthesis of conjugated, addition and condensation polymers.

Recommended Books

1. Carey, F. A. & Sundberg, R. J. (2007). *Advanced Organic Chemistry. Part B: Reactions and Synthesis* (5th ed.). Springer New York. ISBN 978-0-387-71481- 3.
2. Solomons, Craig, T. W. G. & Fryhle, B. (2014). *Organic Chemistry* (11th ed.). John Wiley & Sons, Inc. New York. ISBN 978-047-183659-9.
3. Eliel, L. & Wilen, S.H. (2014). *Stereochemistry of Organic compounds* (1st ed.). John Wiley & Sons, Inc. New York. ISBN 978-047-101670-0.
4. Clayden, N. Greeves, S. Warren & P. Wothers, (2022). *Organic Chemistry* (2nd ed.). John Wiley & Sons, Inc. New York. ISBN 978-019-927029-3.
5. Furniss, B. S. Hannaford, A. S. Smith, A. S. & Tatchell, A. R. (2000). *Vogel's- Textbook-of- Practical-Organic-Chemistry* (6th ed.). Thames Ploytechnic, London, Copublished in the United States with John Wiley & Sons, Inc., New York. ISBN 978-817-758180-5.
6. Caron, S. (2020). *Practical Synthetic Organic Chemistry-Reactions, Principle and Techniques* (2nd ed.). John Wiley & Sons Inc. New York. ISBN: 978-0-470- 03733-1.
7. Gilbert, J. C. Martin, S. F. (2016). *Experimental Organic Chemistry - A Mini- scale and Microscale Approach* (6th ed.). Cengage Learning. ISBN: 978-130- 508046-1.
8. Current Literature and Reviews.

| CHEM-592 | Advanced Inorganic Chemistry | 3 (2-1) | Major |
|--|------------------------------|---------|-------|
| Course Contents Chemistry of d-block elements and coordination complexes Electronic configuration, background of coordination chemistry, nomenclature and structure, chelates and chelate effect. Theories of bonding: Werner's theory, valence bond theory (VBT crystal field theory (CFT) and molecular orbital theory (MOT). Jahn-Teller theorem. Properties and applications: Using CFT/MOT to explain magnetic properties, spectral properties, isomerism, stereochemistry, stability constants, catalytic activity, and spectral properties in bioinorganic systems (e.g., hemoglobin). Correlation of properties to function in industrial catalysts (e.g., Ziegler-Natta catalysis) and materials applications. Chemistry of f-block elements Lanthanides: General characteristics, occurrence, extraction and separation principles, electronic structure, lanthanide contraction, oxidation states, spectral and magnetic properties. Applications of Lanthanides: in permanent magnets, phosphors (displays and lighting), and catalysts. Environmental context of extraction and separation. | | | |

Actinides: General characteristics, electronic structure, oxidation states. Radioactivity: half-life and decay law. Introduction to nuclear energy. Environmental and safety considerations of radioactive decay and nuclear waste.

Course Learning Outcomes

By the end of this course, students will be able to:

1. Describe the fundamental properties, bonding, and reactivity of inorganic compounds.
2. Analyze the chemical behavior of elements and their compounds, with relevance to
3. industrial and environmental applications.
4. Evaluate the applications of inorganic compounds in materials science, catalysis, and
5. environmental management.

Relevant Experiments

1. Preparations of following Inorganic Complexes;
2. Tetra ammine copper (II) sulphate.
3. Potassiumtrioxalatochromate (III).
4. Potassiumtrioxalatoaluminate (III).
5. Cis-Potassium dioxalatoaquachromate (III).
6. Determination of zinc and cadmium by complexometric titration
7. Chromatographic separations of transition metals;
8. Separation of Ni^{2+} & Co^{2+} ions in a mixture by paper chromatography.
9. Separation of Cu^{2+} & Fe^{2+} ions in a mixture by paper chromatography.
10. Spectrophotometric determination of iron, manganese and nickel.
11. Determination of the Formula of a Complex Ion by Job's Method
12. Determination of Hardness of Water by Complexometric Titration.
13. Qualitative determination of the magnetic property of complexes.

Recommended Books

1. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, 6th ed., Pearson Education, (2022).
2. Housecroft, C. E., Sharpe, A. G., Inorganic Chemistry, 5th ed., Pearson Education, (2018).
3. Weller, M., Overton, T., Rourke, J., Armstrong, F., Inorganic Chemistry, 7th ed., Oxford University Press, (2018).
4. Rayner-Canham, G., Overton, T., Descriptive Inorganic Chemistry, 6th ed., W.H. Freeman, (2018).
5. Reedijk, J., Poeppelmeier, K. (Eds.), Comprehensive Inorganic Chemistry III, 3rd ed., Elsevier, (2023).
6. Lee, J. D., Concise Inorganic Chemistry, 5th ed., Wiley-Blackwell, (2008).
7. Rodgers, G. E., Descriptive Inorganic, Coordination, and Solid-State Chemistry, 3rd ed., Brooks Cole, (2012).
8. Shriver, D. F., Atkins, P. W., Langford, C. H., Inorganic Chemistry, 2nd ed., Oxford University Press, (1994).
9. Cotton, F. A. and Wilkinson, G., Advanced Inorganic Chemistry, 6th ed., John-Wiley & Sons, New York, (2007).
10. Huheey, J. E., Inorganic Chemistry: Principles of Structure and Reactivity, 3rd ed., Harper International SI Edition, (2006).

11. Kathleen A. H., James E. H., Descriptive Inorganic Chemistry, 2nd ed., Brooks Cole, (2010).

| | | | |
|---|-----------------------------|---------|-------|
| CHEM-522 | Advanced Physical Chemistry | 3 (2-1) | Major |
| Course Contents | | | |
| Chemistry of d-block elements and coordination complexes | | | |
| Chemical thermodynamic | | | |
| Equation of states, ideal and real gases, the virial equation and the van der Waals equation for real gases, critical phenomena and critical constants, four laws of thermodynamics and their applications, thermochemistry, calorimetry, heat capacities and their dependence on temperature, pressure and volume, reversible and non-reversible processes, spontaneous and non-spontaneous processes, relations of entropy and Gibbs free energy with equilibrium constant, Gibbs Helmholtz equation, fugacity and activity. | | | |
| Quantum Chemistry: | | | |
| Black body radiation, photoelectric effect, line spectra of elements, Bohr atomic model, wave and particle nature of matter, de Broglie's equation, Young's double slit experiment, Heisenberg's uncertainty principle, wave functions and Born interpretation of wave functions, probability density. Eigen functions and eigenvalues, Hamiltonian operator, Schrödinger wave equation, wave functions for hydrogen-like atomic orbitals, effective nuclear charge, orbital energies, periodic trends in the properties of the elements in the periodic table. | | | |
| The rates of reactions, zero, first, second and third order reactions with same and different initial concentrations, half-lives of reactions, experimental techniques for rate determination and methods for determination of order of reaction (integration, half-life, initial rate, and graphical methods), Arrhenius equation. | | | |
| Course Learning Outcomes | | | |
| By the end of this course, students will be able to: | | | |
| <ol style="list-style-type: none">1. Explain thermodynamic, kinetic, and quantum mechanical principles related to chemical2. behavior and molecular interactions.3. Analyze chemical processes using mathematical models and computational techniques4. relevant to physical chemistry.5. Apply physical chemistry concepts to problems in materials science, nanotechnology and6. chemical engineering etc | | | |
| Relevant Experiments | | | |
| <ol style="list-style-type: none">1. Preparations of following Inorganic Complexes;2. Tetra ammine copper (II) sulphate.3. Potassiumtrioxalatochromate (III).4. Potassiumtrioxalatoaluminate (III).5. Cis-Potassium dioxalatodiaquachromate (III).6. Determination of zinc and cadmium by complexometric titration7. Chromatographic separations of transition metals;8. Separation of Ni²⁺ & Co²⁺ ions in a mixture by paper chromatography. | | | |

9. Separation of Cu^{2+} & Fe^{2+} ions in a mixture by paper chromatography.
10. Spectrophotometric determination of iron, manganese and nickel.
11. Determination of the Formula of a Complex Ion by Job's Method
12. Determination of Hardness of Water by Complexometric Titration.
13. Qualitative determination of the magnetic property of complexes.

Recommended Books

1. Miessler, G. L., Fischer, P. J., Tarr, D. A., Inorganic Chemistry, 6th ed., Pearson Education, (2022).
2. Housecroft, C. E., Sharpe, A. G., Inorganic Chemistry, 5th ed., Pearson Education, (2018).
3. Weller, M., Overton, T., Rourke, J., Armstrong, F., Inorganic Chemistry, 7th ed., Oxford University Press, (2018).
4. Rayner-Canham, G., Overton, T., Descriptive Inorganic Chemistry, 6th ed., W.H. Freeman, (2018).
5. Reedijk, J., Poeppelemeier, K. (Eds.), Comprehensive Inorganic Chemistry III, 3rd ed., Elsevier, (2023).
6. Lee, J. D., Concise Inorganic Chemistry, 5th ed., Wiley-Blackwell, (2008).
7. Rodgers, G. E., Descriptive Inorganic, Coordination, and Solid-State Chemistry, 3rd ed., Brooks Cole, (2012).
8. Shriver, D. F., Atkins, P. W., Langford, C. H., Inorganic Chemistry, 2nd ed., Oxford University Press, (1994).
9. Cotton, F. A. and Wilkinson, G., Advanced Inorganic Chemistry, 6th ed., John-Wiley & Sons, New York, (2007).
10. Huheey, J. E., Inorganic Chemistry: Principles of Structure and Reactivity, 3rd ed., Harper International SI Edition, (2006).
11. Kathleen A. H., James E. H., Descriptive Inorganic Chemistry, 2nd ed., Brooks Cole, (2010).

| CHEM-522 | Advanced Analytical Chemistry | 3 (2-1) | Major |
|--|-------------------------------|---------|-------|
| <p>Course Contents</p> <p>Foundations of Analytical Data Introduction to figures of merit: accuracy, precision, detection limit, and selectivity. Principles of calibration, validation protocols, and ensuring reproducibility. Rationale for selecting analytical techniques based on detection limits, selectivity, and sample matrix complexity.</p> <p>Separation Methods Principles of masking, precipitation, filtration, and solvent extraction. Fundamentals of chromatography; classification of techniques. Overview and applications of paper, thin layer, and ion exchange and size exclusion chromatography.</p> <p>Analytical Spectrophotometry</p> | | | |

Interaction of light with matter; ultraviolet and visible light principles. Electronic transitions, absorption of radiation, and the Beer-Lambert Law (including its limitations). Instrumentation: light sources, monochromator/filters, and detectors (phototube, photodiode array). Single and double beam spectrophotometer, Quantitative and qualitative applications in environmental, pharmaceutical, and industrial chemistry.

Course Learning Outcomes

By the end of this course, students will be able to:

Explain advanced principles of analytical chemistry relevant to complex chemical systems.

Apply instrumental techniques to solve real-world analytical problems in environmental, pharmaceutical and industrial chemistry etc.

Critically assess analytical data to ensure precision, accuracy and reproducibility in scientific research and industrial applications.

Relevant Experiments

The practical component of this course will be adapted based on the availability of facilities, apparatus, and chemical reagents. The list below is provided as a reference guide to the types of practical work that align with this course.

1. Demonstration of Masking Agents in Qualitative Analysis.
2. Separation by Solvent Extraction: Isolation and Spectrophotometric Determination of Caffeine.
3. Thin-Layer Chromatography (TLC) and Determination of R_f Values.
4. Separation by Ion Exchange Column Chromatography: Separation of Metal Cations (e.g., Ni²⁺ and Cu²⁺).
5. Determination of λ_{max} and verification of the Beer-Lambert Law and determination of Molar Absorptivity.
6. Qualitative identification of an Unknown Dye via Absorption Maxima (λ_{max}).
7. Determination of Iron in a Vitamin Tablet by Spectrophotometry.
8. Quantitative determination of Aspirin in a Tablet using a Calibration Curve.
9. Determination of the pK_a of an Indicator using UV-Vis Spectroscopy.
10. Deionization and softening of water using ion exchange chromatography.
11. Simultaneous Spectrophotometric Determination: Resolving a Two-Component Mixture (e.g., Chromate/Dichromate).
12. Analysis of Provided Thermogravimetric Analysis (TGA) Thermograms: Determination of Water of Hydration and Thermal Stability.
13. Quality Control of a Commercial Product using Extraction and Spectrophotometry.
14. Gravimetric Determination of Nickel by Precipitation with Dimethylglyoxime.
15. Determination of stoichiometry of a metal complex by visible spectrometry.

Recommended Books

1. Skoog, D. A., West, P. M., Holler, F. J., Crouch, S. R., Fundamentals of Analytical Chemistry, 9th ed., Brooks Cole Publishing Company, (2013).
2. Harris, D. C., Quantitative Chemical Analysis, 8th ed., W. H. Freeman and Company, New York, USA, (2011).

3. Christian, G. D., Analytical Chemistry, 6th ed., John Wiley and Sons, New York, (2006).
4. Kealey, D. and Haines, P. J., BIOS Instant Notes in Analytical Chemistry, 1st ed., Bios Saence Publisher Ltd. Oxford UK. (2002)
5. Pavia, D. L., Lampman, G. M., Kriz, G. S. and Vyvyan, J. A., Introduction to spectroscopy, 4th ed., Cengage Learning, (2008).
6. Wall, P. E., Thin Layer Chromatography: A Modern Approach (RSC Chromatography Monographs), 1st ed., Royal Society of Chemistry, (2005).
7. Deinstrop, E. H., Applied Thin Layer Chromatography, 2nd ed., Wiley-VCH, (2006).
8. Kellener, R., Mermet, J. M., Otto, M., Valcarcel, M., Widmer, H.M., Analytical Chemistry: A Modern Approach to Analytical Science, Wiley.VCH, (2004)
9. Hollas, J. M., Modern Spectroscopy, 4th ed., John-Wiley & Sons, Ltd., England (2004).

| CHEM-541 | Soil Chemistry | 3 (2-1) | Major |
|--|----------------|---------|-------|
| <p>Course Contents</p> <p>Soil Chemistry; Soil composition, properties, solution and remediation. Soil formation processes. Soil components: minerals, organic matter, water, air. Soil texture and structure. Soil colloids. Isomorphous substitution. Cation/anion exchange capacity (CEC/AEC). Soil- ion interactions. Soil oxidation and reduction. Minerals stability. Soil solution composition. Ionic equilibria. Solubility product. Precipitation-dissolution reactions. Soil pH. Buffering capacity. Acid/alkaline/saline/sodic soils. Salinity management. Active vs potential acidity. Function of organic matter in soil. Soil organic matter composition. Humification. Nutrient cycling. Macro/micronutrient chemistry. Fertilizers. Soil contamination: heavy metals, pesticides. Environmental remediation.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Explain and analyze the chemical composition and fundamental properties of soils. 2. Evaluate soil solution chemistry and its impact on soil acidity, salinity, and overall soil health. 3. Assess the role of soil organic matter and environmental interactions in nutrient cycling, soil contamination, and remediation. <p>Relevant Experiments</p> <p>Soil texture analysis. pH and Electric conductivity measurement; EC. Cation exchange capacity (CEC). Organic matter estimation. Sodium absorption ratio (SAR). Nutrient availability: Nitrogen, Phosphorous and Potassium; NPK. Adsorption isotherm modeling. Soil sampling techniques. Soil moisture content.</p> <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Strawn, D. G., Bohn, H. L., & O'Connor, G. A. (2019). <i>Soil Chemistry</i> (2nd ed.). John Wiley | | | |

- & Sons. ISBN: 978-1-119-51525-8.
- Ahamed, M. I., Boddula, R., & Altalhi, T. (Eds.). (2021). *Applied Soil Chemistry* (1st ed.). John Wiley & Sons. ISBN: 9781119711520.
 - Sposito, G. (2008). *Chemistry of Soils* (2nd ed.). Oxford University Press. ISBN: 9780195313697.
 - Sparks, D. L., Singh, B., & Siebecker, M. G. (2023). *Environmental Soil Chemistry* (3rd ed.). Elsevier. ISBN: 978-0-443-14034-1.
 - Tan, K. H. (2010). *Principles of Soil Chemistry* (4th ed.). CRC Press. ISBN: 9780429184406.
 - Weil, R. R., Brady, N. C., & Weil, R. R. (2017). *Nature and Properties of Soils* (15th ed.). Pearson. ISBN: 0-13-325448-8.
 - Current Literature and Reviews.

| CHEM-541 | Computational Chemistry | 3 (2-1) | Major |
|---|-------------------------|---------|-------|
| <p>Course Contents Introduction to Computational Chemistry: Overview of historical development and key applications in drug design, materials science, and biochemistry. Quantum Mechanics Basics: Schrödinger equation, Born-Oppenheimer approximation, and Hartree-Fock theory. Molecular Mechanics and Force Fields: Principles of molecular dynamics (MD) and energy minimization techniques. Electronic Structure Methods: Density Functional Theory (DFT) and semi-empirical methods. Spectroscopy and Properties Prediction: Computational approaches to UV-Vis, IR, and NMR spectroscopy. Solvation and Environmental Effects: Implicit and explicit solvent models.</p> <p>Course Learning Outcomes:</p> <p>After completing this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Explain key computational chemistry concepts (e.g., wavefunctions, energy surfaces, and solvent effects). 2. Perform basic computations for molecular properties (e.g., bond energies, vibrational frequencies, and electronic spectra). 3. Design and execute computational projects to solve chemical problems (e.g., predicting reaction mechanisms or drug-receptor interactions). <p>Relevant experiments</p> <ol style="list-style-type: none"> 1. Software Tutorials: Hands-on introduction to computational tools (e.g., Gaussian, Avogadro, or Python libraries). 2. Molecular Geometry Optimization: Calculating equilibrium structures and conformational analysis. 3. Reaction Modeling: Transition state theory and reaction pathway analysis. 4. Data Visualization and Analysis: Interpreting output files and creating graphical representations. | | | |

Recommended Books

1. Jensen, F. (2017). Introduction to computational chemistry. John wiley & sons.
2. Cramer, C. J. (2013). Essentials of computational chemistry: theories and models. John Wiley & Sons.
3. Leach, A. R. (2001). Molecular modelling: principles and applications. Pearson education.
4. Lewars, E. (2003). Computational chemistry: introduction to the theory and applications of molecular and quantum mechanics. Boston, MA: Springer US.
5. Kohanoff, J. (2006). Electronic structure calculations for solids and molecules: theory and computational methods. Cambridge university press.
6. Onishi, T. (2018). Quantum computational chemistry (pp. 1-290). Singapore:: Springer..
7. Frenkel, D., & Smit, B. (2023). Understanding molecular simulation: from algorithms to applications. Elsevier.
8. Allen, M. P., & Tildesley, D. J. (2017). Computer simulation of liquids. Oxford university press.

| Year - III | | | |
|-------------------------------|---------------------------------------|---------|-------------------|
| SEMESTER 6 | | | |
| CHEM-511 | Agricultural Chemistry | 3 (2-1) | Major |
| CHEM-5-- | Elective – I* | 3 (3-0) | Major |
| CHEM-5-- | Elective – II* | 3 (3-0) | Major |
| CHEM-501 | Scientific Writing & Research Methods | 3 (3-0) | Interdisciplinary |
| GEN-540 | Statistics for Chemists | 3 (3-0) | Interdisciplinary |
| CHEM-500 | Internship** | 3 | Internship |
| TOTAL CREDIT HOURS: 18 | | | |

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| CHEM-511 | Agricultural Chemistry | 3 (2-1) | Major |
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Course Contents

Soil formation, classification, and physicochemical properties, interactions of soil minerals, organic matter, and humic substances, soil colloids and ion exchange mechanisms (CEC, AEC), soil pH, salinity, alkalinity, and redox chemistry, soil microbial ecosystems and their chemical roles, sacro- and micronutrients: biochemical roles, deficiency symptoms, and toxicity, nutrient bioavailability, mobility, and soil-plant interactions, chemical transformations of N, P, K, S, Ca, Mg, Fe, Zn, Cu, Mn, B, and Mo, soil amendments, liming, and gypsum applications, types and formulations: synthetic (Urea, DAP, SSP, MOP) and organic fertilizers, industrial production processes and quality control, organic amendments: compost, vermicompost, green manure, and biochar, biofertilizers, pesticide chemistry and management, chemical classes: organophosphates, carbamates, pyrethroids, neonicotinoids, mechanisms of action, degradation pathways, and environmental fate, toxicology, human health risks, and antidote strategies, integrated pest management (IPM) and biopesticides, hormones: auxins, gibberellins, cytokinins, ethylene, abscisic acid, applications in stress mitigation, flowering, and yield optimization, biochemical and molecular mechanisms of action, maximum residue limits (MRLs): Codex Alimentarius, FAO/WHO, EPA standards, food safety regulations: Pakistan's framework and global compliance, environmental impacts of agrochemical overuse (eutrophication, soil degradation), strategies for pollution mitigation and cleaner production, integrated nutrient management (INM) and organic farming, precision agriculture: sensor-based nutrient and pesticide application, climate-smart practices and agrochemical innovations.

Course Learning Outcomes

By the end of this course, the students will be able to:

1. Explain core principles of agricultural chemistry, including plant nutrition,

- agrochemicals, and soil-plant interactions.
- Analyze the effects of fertilizers, pesticides, and bio-stimulants on crop yield, soil health, and environmental sustainability.
 - Develop strategies for sustainable agricultural practices by integrating chemical knowledge with modern farming techniques.

Relevant Experiments

Soil analysis: pH, electrical conductivity (EC), texture, and organic matter; Measurement of nitrate, phosphate, and potassium content of soil; Pesticide residue detection using qualitative and quantitative methods; Preparation and analysis of compost and vermicompost; Bioassays for plant growth regulators (seed germination, root elongation).

Recommended Books

- Lamb, E. (2022). *Agricultural Chemistry: Concepts and Applications* (1st ed.). NY Research Press. ISBN: 9781632388377
- Gill, T. (2022). *Introduction to Agricultural Chemistry*. Willford Press. ISBN: 9781682859995
- Dhok, R. (2021). *Agricultural Chemistry*. Savitribai Phule Pune University. ISBN: 9789354571787
- Reddy, P.P. (2019). *Agro-ecological Approaches to Pest Management for Sustainable Agriculture*. Springer Singapore. ISBN: 9789811043246
- Hudson, B. (2017). *Agricultural Chemistry*. Larsen and Keller Education. ISBN: 9781635490169
- Brady, N.C., & Weil, R.R. (2016). *The Nature and Properties of Soils* (15th ed.). Pearson. ISBN: 9780133254488
- Anderson, T. (2015). *Elements of Agricultural Chemistry*. CreateSpace Independent Publishing Platform. ISBN: 9781514761663
- Havlin, J., Tisdale, S., Nelson, W., & Beaton, J. (2014). *Soil Fertility and Fertilizers: An Introduction to Nutrient Management*. 8th Edition. Pearson. ISBN: 9780135033739.
- Current Literature and Reviews.

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| CHEM-501 | Scientific Writing & Research Methods | 3 (3-0) | Interdisciplinary |
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Course Contents

Introduction to research: definition and purpose. Types of research: quantitative, qualitative, mixed methods, experimental, observational, descriptive, analytical, deductive, inductive, theoretical, applied, interdisciplinary. Scientific method: observation, hypothesis, experimentation, data collection, analysis, conclusion, reporting. Hypotheses: null, alternative, directional, non-directional; formulation and role. Ethics: data integrity, plagiarism, fabrication. Scientific articles: research papers, reports, reviews, letters, case studies. Literature review: keywords, Boolean logic, databases, AI tools. References: management software, citation styles, plagiarism, copyright.

Capstone and Paper components: abstract, introduction, methods, results, discussion, conclusions, future prospects. Critically evaluate article: hand on practice. Abstract writing: structured, graphical. Writing conventions: SI units. Presentations: posters, oral, graphs. Tools: chemical drawing, equations, illustration software, AI image tools, ethics. Integrity: conflicts of interest. Mock report writing. Role of AI, Python and machine learning in chemistry research; AI writing assistance ethics. Overview of research-based social media: ResearchGate, LinkedIn, ORCID; profiles, CVs, and research opportunities.

Course Learning Outcomes:

By the end of this course, the students will be able to:

1. Describe methods for conducting scientific research, including data collection and analysis.
2. Write clear and concise scientific reports, adhering to standards of academic integrity and citation.
3. Communicate research findings effectively to contribute to the scientific community.

Recommended Books

1. Tyowua, A. T. (2023). *A Practical Guide to Scientific Writing in Chemistry: Scientific Papers, Research Grants and Book Proposals* (1st ed.). CRC Press. ISBN: 9781003186748.
2. Thomas, C. G. (2021). *Research Methodology and Scientific Writing* (2nd ed.). Springer. ISBN: 978-3-030-64865-7.
3. Stewart Jr, C. N. (2023). *Research Ethics for Scientists: A Companion for Students* (2nd ed.). John Wiley & Sons. ISBN: 9781119837886.
4. Creswell, J. W., & Creswell, J. D. (2022). *Research Design: Qualitative, Quantitative, and Mixed Methods Approaches* (6th ed.). Sage Publications. ISBN: 9781071817964.
5. Coghill, A. M., & Garson, L. R. (Eds.). (2006). *The ACS Style Guide: Effective Communication of Scientific Information* (3rd ed.). American Chemical Society. ISBN: 9780841239999.
6. Bailey, S. (2014). *Academic Writing: A Handbook for International Students* (4th ed.). Routledge. ISBN: 9781315768960.
7. Schimel, J. (2012). *Writing Science: How to Write Papers That Get Cited and Proposals That Get Funded* (1st ed.). Oxford University Press USA. ISBN: 9780199760244.
8. Pollock, T. G. (2025). *How to Use Storytelling in Your Academic Writing: Techniques for Engaging Readers and Successfully Navigating the Writing and Publishing Processes* (2nd ed.). Edward Elgar Publishing. ISBN: 9781035325900

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| GEN-540 | Statistics for Chemists | 3 (3-0) | Interdisciplinary |
| Course Contents | | | |
| Fundamentals of Data in Chemistry: The Role of Statistics in Chemistry: Accuracy vs. Precision, Error Analysis. Types of Data: Continuous vs. Discrete, Univariate vs. Multivariate. | | | |

Descriptive Statistics: Mean, Median, Mode, Standard Deviation, Variance. Graphical Data Representation: Histograms, Box plots, and Scatter plots for chemical data.

Probability Distributions in Chemical Systems: Basic Probability Concepts. The Normal (Gaussian) Distribution: Properties and the Central Limit Theorem. Standard Normal Distribution and Z-scores. Application: Confidence Intervals for the Mean.

Statistical Inference I - Hypothesis Testing: Introduction to Hypothesis Testing: Null and Alternative Hypotheses. Student's t-tests: One-sample, Two-sample (comparing means), and Paired t-tests. Applications: Comparing a measured value to a known standard, comparing two analytical methods.

Statistical Inference II - Comparing Multiple Variances and Means: The F-test for Comparing Variances (Precision). Analysis of Variance (ANOVA): One-way ANOVA. Application: Comparing the yield of a reaction under multiple different conditions or catalysts.

Regression Analysis and Calibration: Linear Least-Squares Regression: Theory and assumptions. The Calibration Curve: The foundation of analytical chemistry. Calculation of unknown concentrations, limits of detection (LOD), and limits of quantification (LOQ). Correlation vs. Causation.

Analysis of Variance in Experimental Design: Introduction to Experimental Design: Replication, Randomization, Blocking. Two-way ANOVA: Investigating the effect of two independent factors. Application: Optimizing reaction conditions (e.g., effect of temperature AND catalyst on yield).

Course Learning Outcomes

After successfully completing this course, students will be able to:

1. Define key statistical terms (e.g., confidence interval, p-value, regression).
2. Describe the assumptions behind common statistical tests (t-test, ANOVA, regression).
3. Perform hypothesis tests (e.g., t-tests, ANOVA, F-test) to draw conclusions from chemical data.
4. Construct, interpret, and use a linear calibration curve to determine unknown concentrations and calculate LOD/LOQ.
5. Use statistical software (e.g., Excel, R, Minitab, or Python) to manipulate datasets, perform statistical calculations and generate graphs.
6. Present statistical results clearly and professionally in written and graphical form, as in a lab report or scientific paper.

Recommended Books

1. Miller, J., & Miller, J. C. (2018). Statistics and chemometrics for analytical chemistry. Pearson education.
2. Otto, M. (2023). Chemometrics: statistics and computer application in analytical chemistry. John Wiley & Sons.
3. Kowalski, B. R. (Ed.). (2013). Chemometrics: mathematics and statistics in chemistry (Vol. 138). Springer Science & Business Media.

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| <p>4. Schmuller, J. (2025). Statistical analysis with R for dummies. John Wiley & Sons.</p> <p>5. Schmuller, J. (2013). Statistical analysis with Excel for dummies. John Wiley & Sons.</p> <p>6. Haslwanter, T. (2016). An introduction to statistics with python. With applications in the life sciences. Switzerland: Springer International Publishing.</p> |
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| Year - IV | | | |
|-------------------------------|-----------------------------------|---------|-------------------|
| SEMESTER 7 | | | |
| CHEM-601 | Chemical Safety & Risk Management | 3 (3-0) | Major |
| CHEM-6-- | Elective – III* | 3 (3-0) | Major |
| CHEM-6-- | Elective – IV* | 3 (3-0) | Major |
| CHEM-6-- | Elective – V* | 3 (3-0) | Major |
| CHEM-602 | Materials Science | 3 (2-1) | Interdisciplinary |
| CHEM-671 | Fuel Chemistry | 3(2-1) | Major |
| TOTAL CREDIT HOURS: 18 | | | |

| CHEM-601 | Chemical Safety & Risk Management | 3 (3-0) | Major |
|--|--|----------------|--------------|
| Course Contents | | | |
| <p>Introduction to chemical safety & risk management principles. Types of hazards (physical, health, environmental, chemical and electrical). Understanding Safety Data Sheets (SDS) components, & Globally Harmonized System (GHS) of classification and labeling. Safe handling & storage of chemicals. Personal Protective Equipment (PPE) selection and usage. Waste management. Regulatory Frameworks (OSHA, EPA, REACH regulations), industry-specific safety standards & compliance. Spill control and containment procedures. Fire safety and extinguisher types (PASS technique). First-aid for chemical exposures (inhalation, ingestion, eye & skin contact). Risk Assessment, control measures, emergency response & incident management. Industrial accidents and lessons learned. Ethical responsibility in chemical safety.</p> | | | |
| Course Learning Outcomes | | | |
| <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Identify hazards and assess risks associated with chemical handling, storage, and disposal in laboratories and industries. | | | |

2. Implement safety protocols and hazard management strategies to minimize chemical and health risks.
3. Assess the importance of chemical safety in maintaining environmental sustainability and regulatory compliance in industry.

Recommended Books

1. Leeuwen, C. J. & Vermeire, T.G. (Eds.). (2007). *Risk Assessment of Chemicals: An Introduction* (2nd ed.). Springer Dordrecht. ISBN: 978-1-4020-6101-1.
2. Shah, M. R. (2023). *Safety in the Chemical Laboratory and Industry-A Practical Guide* (2nd ed.). Elsevier. ISBN: 978-0-323-95181-4.
3. National Research Council (2011). *Prudent Practices in the Laboratory: Handling and Management of Chemical Hazards* (2nd revised ed.). National Academies Press. ISBN: 978-0309138642.
4. Finster, D. C. & Hill, R. (2016). *Laboratory Safety for Chemistry Students* (3rd ed.). Wiley. ISBN 978-1119027669
5. National Academies of Sciences, Engineering, and Medicine (2016). *Chemical Laboratory Safety and Security: A Guide to Developing Standard Operating Procedures*. National Academies Press. ISBN: 978-0-309-39220-4.
6. Current Literature and Reviews.

| CHEM-602 | Materials Science | 3 (2-1) | Interdisciplinary |
|--|-------------------|---------|-------------------|
| <p>Course Contents</p> <p>Materials, Structure of materials: metals, alloys, ceramics, polymers, composite materials and their classification, matrices and reinforcements for materials, Properties of materials (thermal, morphological, mechanical, electrical, magnetic and optical). Applications of materials, Characterization techniques use in materials, Spectroscopic and microscopic analysis.</p> <p>Course Learning Outcomes: After successfully completing this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Explain fundamental principles of nano-chemistry, including nanoscale properties, quantum effects, and surface-to-volume ratio implications. 2. Identify and describe various synthesis methods and characterization techniques used in nanomaterials, <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Callister, W. D.; Rethwisch, D. G. <i>Materials Science and Engineering: An Introduction</i>, 10th ed.; Wiley: Hoboken, NJ, 2021. 2. Askeland, D. R.; Wright, W. J. <i>The Science and Engineering of Materials</i>, 7th ed.; Cengage Learning: Boston, MA, 2019. | | | |

3. Smith, W. F.; Hashemi, J. *Foundations of Materials Science and Engineering*, 5th ed.; McGraw-Hill Education: New York, NY, 2010.
4. Van Vlack, L. H. *Elements of Materials Science and Engineering*, 6th ed.; Addison-Wesley: Reading, MA, 1989.
5. Cullity, B. D.; Stock, S. R. *Elements of X-ray Diffraction*, 3rd ed.; Pearson: Upper Saddle River, NJ, 2011.

| CHEM-671 | Fuel Chemistry | 3 (2-1) | Major |
|--|----------------|---------|-------|
| <p>Course Contents Chemistry of fossil fuels: Classification of fossil fuels. Origin of coal, petroleum and natural gas. Preliminary treatment of crude oil. Fractionation of crude oil. Properties of petroleum products i.e. CNG, LPG, gasoline, kerosene, diesel fuels and lubricating oils. Coal storage and cleaning. Carbonization of coal: Low temperature and high temperature carbonization, Coking and non-coking coals, Separation of tar from coke oven gas, Hydrogen sulfide removal from coke oven gas. Introduction to alternate sources of energy: Biomass as energy resources: Bio gas technology. Alcohols: Alcohols and its uses as alternative fuel. Hydrogen: Hydrogen production, storage, handling and its uses as alternative fuel. Fuel Cells and its application, Solar Energy: Solar energy collectors. Nuclear fuels: fission and fusion, nuclear reactors and introduction to Hydel energy.</p> | | | |
| <p>Experimental Work</p> <ul style="list-style-type: none"> • Determination of moisture contents of coal mined in different parts of Pakistan. • Determination of Ash contents of coal mined in different parts of Pakistan. • Determination of Volatile matter of coal. • Determination of fixed carbon contents of coal. • Determination of hydrogen and nitrogen contents of the coal. • Determination of chlorine and oxygen in coal. • Determination of various forms of sulfur in coal. • Determination of specific and API gravity of petroleum fractions. • Estimation of carbon residue in petroleum products (Conradson method). • Determination of ash content in petroleum products. • Determination of sulfated ash in lube oil. • Estimation of water, sediments and oil in crude oil by centrifuge method. • Determination of cloud and pour point of Lube-oil. • Estimation of asphalt in road samples. | | | |
| <p>Course Learning Outcomes:</p> <p>By the end of this course, the students will be able to:</p> <ul style="list-style-type: none"> • Learn how coal, petroleum and natural gas are formed, classified, and processed through fractional distillation and carbonization. | | | |

- Link the chemical properties of products like gasoline and diesel to their performance.
- Interpret fuel quality tests and specifications.
- Learn about alternatives like biogas, alcohols, hydrogen, fuel cells, solar, nuclear, and hydropower. They will be able to compare these options to fossil fuels based on technology, application, and environmental impact.

Recommended Books

1. Schobert, H. (2013). Chemistry of fossil fuels and biofuels. Cambridge University Press.
2. Brown, R. C. (Ed.). (2019). *Thermochemical processing of biomass: conversion into fuels, chemicals and power*. John Wiley & Sons.
3. Lee, S., Speight, J. G., & Loyalka, S. K. (Eds.). (2014). *Handbook of alternative fuel technologies*. crc Press.
4. Lancaster, M. (2025). Green chemistry: an introductory text. Royal society of chemistry.
5. Lee, S. (2023). Alternative fuels. Routledge.
6. Gyngell, E.S. Applied Chemistry for Engineers, Edward Arnold Publisher, Ltd. London. (1989).
7. 2. Harker, J.H. and Backurst, J.R. Fuel and Energy, Academic Press, London and New York (1988).

| Year - IV | | | |
|------------------------|--------------------------------------|---------|-------------------|
| SEMESTER 8 | | | |
| CHEM-6-- | Elective – VI* | 3 (3-0) | Major |
| CHEM-6-- | Elective – VII* | 3 (3-0) | Major |
| CHEM-603 | Artificial Intelligence in Chemistry | 3 (2-1) | Interdisciplinary |
| CHEM-604 | Quality Control & Assurance | 3 (2-1) | Interdisciplinary |
| CHEM-600 | Capstone**** | 3 | Capstone |
| TOTAL CREDIT HOURS: 15 | | | |

| | | | |
|--|---|----------------|--------------------------|
| CHEM-603 | Artificial Intelligence in Chemistry | 3 (2-1) | Interdisciplinary |
| Course Contents | | | |
| Introduction to AI and its role in modern chemistry, scope and significance of data-driven | | | |

approaches; Python basics for chemistry applications, data handling with libraries; supervised and unsupervised learning, decision trees, k-nearest neighbors, neural networks, and workflow of ML projects; prediction of chemical properties and reactions, molecular modeling, large dataset analysis and pattern recognition; evaluation using accuracy, precision, recall, F1-score, confusion matrix, visualization of results, reliability and bias assessment; advanced approaches including deep learning, transfer learning, clustering methods, challenges of overfitting, data quality, and role of domain expertise.

Course Learning Outcomes:

After successfully completing this course, students will be able to:

3. Understand machine learning concepts and their applications in chemistry
4. Develop programming skills for chemical data analysis
5. Apply algorithms for prediction of chemical properties and reactions
6. Evaluate, visualize, and interpret model results
7. Explore advanced AI approaches and address challenges in chemical research.

Relevant Experiments

1. Introduction to Python environment and libraries (NumPy, Pandas, Matplotlib, RDKit, Scikit-learn)
2. Data preprocessing: importing, cleaning, and handling chemical datasets
3. Implementing supervised learning models (decision trees, k-NN) on chemical data
4. Unsupervised learning (clustering, dimensionality reduction) for chemical datasets
5. Neural network basics with chemical property prediction
6. Visualization of chemical data and model outputs
7. Model evaluation: confusion matrix, accuracy, precision, recall, F1-score
8. Mini-project: applying AI tools to real-world chemical data (property prediction, reaction outcome, or molecular modeling)

Recommended Books

1. Hill, C. (2023). Python for Chemists. Cambridge University Press.
2. Cartwrigth HM (2020) Machine Learning in Chemistry: The Impact of Artificial Intelligence. The Royal Society of Chemistry
3. Quantrille, T. E., & Liu, Y. A. (2012). Artificial intelligence in chemical engineering. Elsevier.
4. Otto, M. (2023). Chemometrics: statistics and computer application in analytical chemistry. John Wiley & Sons.
5. Goodfellow, I., Bengio, Y., Courville, A., & Bengio, Y. (2016). Deep learning (Vol. 1, No. 2). Cambridge: MIT press.

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|--|--|----------------|--------------------------|
| CHEM-604 | Quality Control & Assurance | 3 (2-1) | Interdisciplinary |
| <p>Course Contents</p> <p>Definition of quality, Quality in services and products, History and fundamentals of quality management system, Deming's philosophy of transformational management, customer, specification, measurement, design, leadership, responsibility and authority, training, resource management, Implementation and Auditing, focus and responsibilities QC and QA, quality policy, tools of quality control and quality assurance, six sigma methodologies, Problem solving tools. Empowerment, management reviews, external audits, internal audits, documentation and records, Accreditation and quality management certificates (ISO), workplace ethics.</p> <p>Course Learning Outcomes: After successfully completing this course, students will be able to:</p> <ol style="list-style-type: none"> Describe principles of quality control and assurance in chemical manufacturing and laboratory testing. Understand the requirements of good manufacturing practices (GMP) and quality management systems to ensure product safety, efficacy, and regulatory compliance. Explain the importance of quality control in maintaining industrial standards and consumer safety. <p>Relevant Experiments</p> <p>Calibration of glassware for quality assurance perspectives, calibration of equipment's/ testing of water quality parameters, monitoring of environmental parameters and draw control charts</p> <p>Recommended Books</p> <ol style="list-style-type: none"> Mitra, A. (2016). Fundamentals of quality control and improvement. John Wiley & Sons. ISBN 978-1-118-70514-8 Prichard, E. & V. Barwick, (2007). <i>Quality assurance in analytical chemistry</i>. John Wiley & Sons. ISBN 978-0-470-01203-1 Wenclawiak, B. W., M. Koch, E. Hadjicostas, and E. Hadjicostas, (2010), <i>Quality assurance in analytical chemistry: training and teaching</i> 2nd Edition. Springer Publisher. ISBN 978-3-642-13608-5 Erick Jones (2017). <i>Quality Management for Organizations Using Lean Six Sigma Techniques</i>. Taylor & Francis Group CRC Press. ISBN 9781138075122 Piotr Konieczka and Jacek Namiesnik (2009) <i>Quality Assurance and Quality Control in the Analytical Chemical Laboratory: A Practical Approach</i>, Taylor and Francis Group, CRC Press ISBN 13: 978-1-4200-8270-8 Miller, J. N. & J. C. Miller, (2010). <i>Statistics and chemometrics for analytical chemistry</i>. 6th edition Pearson publishers. ISBN: 978-0-273-73042-2 Günzler, H., & Williams, A. (2001). <i>Handbook of analytical techniques</i>. 1st edition Evolution, 1, 1-2. CRC Press, ISBN 3-527-30165-8 <p>Current Literature and Reviews</p> | | | |

SPECIALIZATION: ANALYTICAL CHEMISTRY

Elective Courses

| SEMESTER 6 | | | |
|-------------------|---|---------|-------|
| CHEM-523 | Atomic Spectroscopy | 3 (3-0) | Major |
| CHEM-524 | Separation Techniques in Analytical Chemistry | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-625 | Molecular Spectroscopy | 3 (3-0) | Major |
| CHEM-627 | Advanced Chromatography | 3 (3-0) | Major |
| CHEM-628 | Quality Control & Quality Assurance Analysis | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-629 | Sample Preparation | 3 (3-0) | Major |
| CHEM-620 | Electroanalytical Techniques | 3 (3-0) | Major |

| CHEM- | ATOMIC SPECTROSCOPY | 3 (3-0) | Major |
|---|---------------------|---------|-------|
| <p>Course Contents</p> <p>Flame Photometry Origin of atomic spectrum, principle of flame photometry, flame types and its characteristics, electro-thermal atomizers, instrumentation, merits and limitations of flame photometry.</p> <p>Atomic Absorption Spectrophotometry Principle of atomic absorption spectrophotometry, concentration dependence, instrumentation; radiation sources, atomizers and types, interferences, applications of atomic absorption spectrophotometry, merits and limitations.</p> <p>Atomic Fluorescence Spectrometry Origin of atomic fluorescence, principle of atomic fluorescence spectrometry, types of atomic fluorescence, factor affecting fluorescence intensity, analyte concentration, instrumentation, applications, interferences, merits and limitations of atomic fluorescence spectrometry.</p> <p>Atomic Emission Spectrophotometry Introduction, principle of atomic emission spectrometry, plasma and its characteristics, plasma types, applications, merits and limitations of atomic emission spectrometry.</p> <p>Learning Outcomes</p> <p>By the end of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Evaluate flame and plasma-based atomization processes including interferences, background correction, and optimization for accurate quantitative analysis. 2. Compare and contrast analytical merits and limitations of each technique (sensitivity, selectivity, detection limits). 3. Validate results through calibration, sample preparation, and background correction protocols. 4. Students will acquire knowledge about theoretical aspects and instrumentation of different atomic spectroscopic methods as well as learn about the applications of these techniques in the field of chemical sciences. 5. Understand and apply atomic spectroscopic techniques for quantitative and qualitative elemental analysis), adhering to modern analytical protocols. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Christian, G. D., Analytical Chemistry, 6th ed., John-Wiley & Sons, New York, (2006). 2. Harris, D. C., Quantitative Chemical Analysis, 8th ed., W. H. Freeman and Company, New York, (2011). 3. Sardans, J., Penuelas, J., and Zavadlav, S., Atomic Spectroscopy in Environmental Analysis, 1st ed., Elsevier, Amsterdam, (2022). | | | |

4. Reynolds, R. J., Flame Photometry: Modern Methods and Applications in Clinical and Environmental Analysis, 2nd ed., Springer Nature, Switzerland, (2021).
5. O'Haver, T. C., Atomic Fluorescence Spectrometry: Fundamentals and Instrumentation, 1st ed., Royal Society of Chemistry, Cambridge, (2019).
6. Bings, N. H., Bogaerts, A., and Broekaert, J. A. C., Atomic Spectroscopy: A Review, 1st ed., Elsevier, Amsterdam, (2021).
7. Pandey, P., Advanced Atomic Emission Spectroscopy: ICP-OES and LIBS, 1st ed., Springer, Singapore, (2023)
8. Sharma, B. K., Instrumental Methods of Chemical Analysis, 24th ed., Goel Publishing House, Meerut, India, (2005).
9. Skoog, D. A. and West. D. M., Fundamentals of Analytical Chemistry, 8th ed., Hot Reinehart Inc., London, (2008).
10. Ebdon, L., Evans, E.H, Fischer, A., and Hill, S.J., An Introduction to Analytical Atomic Spectrometry, John Wiley & Sons, England. (1998).
11. Bernhard Welz, Michael Sperling, Atomic Absorption Spectrometry, 3rd ed., Wiley-VCH, Germany, (1998).
12. Farrukh, M. A., Atomic Absorption Spectroscopy, In Tech, (2012).
13. Kellner, R., Mermet, J. M, Otto, M., Valcarcel, M., Widmer, H.M., Analytical Chemistry: A Modern Approach to Analytical Science, Wiley-VCH,(2004).

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|---|--|----------------|--------------|
| CHEM- | SEPARATION TECHNIQUES IN ANALYTICAL CHEMISTRY | 3 (3-0) | Major |
| <p>Course Contents</p> <p>Classical Separation methods</p> <p>Essential separation techniques in analytical chemistry, filtration (gravity, vacuum, membrane), distillation (simple, fractional, vacuum), crystallization (recrystallization, fractional crystallization), sublimation, principles, applications, and limitations of classical methods.</p> <p>Extraction techniques</p> <p>Basic principle of solvent extraction, distribution coefficient, distribution ratio Liquid-liquid extraction, solid-phase extraction, modern micro-extraction techniques, counter current distribution, applications of solvent extraction in sample preparation.</p> <p>Non-Chromatographic Separation</p> <p>Membrane separations (dialysis, ultrafiltration), Theory and principle of capillary electrophoresis and types of electrophoresis separation, instrumentation, and applications.</p> <p>Learning Outcomes</p> <p>The students will be able to gain knowledge about the principles and applications of various separation techniques.</p> <p>By the end of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Apply classical separation methods for compound isolation and purification. 2. Design extraction workflows for analyte pre-concentration and cleanup. 3. Evaluate modern non-chromatographic techniques for analytical problem-solving. 4. Apply green separation strategies for pharmaceutical, environmental, and bioanalytical applications. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Skoog, D. A., West, P. M., Holler, F. J. and Crouch, S. R., Fundamentals of Analytical Chemistry, 9th ed., Cengage Learning, (2013). 2. Christian, G. D., Analytical Chemistry, 6th ed., John-Wiley & Sons, New York, (2004). 3. Kealey, D. and Haines, P. J., BIOS Instant Notes in Analytical Chemistry, 1st ed., Taylor & Francis, (2002). 4. Sharma, B.K. Instrumental Methods of Chemical Analysis, 24th ed., Goel Publishing House, Meerut, India, (2005). 5. Grob, R. L., Eugene, F. Barry, Modern Practice of Gas Chromatography, 4th ed., John-Wiley & Sons, USA, (2004). 6. Kellner, R., Mermet, J-. M., Otto, M., Valcarcel, M. and Widmer, H. M., Analytical Chemistry: A Modern Approach to Analytical Science, Wiley-VCH, (2004). | | | |

7. Meyer, V. R., Practical High-Performance Liquid Chromatography, 5th ed., John-Wiley & Sons, Ltd., (2010).
8. Braitwaite, A. and Smith, F. J., Chromatographic Methods, 5th ed., Kluwer Academic Publishers, (1999).
9. Miller, J. M., Chromatography: Concepts and Contrasts, 2nd ed., John-Wiley & Sons, Inc., (2005).
10. 11. Camilleri, P., Capillary Electrophoresis: Theory and Practice, 2nd ed., CRC Press, (1998).

| | | | |
|--|-------------------------------|----------------|--------------|
| CHEM- | MOLECULAR SPECTROSCOPY | 3 (3-0) | Major |
| <p>Course Contents</p> <p>Luminescence Spectrophotometry</p> <p>Introduction, origin of fluorescence and phosphorescence spectra, Jablonski diagram, activation and deactivation, fluorescent and phosphorescent species, structural and environmental factors affecting fluorescence, fluorescence quenching, quantum yield, instrumentation; sources, wavelength selectors, detectors, read out devices, instrumentation for phosphorescence measurement, applications of fluorescence and phosphorescence.</p> <p>IR Spectroscopy</p> <p>Introduction, Vibrational modes and absorption frequencies, Hooks Law, Instrumentation, Characteristic absorptions frequencies of some common functional groups, Interpretation and applications of Infrared spectroscopy.</p> <p>Introduction of NMR Spectroscopy</p> <p>Introduction, basic principle, Molecular structure and chemical shifts, Instrumentation, quantitative analysis and qualitative applications.</p> <p>Learning Objectives</p> <p>By the end of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Understand and apply luminescence principles to analyze samples, operate spectrophotometers, and interpret spectra. 2. Students will acquire knowledge about the theoretical and instrumental aspects of molecular spectroscopy such as absorption, and luminescence spectroscopy and of analysis in addition to learning about their applications. 3. Identify molecular structures using IR spectroscopy by recognizing functional group absorptions. 4. Identify the basic information contained in an NMR spectrum (chemical shift, integration) and describe its primary applications in quantitative analysis and molecular confirmation. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Harvey, D. T., Modern Analytical Chemistry, 3rd ed., McGraw-Hill Education, New York, (2023). 2. Christian, G. D., Analytical Chemistry. 6th ed., John-Wiley & Sons, New York, (2006). 3. Harris, D. C., Quantitative Chemical Analysis, 8th ed., W. H. Freeman and Company, New York, (2011). 4. Braun, R. D., Introduction to Instrumental Analysis, 1st ed., McGraw-Hill Book Co., New York, USA (1987). 5. Lakowicz, J. R., Principles of Fluorescence Spectroscopy, 3rd ed., Springer (2006). | | | |

6. Pavia, D. L., Lampman, G. M., Kriz, Jr., G. S., Introduction to Spectroscopy, 2nd ed., W.B. Saunders, (1979).
7. Skoog, D. A., Holler, F. J., Crouch, S. R., Principles of Instrumental Analysis, 7th ed., Cengage Learning, Boston, USA (2017).
8. Banwell, C. N., McCash, E. M., Fundamentals of Molecular Spectroscopy, 5th ed., McGraw-Hill Education, London, (2021).
9. Gauglitz, G., Moore, D. S. (Eds.), Handbook of Spectroscopy, 2nd ed., Wiley-VCH, Weinheim, (2014).
10. Keeler, J., Understanding NMR Spectroscopy, 2nd ed., John Wiley & Sons, Chichester, (2010).

| CHEM- | ADVANCED CHROMATOGRAPHY | 3 (3-0) | Major |
|--|-------------------------|---------|-------|
| <p>Course Contents</p> <p>Introduction</p> <p>Classifications of chromatographic techniques, rate theory of chromatography, Van-Deemter equation and its significance in evaluating column efficiency.</p> <p>High-Performance Liquid Chromatography (HPLC)</p> <p>Basic principles of liquid chromatography; common separation modes: reversed-phase and normal-phase; introduction to hydrophilic interaction and ion-pair chromatography; components of an HPLC instrument (pump, injector, column, detector); introduction to Ultra-High Performance Liquid Chromatography; practical method development steps; applications in drug analysis, food safety, and environmental monitoring.</p> <p>Gas Chromatography (GC)</p> <p>Principles of gas-solid and gas-liquid chromatography; sample introduction methods: split/splitless and on-column injection; columns types; common detectors: FID, ECD, and MS; applications in analyzing fuels, environmental pollutants, and forensic samples etc.</p> <p>Ion Chromatography (IC)</p> <p>Separation principle based on ion-exchange; stationary phases for anions and cations; suppressed conductivity detection for high sensitivity; quantification of common ions (e.g., chloride, nitrate, sulfate, sodium, potassium, calcium) in drinking water, wastewater, and food products.</p> <p>Learning Outcomes</p> <p>Upon successful completion of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Select and optimize chromatographic methods (GC, HPLC, and IC) for pharmaceutical, environmental, and bioanalytical applications. 2. Develop separation protocols for complex samples (chiral molecules, oligonucleotides) through column selection, mobile phase optimization, and derivatization techniques. 3. Learn modern instrumentation to characterize biopharmaceuticals, microplastics, and ionic compounds with high resolution. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Skoog, D. A., West, P. M., Holler, F. J. and Crouch, S. R., Fundamentals of Analytical Chemistry, 9th ed., Cengage Learning, (2013). 2. Christian, G. D., Analytical Chemistry, 6th ed., John-Wiley & Sons, New York, (2004). | | | |

3. Kealey, D. and Haines, P. J., BIOS Instant Notes in Analytical Chemistry, 1st ed., Taylor & Francis, (2002).
4. Sharma, B.K. Instrumental Methods of Chemical Analysis, 24th ed., Goel Publishing House, Meerut, India, (2005).
5. Grob, R. L., Eugene, F. Barry, Modern Practice of Gas Chromatography, 4th ed., John-Wiley & Sons, USA, (2004).
6. Kellner, R., Mermet, J.- M., Otto, M., Valcarcel, M. and Widmer, H. M., Analytical Chemistry: A Modern Approach to Analytical Science, Wiley-VCH, (2004).
7. Meyer, V. R., Practical High-Performance Liquid Chromatography, 5th ed., John-Wiley & Sons, Ltd., (2010).
8. Lindsay, S., High Performance Liquid Chromatography, 2nd ed., John-Wiley & Sons, Ltd., (1992).
9. Braitwaite, A. and Smith, F. J., Chromatographic Methods, 5th ed., Kluwer Academic Publishers, (1999).
10. Weiss, J., Handbook of Ion Chromatography, 4th ed., Wiley-VCH, Weinheim, Germany, (2016).
11. Haddad, P. R., Jackson, P. E., and Heckenberg, A. L., Ion Chromatography: Principles and Applications, 1st ed., Elsevier, Amsterdam, (2016).
12. Michalski, R., Ion Chromatography as a Reference Method for Determination of Inorganic Ions, 1st ed., Springer, Cham, Switzerland, (2019).
- 13.** Thurman, E. M., Ion Chromatography for Water Analysis, 1st ed., CRC Press, Boca Raton, USA, (2021).

| CHEM- | QUALITY CONTROL & QUALITY ASSURANCE ANALYSIS | 3 (3-0) | Major |
|--|--|---------|-------|
| <p>Quality Control</p> <p>Introduction and concept of quality control and quality assurance, Quality Control (QC) and Quality Assurance (QA) in analytical chemistry, emphasizing their critical role in ensuring accuracy, precision, and reliability of laboratory results. Development of quality standards in industries, Quality control chart, Quality control in some industries, General safety practices, Good laboratory practices</p> <p>Quality Assurance</p> <p>Internal Methods of Quality Assessments, External Methods of Quality Assessments, Evaluation of quality assurance data, Prescriptive approach, Performance-based approach.</p> <p>Automation in analytical methods Automatic, automated and smart instruments and their applications with special emphasis on clinical, industrial and quality control aspects.</p> <p>Learning Outcomes</p> <p>By the end of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Selection of analytical methods for problem solving, Optimizing the experimental procedures, Single operator characteristics, Blind analysis of standard samples, Ruggedness testing, Equivalency testing, Sensitivity of instruments, Limits of detection and Signal-to-noise ratio. 2. Understand method development and validation by selecting analytical techniques, optimizing procedures, and assessing performance parameters for reliable chemical analysis. 3. Apply quality control and assurance principles through control charts, safety protocols, and industry standards to ensure accurate and reproducible/reliable lab results. 4. Evaluate automation in analytical chemistry by studying smart instruments, their applications in clinical, industrial, and QC labs, and comparing manual vs. automated methods. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Prichard, E., & Barwick, V. (2007). Quality Assurance in Analytical Chemistry. Publisher: John Wiley and Sons, New York 2. Mahapatra, S. N. (2016). Principles of Quality Assurance and Quality Control in the Analytical Chemistry Laboratory. Publisher: Springer. 3. Meier, P. C., & Zünd, R. E. (2000) Statistical Methods in Analytical Chemistry (2nd ed.). Publisher: Wiley-Interscience. 4. Fifield, F. W., & Kealey, D. (2000). Quality Control in the Analytical Laboratory. Publisher: Blackwell Science. ISBN: 978-0632056156 5. Christian, G.D. 2003. Analytical Chemistry. Sixth edition, John Wiley and Sons, New York 6. Harvey, D. 2008. Modern Analytical Chemistry. The McGraw Hill Companies, Inc.USA. | | | |

7. Bender, G.T. 1987. "Principles of Chemical Instrumentation" W.B. Saunders Co., London
8. Harris, D. C., Quantitative Chemical Analysis, 8th ed., W. H. Freeman and Company, New York, USA, (2011).
9. Mitra A., Fundamentals of Quality Control and Improvement, 3rd ed., John-Wiley & Sons, (2008).
10. Miller, James, and Jane C. Miller. Statistics and chemometrics for analytical chemistry. Pearson education, 201Publishing Co., London
11. FAO and WHO (2000). Codex Alimentarius General Requirement Vol. 14
- 12.** 12. Reilley, C. 1993. Laboratory Manual of Analytical Chemistry. Allyn& Bacon, London.

| CHEM- | SAMPLE PREPARATION TECHNIQUES | 3 (3-0) | Major |
|---|-------------------------------|---------|-------|
| <p>Course Contents</p> <p>Sample preparation techniques for analytical chemistry, specialized protocols for handling diverse sample types including soils, waters (wastewater, drinking water, seawater), air particulates, and biological materials (tissues, fluids). Technique-specific preparation methods for major analytical instruments: IR spectroscopy (KBr pellets, ATR), NMR (deuterated solvents, solid phase samples), UV-Vis (solvent selection), TGA and DSC (drying protocols, weighting and sample loading), GPC (sample preparation, solvent selection and reference selection), XRD (powder preparation), and single-crystal XRD (mounting techniques). Digestion methods (microwave-assisted, wet ashing, fusion), extraction techniques (SPE, Soxhlet, QuEChERS), and gravimetric analysis (precipitation, drying, weight). Proper sample storage, temperature control (e.g., refrigeration, freezing, or cryopreservation), container selection (amber vials for light-sensitive samples, inert materials for reactive species), and chemical stabilizers. Handling air sensitive materials, storage in Glove Box, To ensure analytical reliability, methods must be optimized for accuracy, precision, reducing waste, and adopting energy-efficient processes.</p> <p>Learning Outcomes</p> <p>By the end of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Learn sample preparation techniques for diverse matrices ensuring compatibility with analytical instruments (IR, NMR, XRD, etc.). 2. Apply proper storage and preservation protocols to maintain sample integrity and prevent degradation before analysis. 3. To equip students with systematic approaches for proper sample collection, preservation, and preparation across diverse matrices. 4. Learn green approaches to enhance accuracy, precision, and sustainability while minimizing waste and energy consumption in analytical processes. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Mitra, S. (2003). <i>Sample Preparation Techniques in Analytical Chemistry</i>. Wiley. ISBN: 978-0471328452 2. Pawliszyn, J. (Ed.). <i>Comprehensive Sampling and Sample Preparation: Analytical Techniques for Scientists</i> (1st ed., 4 Volumes). Academic Press. (2012). 3. Flores, E. <i>Microwave-Assisted Sample Preparation for Trace Element Analysis</i>. Elsevier. (2014). 4. Skoog, D. A., Holler, F. J., & Crouch, S. R. <i>Principles of Instrumental Analysis</i> (7th ed.). Cengage. (2017). 5. Thomas, R. <i>Practical Guide to ICP-MS and Other Atomic Spectroscopy Techniques</i> (3rd ed.). CRC Press. (2019). ISBN: 978-1138036233 | | | |

6. Flores, É. M. M. Microwave-Assisted Sample Preparation for Trace Element Analysis. Elsevier. (2014)
7. Zhang, W., Cue, B. (Eds.). Green Techniques for Organic Synthesis and Medicinal Chemistry. Wiley. (2018).
8. Nielsen, S. S. (Ed.). Food Analysis Laboratory Manual (3rd ed.). Springer International Publishing. (2017). ISBN: 978-3319444252
9. U.S. Environmental Protection Agency. Methods for Chemical Analysis of Water and Wastes (EPA/600/4-79/020). (1983). Environmental Monitoring and Support Laboratory.
10. AOAC International. Official Methods of Analysis (22nd ed.). Gaithersburg, MD, USA: AOAC International. (2023).

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|--|-------------------------------------|----------------|--------------|
| CHEM- | ELECTROANALYTICAL TECHNIQUES | 3 (3-0) | Major |
| <p>Course Contents</p> <p>Students will acquire sound knowledge regarding the theoretical, instrumental as well as application related aspects of different electroanalytical techniques.</p> <p>Voltammetry and Polarography</p> <p>Basic principle, voltammogram, polarizable and non-polarizable electrodes, solid electrodes, their scope and limitations, cyclic voltammetry, anodic stripping voltammetry, Voltametric equation, Principle of polarography and interpretation of polarographic curves, measurement of decomposition potential, diffusion and limiting currents, derivation of Ilkovic equation, logarithmic analysis of polarographic wave, advantages and limitation of dropping mercury electrode.</p> <p>Potentiometry</p> <p>Electrode potential, Nernst equation and its use for measuring half-cell potential, different kinds of electrodes, working of potentiometer and its applications including pH measurements, Ion selective electrode systems, Ion exchange membrane electrode, solid state membrane electrodes, and bio-membrane electrodes, Potentiometric titrations and applications.</p> <p>Coulometry and Electrogravimetry</p> <p>Basic electrochemistry, principle and instrumentation of coulometry, principle and instrumentation of electrogravimetry, Ohmic drop, activation over potential, concentration and gas polarization, basic difference and merits/demerits of coulometry and electrogravimetry.</p> <p>Learning Outcomes</p> <p>By the end of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Apply voltametric/polarographic techniques determine analyte concentrations and study redox processes using modern electrode systems. 2. Design and execute potentiometric measurements and interpret Nernstian response for quantitative analysis and endpoint detection in titrations. 3. Differentiate and implement coulometric/electrogravimetric methods, optimizing parameters (potential control, mass transport) while evaluating limitations (polarization effects, ohmic drop). <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Harris, D. C., Quantitative Chemical Analysis, 8th ed., W. H. Freeman and Company, New York, (2011). 2. Kealey, D. and Haines, P. J., BIOS Instant Notes in Analytical Chemistry, Bios Scientific Publishers Limited, Oxford, UK, (2002). 3. Sharma, B. K., Instrumental Methods of Chemical Analysis, 24th ed., Goel Publishing House, Meerut, India, (2005). 4. Skoog, D. A. and West., D. M., Fundamentals of Analytical Chemistry, 8th ed., Hot Reinehart Inc., London, (2008). | | | |

5. Bard, A. J., Faulkner, L. R., and White, H. S., *Electrochemical Methods: Fundamentals and Applications*, 3rd ed., John Wiley & Sons, New York, (2022).
6. Wang, J., *Analytical Electrochemistry*, 4th ed., Wiley-VCH, Hoboken, USA, (2023).
7. Scholz, F., *Voltammetric Techniques of Analysis: The Essentials*, 1st ed., Springer, Cham, Switzerland, (2023).
8. Brett, C. M. A. and Brett, A. M. O., *Electroanalysis: Analytical Chemistry*, 2nd ed., Oxford University Press, Oxford, UK, (2022).
9. Bakker, E. and Pretsch, E., *Modern Potentiometry: Ion-Selective Electrodes and their Applications*, 1st ed., Royal Society of Chemistry, Cambridge, (2019).
10. Compton, R. G. and Banks, C. E., *Understanding Voltammetry*, 3rd ed., Imperial College Press, London, (2018).
11. Zoski, C. G. (Ed.), *Handbook of Electrochemistry*, 2nd ed., Elsevier, Amsterdam, (2024).

**Specialization Biochemistry
Elective courses**

| SEMESTER 6 | | | |
|-------------------|--|---------|-------|
| CHEM-531 | Advanced Molecular Biological Techniques | 3 (3-0) | Major |
| CHEM-533 | Clinical Biochemistry | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-634 | Endocrinology | 3 (3-0) | Major |
| CHEM-635 | Enzymology & Catalysis | 3 (3-0) | Major |
| CHEM-639 | Metabolic Pathways & Regulation | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-630 | Molecular Immunology | 3 (3-0) | Major |
| CHEM-632 | Nucleic Acid Chemistry | 3 (3-0) | Major |

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|--|---|----------------|--------------|
| CHEM-531 | Advanced Molecular Biological Techniques | 3 (3-0) | Major |
| <p>Course Contents</p> <p>Extraction, Fractionation and Purification of macromolecules: Homogenization, Solubilization and Concentration including ultrasonication, lyophilization and ultra decantation. Purification based on differential solubility techniques, Ion-exchange chromatography, Gel chromatography, Affinity chromatography, Paper & Thin layer chromatography and HPLC. Western blotting, PCR and its types, Primer designing, Sanger sequencing. Genome browsers and databases.</p> <p>Electrophoresis</p> <p>Paper and Gel electrophoresis. Two-dimensional electrophoresis. Capillary electrophoresis. Electro focusing Preparative and Analytical electro focusing.</p> <p>Centrifugation</p> <p>Principle. Preparative centrifugation. Application of density gradient and differential centrifugation. Ultracentrifugation. Application of analytical centrifugation.</p> <p>ELISA Techniques</p> <p>Course Learning Outcomes: By the end of this course the students will be able to:</p> <ol style="list-style-type: none"> 1. Apply techniques for extraction, fractionation, and purification of macromolecules using chromatography, electrophoresis, and centrifugation. 2. Perform molecular biology protocols including PCR, Western blotting, Sanger sequencing, and utilize genome databases effectively. 3. Operate and interpret advanced analytical tools such as HPLC, ultracentrifugation, and electrophoretic systems for preparative and diagnostic purposes. <p>Recommended Books</p> <ol style="list-style-type: none"> 8. Cooper, T. G., The tools of Biochemistry, John Wiley & Sons, New York, 1977. 9. Bryan, L. W.; Keith, W.; Arnold, E., A Biologists guide to principles and techniques of practical biochemistry, London, 1981. 10. Scope, R. K., Protein purification: principle and practice, 3rd ed., Springer Verlag, New York, 1994. 11. Dawes, E.A., Quantitative problems in biochemistry, 6th ed., Livingstone, 1980. 12. www.bio.mtu.edu/campbell/401sch1.html | | | |

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|----------|-----------------------|---------|-------|
| CHEM-533 | Clinical Biochemistry | 3 (3-0) | Major |
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Course Contents

Common clinical chemistry tests:

Electrolytes: Sodium, Potassium, Chloride, Bicarbonate.

Renal (Kidney) Function Tests: Creatinine, Blood urea nitrogen.

Liver Function Tests: Total protein (serum): Albumin, Globulins, A/G ratio (albumin-globulin), Protein electrophoresis, Urine protein, Bilirubin; direct; indirect; total, Aspartate transaminase (AST), Alanine transaminase (ALT), Gamma-glutamyl transpeptidase (GGT), Alkaline phosphatase (ALP).

Cardiac Markers: Troponin, Myoglobin, CK-MB, B-type natriuretic peptide (BNP). **Minerals:** Calcium, Magnesium, Phosphate, Potassium, sodium.

Blood Disorders: Iron, Transferrin, TIBC, Vitamin B12, Folic acid

Miscellaneous: PCO₂, Glucose, C-reactive protein, Glycated hemoglobin (HbA1c), Uric acid, Arterial blood gases ([H⁺], PO₂), Adrenocorticotrophic hormone (ACTH), Toxicological screening and forensic toxicology (drugs and toxins), Neuron-specific enolase (NSE), fecal occult blood test (FOBT), Panel tests, hematology, urine analysis. Description of body fluids, Use of different diagnostic kits.

Course Learning Outcomes

By the end of this course the students will be able to:

1. Interpret results from common clinical chemistry tests to assess organ function, electrolyte balance, and metabolic status.
2. Apply diagnostic techniques including toxicological screening, hormone assays, and body fluid analysis using appropriate kits.
3. Evaluate biochemical markers for disease detection and monitoring, with emphasis on renal, hepatic, cardiac, and hematological conditions.

Recommended Books

1. Burtis, Carl A.; Ashwood, Edward R.; Bruns, David E. (2006). Tietz textbook of clinical chemistry (4th ed.). Saunders. ISBN 978-0-7216-0189-2.
2. Stephen K. Bangert MA MB BChir MSc MBA FRCPATH; William J. Marshall MA MSc PhD MBBS FRCP FRCPATHFRCPEDINFIBiol; Marshall, William Leonard (2008). Clinical biochemistry: metabolic and clinical Livingstone/Elsevier. ISBN 0-443-10186-8. aspects. Philadelphia: Churchill
3. 3. Medical toxicology By Richard C. Dart Edition: 3, illustrated Published by Lippincott Williams & Wilkins, 2004 ISBN 0-7817-2845-2.
4. 4. Walter F., PhD. Boron (2005). Medical Physiology: A Cellular and Molecular Approach. Elsevier/Saunders. ISBN 1-4160-2328-3.

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|---|----------------------|----------------|--------------|
| CHEM-634 | Endocrinology | 3 (3-0) | Major |
| <p>Course Contents</p> <p>Introduction to Endocrinology, Hormone Classification and Mechanisms of Action, Hypothalamus and Pituitary Axis, Thyroid Gland and Metabolic Regulation, Adrenal Gland – Cortisol, Aldosterone, Catecholamines, Pancreas – Insulin, Glucagon, Somatostatin, Calcium Homeostasis – Parathyroid & Vitamin D, Reproductive Endocrinology (Male & Female), Endocrine Control of Pregnancy & Lactation, Gastrointestinal Hormones, Endocrine Disorders – Diabetes, Hypothyroidism, Cushing’s, Hormone Receptors and Signal Transduction, Endocrine Pharmacology and Therapeutics, Endocrine Disruptors and Environmental Impact.</p> <p>Course Learning Outcomes By the end of this course the students will be able to</p> <ol style="list-style-type: none"> 1. Understand the classification, synthesis, and mechanisms of hormone action across major endocrine systems. 2. Analyze hormonal regulation in physiological processes including metabolism, reproduction, and calcium homeostasis. 3. Evaluate endocrine disorders, therapeutic strategies, and the impact of environmental disruptors on hormonal balance. <p>Recommended Books</p> <p>Melmed, S., Koenig, R., Rosen, C., Auchus, R., & Goldfine, A. (2019). <i>Williams Textbook of Endocrinology</i> (14th ed.). Elsevier.</p> <p>Gardner, D. G., & Shoback, D. (2017). <i>Greenspan’s Basic and Clinical Endocrinology</i> (10th ed.). McGraw Hill.</p> <ol style="list-style-type: none"> 7. Hadley, M. E., & Levine, J. E. (2006). <i>Endocrinology</i> (6th ed.). Pearson Education. 8. Griffin, J. E., Ojeda, S. R. (2004). <i>Textbook of Endocrine Physiology</i> (5th ed.). Oxford University Press. 9. O'Malley, B. W., & Gustafsson, J. A. (2004). <i>Molecular Endocrinology</i>. Academic Press. 10. Dharmalingam, M. (2015). <i>Textbook of Endocrinology</i>. Jaypee Brothers Medical Publishers. 11. Negi, D. S., & Chandra, S. (2013). <i>Introduction to Endocrinology</i>. Alpha Science International. | | | |

| CHEM-635 | Enzymology & Catalysis | 3 (3-0) | Major |
|--|------------------------|---------|-------|
| <p>Course Contents</p> <p>Introduction to Enzymes Definition and general properties of enzymes. Enzyme classification (EC system) and nomenclature, Ribozymes and abzymes, Coenzymes and cofactors (NAD⁺, FAD, FMN, TPP, etc.) Enzyme specificity and types, Models of enzyme-substrate interaction: Lock-and-Key vs. Induced Fit Enzyme turnover number, IU, katal, and specific activity</p> <p>Enzyme Kinetics Michaelis-Menten kinetics and derivation, Km and Vmax: definitions and significance, Lineweaver-Burk plot and graphical analysis, King and Altman method for velocity equations, Bisubstrate reactions and classification, Reaction mechanisms: Serine proteases as case study</p> <p>Enzyme Inhibition Types of inhibition: reversible vs. Irreversible, Reversible inhibition: competitive, non-competitive, uncompetitive, Dose-response curves and graphical determination, mutually exclusive binding of inhibitors, Structure-activity relationships in inhibition</p> <p>Enzyme Regulation & Allostereism Allosteric enzymes and cooperativity, Models of allosteric behavior (concerted vs. sequential), Isoenzymes (e.g., lactate dehydrogenase), Aspartate transcarbamoylase as a regulatory enzyme, Genetic, covalent, and non-covalent regulation</p> <p>Enzyme Isolation & Applications Isolation, purification, and characterization techniques, Enzyme assays and activity measurements, Criteria for enzyme purity, Enzyme reconstitution and membrane-bound enzymes, Industrial applications: leather, detergent, diagnostics, Therapeutic and clinical relevance.</p> <p>Course Learning Outcomes By the end of this course the students will be able to</p> <ol style="list-style-type: none"> 1. Understand and analyze enzyme structure, function, and kinetics 2. Evaluate enzyme regulation and inhibition mechanisms 3. Apply enzyme-related techniques and knowledge to real-world contexts <p>Recommended Books</p> <ol style="list-style-type: none"> 12. . Price, N. C., & Stevens, L. (1999). <i>Fundamentals of enzymology: The cell and molecular biology of catalytic proteins</i> (3rd ed.). Oxford University Press. 13. Punekar, N. S. (2025). <i>Enzymes: Catalysis, kinetics and mechanisms</i> (2nd ed.). Springer Nature. Available on SpringerLink 14. Khan, M. Y., & Khan, F. (2014). <i>Principles of enzyme technology</i>. CRC Press. 15. Prasad, N. K. (2013). <i>Enzyme technology: Pacemaker of biotechnology</i>. Sanfoundry Publications. Reference list 16. Voet, D., & Voet, J. G. (2011). <i>Biochemistry</i> (4th ed.). Wiley. | | | |

| CHEM-639 | Metabolic Pathways & Regulation | 3 (3-0) | Major |
|--|------------------------------------|---------|-------|
| <p>Course contents</p> <p>Introduction to Metabolism: Catabolism vs. anabolism, metabolic maps, energy flow Thermodynamics of Metabolic Reactions: Gibbs free energy, ATP hydrolysis, coupling reactions Carbohydrate Metabolism I : Glycolysis, gluconeogenesis, regulation by ATP/AMP, insulin, glucagon Carbohydrate Metabolism II: Pentose phosphate pathway, glycogen synthesis, glycogen degradation Citric Acid Cycle & Anaplerosis: TCA cycle steps, amphibolic nature, regulation of key enzymes Oxidative Phosphorylation: Electron transport chain, ATP synthase, uncoupling, inhibitors Lipid Metabolism I: β-oxidation of fatty acids, fatty acid synthesis, ketone body formation Lipid Metabolism II: Cholesterol biosynthesis, lipoprotein transport, lipoprotein metabolism Amino Acid Metabolism: Transamination, deamination, urea cycle, essential amino acids, non-essential amino acids Nucleotide Metabolism: Purine biosynthesis, pyrimidine biosynthesis, salvage pathways Integration of Metabolism: Fed state metabolism, fasting state metabolism, tissue-specific metabolic roles Hormonal Regulation: Insulin, glucagon, cortisol, thyroid hormones Genetic & Enzymatic Regulation: Allosteric regulation, covalent modification, operon models, transcriptional control Metabolic Disorders Diabetes mellitus, phenylketonuria (PKU), hyperlipidemia, mitochondrial diseases Experimental Approaches: Isotope tracing, metabolomics, flux analysis</p> <p>Course Learning Outcomes:</p> <p>By the end of this course the students will be able to:</p> <ol style="list-style-type: none"> 1. Understand the structure and function of major metabolic pathways, 2. Analyze regulatory mechanisms at enzymatic, genetic, and hormonal levels, 3. Explore the integration of metabolism in multicellular systems and disease states, Apply biochemical principles to interpret metabolic flux and control. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Frayn, K. N., & Evans, R. D. (2019). <i>Human Metabolism: A Regulatory Perspective</i> (4th ed.). Wiley-Blackwell. A comprehensive and student-friendly guide focusing on metabolic regulation in health and disease. Available on Amazon 2. Nelson, D. L., & Cox, M. M. (2021). <i>Lehninger Principles of Biochemistry</i> (8th ed.). Macmillan. A foundational text with detailed coverage of metabolic pathways and their control mechanisms. | | | |

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| <ol style="list-style-type: none"> 3. Berg, J. M., Tymoczko, J. L., & Stryer, L. (2019). <i>Biochemistry</i> (8th ed.). W.H. Freeman. Offers clear explanations of metabolic processes with emphasis on regulation and integration. 4. Voet, D., Voet, J. G., & Pratt, C. W. (2016). <i>Fundamentals of Biochemistry: Life at the Molecular Level</i> (5th ed.). Wiley. Integrates molecular biology with metabolism, ideal for undergraduate students. 5. Stryer, L. (2002). <i>Metabolic Regulation: A Human Perspective</i> (Earlier edition of Frayn's book). Focuses on human metabolic adaptation and control, useful for comparative reading. |
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| CHEM-630 | Molecular Immunology | 3 (3-0) | Major |
|--|----------------------|---------|-------|
| <p>Course contents Introduction to Molecular Immunology: Properties of the immune system, innate vs. adaptive immunity Complement System: Activation pathways, biological functions, regulation Antigen-Antibody Interactions: Affinity, specificity, cross-reactivity, diagnostic applications Humoral Immunity: B cell activation, antibody production, class switching Cell-Mediated Immunity: T cell development, activation, cytotoxic responses Development of Lymphocytes: Hematopoiesis, thymic selection, clonal expansion Cytokines: Types, signaling mechanisms, roles in immunity and inflammation Immunity to Microbes: Viral, bacterial, fungal, and parasitic immune responses Immune Signal Transduction: Receptor-ligand interactions, intracellular signaling cascades Immune Calcium Signals and Ion Channels: Role in activation and regulation of immune cells Autoimmune Diseases: Mechanisms of self-tolerance failure, examples (e.g., lupus, rheumatoid arthritis) Immune Cell Metabolism: Metabolic reprogramming during activation and differentiation Molecular Immunology and Therapeutics: Monoclonal antibodies, vaccines, immunomodulators.</p> <p>Course Learning Outcomes: By the end of this course the students will be able to:</p> <ol style="list-style-type: none"> 1. Understand the molecular mechanisms underlying immune responses. 2. Analyze the roles of immune cells, receptors, and signaling pathways. 3. Explore immune regulation, dysfunction, and therapeutic interventions. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Abbas, A. K., Lichtman, A. H., & Pillai, S. (2024). <i>Basic immunology: Functions and disorders of the immune system</i> (7th ed.). Elsevier. 2. Owen, J. A., Punt, J., & Stranford, S. A. (2018). <i>Kuby immunology</i> (8th ed.). W.H. Freeman. 3. Janeway, C. A., Travers, P., Walport, M., & Shlomchik, M. J. (2005). <i>Immunobiology: The immune system in health and disease</i> (6th ed.). Garland Science. | | | |

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| <p>4. Delves, P. J., Martin, S. J., Burton, D. R., & Roitt, I. M. (2017). <i>Roitt's essential immunology</i> (13th ed.). Wiley-Blackwell.</p> <p>5. Sompayrac, L. (2019). <i>How the immune system works</i> (6th ed.). Wiley-Blackwell</p> |
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|---|-------------------------------|----------------|--------------|
| CHEM-632 | Nucleic Acid Chemistry | 3 (3-0) | Major |
| <p>Course contents Chemical structure of nucleotides and nucleosides, purines and pyrimidines, phosphodiester bonds and backbone chemistry, Chargaff's rules and Watson-Crick model, DNA topology and supercoiling, types of DNA and RNA (A-DNA, B-DNA, Z-DNA; mRNA, tRNA, rRNA, snRNA, miRNA), chromatin structure and nucleosomes, DNA replication mechanisms and enzymes, RNA transcription and processing, reverse transcription and retroviruses, translation and genetic code, mutations and DNA repair mechanisms, recombinant DNA technology, PCR and gel electrophoresis, CRISPR-Cas systems, nucleic acid hybridization and blotting techniques, chemical synthesis of oligonucleotides, nucleic acid-based therapeutics and diagnostics.</p> <p>Course Learning Outcomes: By the end of this course the students will be able to:</p> <ul style="list-style-type: none"> • Understand the chemical structure and properties of nucleic acids • Explore the biosynthesis, metabolism, and regulation of DNA and RNA • Analyze the molecular mechanisms of replication, transcription, and translation • Examine nucleic acid techniques and their applications in biotechnology and medicine <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Nelson, D. L., & Cox, M. M. (2008). <i>Lehninger principles of biochemistry</i> (5th ed.). W.H. Freeman. 2. Stryer, L. (2006). <i>Biochemistry</i> (5th ed.). W.H. Freeman. 3. Voet, D., & Voet, J. G. (2011). <i>Biochemistry</i> (4th ed.). Wiley. 4. Watson, J. D., et al. (2013). <i>Molecular biology of the gene</i> (7th ed.). Pearson. 5. Alberts, B., et al. (2014). <i>Molecular biology of the cell</i> (6th ed.). Garland Science | | | |

Other Elective(s) courses in Biochemistry

| Course category | Course Code | Course title | Credits |
|------------------------|--------------------|---------------------------|----------------|
| Major | CHEM-333 | Cellular Signaling | 3 |

Course contents

Types of Cell Signaling

Autocrine, paracrine, endocrine, and juxtacrine signaling, Gap junctions and Notch signalling

Signaling Molecules

Hormones, neurotransmitters, cytokines, growth factors, Lipid-based signals and gaseous molecules (e.g., NO)

Receptors and Their Mechanisms

G-protein coupled receptors (GPCRs), Ion channel-linked receptors, Enzyme-linked receptors (e.g., tyrosine kinase receptors)

Nuclear receptors

Intracellular Signal Transduction, Second messengers: cAMP, IP₃ , DAG, Ca²⁺ , cGMP

Protein phosphorylation and kinase cascades, MAPK and PI3K-AKT pathways, Ras and STAT signaling

Gene Regulation and Transcriptional Control

Signal-induced transcription factors, Crosstalk between pathways

Cellular Outcomes

Proliferation, differentiation, apoptosis, Metabolic regulation and immune responses

Disease and Therapeutic Relevance

Dysregulation in cancer, diabetes, and neurodegenerative diseases. Targeting signalling pathways in drug development.

Course Learning Outcomes:

By the end of this course the students will be able to:

- Explain the types of cell signaling and the roles of key signaling molecules and receptors in cellular communication.
- Analyze intracellular signal transduction pathways and their impact on gene regulation and cellular outcomes.
- Evaluate the relevance of signaling mechanisms in disease progression and therapeutic interventions.

Recommended Books

1. Lim WA, Mayer BJ. *Cell Signaling: Principles and Mechanisms*. 2nd ed. Boca Raton: CRC Press; 2023.
2. Marks F, Klingmüller U, Müller-Decker K. *Cellular Signal Processing: An Introduction to the Molecular Mechanisms of Signal Transduction*. 3rd ed. New York: Garland Science; 2016.

3. Gomperts BD, Kramer IM, Tatham PER. *Signal Transduction*. 2nd ed. Oxford: Elsevier Academic Press; 2009.
4. Alberts B, Johnson A, Lewis J, Raff M, Roberts K, Walter P. *Molecular Biology of the Cell*. 6th ed. New York: Garland Science; 2014.
5. Cooper GM, Hausman RE. *The Cell: A Molecular Approach*. 7th ed. Oxford: Oxford University Press; 2019.

| Course category | Course Code | Course title | Credits |
|-----------------|-------------|--------------|---------|
| Major | CHEM-337 | Glycobiology | 3 |

Introduction to Glycobiology

Overview of carbohydrates and glycans, Historical development and scope of glycobiology

Monosaccharide structures and stereochemistry

Glycan Structures and Linkages

Oligosaccharides and polysaccharides, Glycosidic bonds and branching, N-linked and O-linked glycosylation

Biosynthesis of Glycans

Glycosyltransferases and glycosidases, Lipid-linked oligosaccharide precursors, ER and Golgi processing pathways

Glycoproteins and Glycolipids

Structural and functional roles, Lectins and glycan-binding proteins, Glycosylation in protein folding and stability

Glycans in Cell Signalling and Immunity

Role in cell-cell recognition, Glycans in innate and adaptive immunity, Pathogen-host glycan interactions

Glycobiology in Health and Disease

Congenital disorders of glycosylation, Cancer-associated glycan changes, Glycan biomarkers and therapeutic targets

Applied Glycobiology

Glycans in vaccine development, Glyco-bioinformatics and databases, Synthetic glycans and drug design.

Course learning outcomes.

By the end of this course the students will be able to:

1. Explain the structural diversity and biosynthesis of glycans
2. Analyze the biological roles of glycans in cellular function and immunity
3. Apply glycobiological principles to health, disease, and biotechnology

Recommended Books

1. Varki, A., Cummings, R. D., Esko, J. D., Stanley, P., Hart, G. W., Aebi, M., Mohnen, D., Kinoshita, T., Packer, N. H., Prestegard, J. J., & Seeberger, P. H. (2022). *Essentials of glycobiology* (4th ed.). Cold Spring Harbor Laboratory Press. <https://www.cshlpress.com>
2. Chang, C.-F. (Ed.). (2012). *Comprehensive studies on glycobiology and glycotecology*. IntechOpen. <https://doi.org/10.5772/2702>
3. Schnaar, R. L., & Freeze, H. H. (2020). *Glycobiology and human disease*. Academic Press.
4. Taylor-Papadimitriou, J., & Epenetos, A. A. (1990). *Glycobiology and medicine*. Springer-Verlag.
5. Kamerling, J. P. (Ed.). (2007). *Glycoscience: Biology and medicine*. Springer. <https://doi.org/10.1007/978-3-540-30429-6>

| Course category | Course Code | Course title | Credits |
|-----------------|-------------|--------------------|---------|
| Major | CHEM-338 | Lipid Biochemistry | 3 |

Introduction to Lipids

Definition and classification of lipids, Biological functions of lipids, Physical and chemical properties of fatty acids

Structural Lipids

Triglycerides: simple and mixed, Phospholipids and glycolipids, Sphingolipids, sulpholipids, gangliosides, Steroids: cholesterol, bile acids, bile salts

Functional Lipids

Lipids as cofactors, pigments, and signaling molecules. Prostaglandins, thromboxanes, leukotrienes, Lipid aggregates: micelles, bilayers, monolayers, Lipid composition of biological membranes

Lipid Metabolism

Biosynthesis and degradation of: Triglycerides, Saturated and unsaturated fatty acids, Phospholipids and cholesterol, Ketone bodies: synthesis and utilization, Regulation of lipid metabolism, Inborn errors of lipid metabolism

Lipidomics and Disease

Lipidation in cell signaling, lipid-related metabolic disorders, therapeutic opportunities in lipid biochemistry, introduction to lipidomics techniques.

Course learning outcomes.

By the end of this course the students will be able to:

1. Explain the structural diversity and biological roles of lipids
2. Evaluate lipid metabolic pathways and their regulation
3. Apply lipidomics concepts to biomedical and therapeutic contexts

Recommended books

1. Ridgway, N. D., & McLeod, R. S. (Eds.). (2022). *Biochemistry of lipids, lipoproteins and membranes* (7th ed.). Elsevier.
2. Gurr, M. I., & Harwood, J. L. (1991). *Lipid biochemistry: An introduction* (5th ed.). Springer.
3. Ntambi, J. M. (Ed.). (2015). *Cellular lipid in health and disease*. Elsevier.
4. Christie, W. W. (1982). *Lipid analysis: Isolation, separation, identification and structural analysis of lipids* (2nd ed.). Pergamon Press.
5. Griffiths, W. J., & Wang, Y. (2021). *Introduction to lipidomics: From sample preparation to data analysis*. Royal Society of Chemistry.

| Course category | Course Code | Course title | Credits |
|-----------------|-------------|---------------------|---------|
| Major | CHEM-339 | Metabolic Disorders | 3 |

Course contents

Introduction to Metabolism and Metabolic Disorders Principles of metabolism; classification of metabolic diseases; genetic and enzymatic basis of metabolic regulation

Carbohydrate Metabolism Disorders Glycogen storage diseases; galactosemia; hereditary fructose intolerance; glucose malabsorption; disorders of gluconeogenesis and glycogenolysis

Lipid Metabolism Disorders Fatty acid oxidation defects; hyperlipidemia; hypertriglyceridemia; cholesterol and lipoprotein metabolism disorders

Amino Acid and Organic Acid Metabolism Disorders Phenylketonuria; maple syrup urine disease; homocystinuria; organic acidemias; aminoacidurias

Urea Cycle and Protein Metabolism Disorders Urea cycle defects; amino acidopathies; disorders of protein turnover

Nucleic Acid and Heme Metabolism Disorders Purine and pyrimidine metabolism; porphyrias; bilirubinemias; disorders of DNA repair

Vitamin and Mineral Metabolism Disorders Biotinidase deficiency; Wilson disease; Menkes disease; cystinosis

Mitochondrial and Peroxisomal Disorders Mitochondrial energy metabolism defects; oxidative phosphorylation disorders; Zellweger syndrome; adrenoleukodystrophy

Lysosomal Storage Disorders Gaucher disease; Tay-Sachs; Niemann-Pick; mucopolysaccharidoses; glycolipid disorders

Hormonal Regulation and Metabolic Adaptations Endocrine control of metabolism; metabolic responses to starvation, exercise, and diabetes mellitus

Diagnostic and Therapeutic Approaches Biochemical assays; genetic testing; dietary management; enzyme replacement therapy; gene therapy

Course Learning Outcomes:

By the end of this course, students will be able to:

1. Explain the biochemical and genetic foundations of metabolic processes and disorders
2. Analyze specific metabolic disorders across major biomolecule classes
3. Apply diagnostic and therapeutic strategies in metabolic disease management

Recommended book

1. Clarke, J. T. R. (2010). *A clinical guide to inherited metabolic diseases* (3rd ed.). Cambridge University Press.
2. Nelson, D. L., & Cox, M. M. (2017). *Lehninger principles of biochemistry* (7th ed.). W.H. Freeman.
3. Newsholme, E., & Leech, A. R. (2009). *Functional biochemistry in health and disease*. Wiley-Blackwell.
4. Saudubray, J. M., Baumgartner, M. R., & Walter, J. H. (2016). *Inborn metabolic diseases: Diagnosis and treatment* (6th ed.). Springer.
5. Scriver, C. R., Beaudet, A. L., Sly, W. S., & Valle, D. (Eds.). (2001). *The metabolic and molecular bases of inherited disease* (8th ed.). McGraw-Hill.

| Course category | Course Code | Course title | Credits |
|------------------------|--------------------|-----------------------|----------------|
| Major | CHEM-3312 | Neurochemistry | 3 |

Course contents

Neurochemical organization of the brain, chemical composition of neurons and glial cells, biosynthesis and metabolism of neurotransmitters (acetylcholine, dopamine, serotonin, glutamate, GABA), neuropeptides and neuromodulators, synaptic transmission and receptor pharmacology, second messenger systems and intracellular signaling, neurochemical basis of learning and memory, neurochemistry of sleep and circadian rhythms, neurochemical mechanisms of addiction and mood disorders, neuroinflammation and oxidative stress, neurochemical changes in neurodegenerative diseases (Alzheimer's, Parkinson's, Huntington's), blood-brain barrier and transport mechanisms, neurochemical techniques (microdialysis, immunohistochemistry, PET imaging), molecular targets for neuropharmacological intervention.

Course Learning Outcomes:

By the end of this course the students will be able to:

- Understand the chemical composition and molecular processes of the nervous system
- Explore neurotransmitter synthesis, release, and receptor interactions
- Analyze neurochemical mechanisms underlying behavior, cognition, and disease
- Apply biochemical principles to neuropharmacology and neurodegeneration

Recommended Textbooks

1. Siegel, G. J., Agranoff, B. W., Albers, R. W., & Fisher, S. K. (2006). *Basic neurochemistry: Principles of molecular, cellular, and medical neurobiology* (7th ed.). Academic Press.
2. Brady, S. T., Siegel, G. J., & Albers, R. W. (2011). *Basic neurochemistry* (8th ed.). Elsevier.
3. Purves, D., Augustine, G. J., Fitzpatrick, D., et al. (2018). *Neuroscience* (6th ed.). Oxford University Press.
4. Zigmond, M. J., Rowland, L. P., & Coyle, J. T. (2014). *Neurobiology of brain disorders: Biological basis of neurological and psychiatric disorders*. Academic Press.
1. Cooper, J. R., Bloom, F. E., & Roth, R. H. (2003). *The biochemical basis of neuropharmacology* (8th ed.). Oxford University Press.

| Course category | Course Code | Course title | Credits |
|-----------------|-------------|--------------------|---------|
| Major | CHEM-3314 | Plant Biochemistry | 3 |

Course Contents

Macromolecular Foundations

- Introduction to plant biochemistry and cellular organization
- Structure and function of carbohydrates, lipids, proteins, and nucleic acids in plants
- Enzyme kinetics, specificity, and regulation in plant systems
- Protein folding, targeting, and purification techniques

Energy and Metabolism

- Photosynthesis: light reactions, Calvin cycle, C4 and CAM pathways
- Photorespiration and its biochemical implications

- Plant respiration: glycolysis, TCA cycle, oxidative phosphorylation
- ATP synthesis and energy transduction

Biosynthesis and Secondary Metabolism

- Biosynthesis of amino acids, nucleotides, and fatty acids
- Secondary metabolites: alkaloids, flavonoids, terpenoids, phenolics
- Role of secondary metabolites in plant defense and signaling
- Plant hormones: biosynthesis and biochemical roles (auxins, gibberellins, cytokinins, ABA, ethylene)

Stress and Adaptation

- Biochemical responses to abiotic stress (drought, salinity, temperature)
- Antioxidant systems and reactive oxygen species (ROS)
- Signal transduction and gene expression under stress conditions

Techniques in Plant Biochemistry

- Chromatography (TLC, paper, column)
- Spectrophotometry and UV-visible analysis
- Enzyme assays and protein quantification
- Nucleic acid extraction and quantification from plant tissues

Course Learning Outcomes:

By the end of this course students will be able to:

- Understand the biochemical processes unique to plant systems
- Explore the structure, function, and metabolism of plant biomolecules
- Analyze photosynthesis, respiration, and secondary metabolite pathways
- Examine plant-specific enzymology and stress responses

Recommended Textbooks

1. Buchanan, B. B., Gruissem, W., & Jones, R. L. (2015). *Biochemistry and molecular biology of plants* (2nd ed.). Wiley.
2. Harborne, J. B. (1997). *Plant biochemistry*. Academic Press.
3. Campbell, M. K., & Farrell, S. O. (2008). *Biochemistry* (6th ed.). Cengage Learning.

4. Stumpf, P. K., & Conn, E. E. (2009). *Outlines of biochemistry* (5th ed.). Wiley.
5. Heldt, H. W., & Piechulla, B. (2011). *Plant biochemistry* (4th ed.). Academic Press.

| Course category | Course Code | Course title | Credits |
|-----------------|-------------|-------------------------------|---------|
| Major | CHEM-3315 | Protein Structure & Functions | 3 |

Course contents

Amino acids and peptide bond formation, stereoisomerism and optical activity of amino acids, classification and properties of amino acids (chemical, nutritional, metabolic), acid-base behavior and titration curves, covalent structure of proteins, primary, secondary, tertiary, and quaternary protein structures, fibrous and globular proteins, structural and functional roles of keratin, collagen, elastin, hemoglobin, and myoglobin, protein folding and denaturation, protein-ligand and protein-protein interactions, enzyme structure and catalytic mechanisms, protein isolation and purification techniques (chromatography, electrophoresis), protein characterization methods (UV-Vis, SDS-PAGE, Western blotting), post-translational modifications, protein engineering and design, computational modeling of protein structures, metalloproteins and motor proteins, membrane proteins and transport mechanisms.

Course Learning Outcomes:

By the end of this course students will be able to:

- Understand the chemical and structural organization of proteins
- Explore the relationship between protein structure and biological function
- Analyze protein folding, stability, and interactions
- Apply biochemical techniques for protein characterization and engineering

Recommended Textbooks

1. Branden, C., & Tooze, J. (1999). *Introduction to protein structure* (2nd ed.). Garland Science.
2. Creighton, T. E. (1993). *Proteins: Structures and molecular properties* (2nd ed.). W.H. Freeman.
3. Kyte, J. (2007). *Structure in protein chemistry* (2nd ed.). Garland Science.

4. Nelson, D. L., & Cox, M. M. (2021). *Lehninger principles of biochemistry* (8th ed.). Macmillan.
5. Kessel, A., & Ben-Tal, N. (2018). *Introduction to proteins: Structure, function, and motion* (2nd ed.). CRC Press.

| Course category | Course Code | Course title | Credits |
|-----------------|-------------|--------------------|---------|
| Major | CHEM-3316 | Structural biology | 3 |

Course contents

Introduction to Structural Biology

- Definition, scope, and importance
- Hierarchical organization of biomolecular structures
- Overview of macromolecules: proteins, DNA/RNA, lipids, carbohydrates

Chemical and Physical Principles

- Non-covalent interactions: hydrogen bonds, van der Waals forces, hydrophobic effects
- Thermodynamics and kinetics of folding and binding
- Molecular symmetry and stereochemistry

Experimental Techniques

- X-ray crystallography: principles, data collection, structure refinement
- Nuclear Magnetic Resonance (NMR) spectroscopy: chemical shifts, NOESY, structure determination
- Cryo-Electron Microscopy (Cryo-EM): sample preparation, image processing
- Circular Dichroism (CD) and fluorescence spectroscopy

Protein Structure and Function

- Primary to quaternary structure
- Domains, motifs, and folds
- Enzyme active sites and catalytic mechanisms
- Structural basis of allosteric regulation and cooperativity

Nucleic Acid Structures

- DNA/RNA secondary and tertiary structures
- DNA-protein interactions (e.g., transcription factors, nucleosomes)
- Ribozymes and RNA folding

Macromolecular Assemblies

- Ribosomes, viral capsids, and membrane channels
- Structural basis of signal transduction and transport
- Supramolecular complexes and scaffolding proteins

Computational Structural Biology

- Protein modeling and homology modeling
- Molecular dynamics simulations
- Structure visualization tools (PyMOL, Chimera)
- Databases: PDB, SCOP, CATH

Applications and Case Studies

- Drug design and structure-based screening
- Mutational analysis and disease-related structural defects
- Structural genomics initiatives

Course Learning Outcomes:

By the end of this course students will be able to:

- Understand the architecture and dynamics of biological macromolecules
- Learn experimental and computational techniques used to determine molecular structures
- Explore structure-function relationships in proteins, nucleic acids, and complexes
- Analyze molecular interactions and conformational changes in biological systems

Recommended Textbooks

1. Rupp, B. (2010). *Biomolecular crystallography: Principles, practice, and application to structural biology*. Garland Science.
2. Branden, C., & Tooze, J. (1999). *Introduction to protein structure* (2nd ed.). Garland Science.

3. Lesk, A. M. (2016). *Introduction to bioinformatics* (5th ed.). Oxford University Press.
4. Petoukhov, M. V., & Svergun, D. I. (2015). *Small-angle X-ray and neutron scattering from solutions of biological macromolecules*. CRC Press.

SEPICILIZATION: INDUSTRIAL CHEMISTRY

Elective Courses

| SEMESTER 6 | | | |
|-------------------|--|---------|-------|
| CHEM-582 | Process Chemistry & Industrial Catalysis | 3 (3-0) | Major |
| CHEM-583 | Industrial Water Treatment | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-684 | Cosmetics Industry | 3 (3-0) | Major |
| CHEM-685 | Petroleum Chemistry | 3 (3-0) | Major |
| CHEM-686 | Industrial Electrochemistry | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-687 | Industrial Waste Treatment & Pollution Control | 3 (3-0) | Major |
| CHEM-689 | Corrosion Science & Protection | 3 (3-0) | Major |

| | Process Chemistry & Industrial Catalysis | 3 (3-0) | Major |
|---|---|----------------|--------------|
| <p>Course Contents:</p> <p>Introduction to process chemistry, industrial vs. laboratory-scale chemistry, process development and optimization: reaction pathways and yield maximization, heat and mass transfer considerations, scale-up principles and pilot plant operations, types of catalysis, homogeneous catalysis, heterogeneous catalysis, enzyme catalysis, surface area and porosity, adsorption isotherms, rate equations, characterization techniques: BET, XRD, SEM, TPD, FTIR, catalyst preparation and catalyst deactivation and regeneration, precipitation, impregnation, sol–gel method, thermal treatments, types of deactivation (poisoning, fouling, thermal degradation), methods of regeneration (oxidation, reduction, reactivation), impact of deactivation on process efficiency, catalytic cracking, hydrotreating, catalytic reforming, alkylation, isomerization, ammonia synthesis (Haber-Bosch process), methanol synthesis, nitric acid production (Ostwald process), sulfuric acid production (contact Process), hydrogenation and dehydrogenation reactions, polymerization catalysis, catalyst support materials, active site design, promoters and inhibitors, shaping and structuring of catalysts (pellets, monoliths), catalytic converters for automobiles, SCR (selective catalytic reduction) for NO_x removal, oxidation catalysts for VOCs (volatile organic compounds) control.</p> <p>Course Learning Outcomes:</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Understand and apply the principles of process chemistry in industrial contexts. 2. Describe different types of catalysis and catalytic mechanisms. 3. Evaluate industrial processes for efficiency, scalability, and environmental impact. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Pant, K.K., Gupta, S.K., & Ahmad, E. (2021). <i>Catalysis for Clean Energy and Environmental Sustainability</i>. Springer Cham. ISBN: 9783030650162. 2. Jones, D.S.J., & Pujadó, P.R. (2015). <i>Handbook of Petroleum Processing</i> (2nd ed.). Springer. ISBN: 9783319145280. 3. Wachs, I.E. (2010). <i>Characterization of Catalytic Materials</i>. Momentum Press. ISBN: 9781606501849. 4. Ozkan, U.S. (2009). <i>Design of Heterogeneous Catalysts: New Approaches Based on Synthesis, Characterization, and Modeling</i>. Wiley-VCH. ISBN 9783527320790. 5. Bartholomew, C.H., & Farrauto, R.J. (2005). <i>Fundamentals of Industrial Catalytic Processes</i> (2nd ed.). Wiley-AIChE. ISBN: 9780471457138. | | | |

| | Industrial Water Treatment | 3 (3-0) | Major |
|--|-----------------------------------|----------------|--------------|
| <p>Course Contents</p> <p>Importance of water in industry, overview of industrial water uses and contaminants, water quality parameters and standards (WHO, EPA, NEQS), water quality parameters for different industrial applications, characterization of industrial wastewater, water treatment operations (pretreatment, coagulation, flocculation, sedimentation, filtration, disinfection), removal of fats, oils and grease, pH control, removal of inorganic constituents, removal of organic constituents, water/wastewater operations: math and technical aspects, advanced physicochemical methods of treatment for industrial wastewaters, advanced oxidation technologies for wastewater treatment, Fenton process, water solids treatment and disposal.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Identify and characterize different types of industrial water contaminants. 2. Explain the chemical and physical processes involved in water treatment and evaluate various treatment technologies for suitability in industrial applications. 3. Understand regulatory standards and environmental impacts of industrial effluents. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Spellman, F.R. (2020). <i>Handbook of Water and Wastewater Treatment Plant Operations</i> (4th ed.). CRC Press. ISBN: 978-0367481681. 2. Feng, D., & Zheng, D. (2020). <i>Advanced Water Treatment: Technologies and Applications</i>. Wiley. ISBN: 9781119474725. 3. Rosen, M.A., & Dincer, I. (2020). <i>Water Resources Management and Sustainability: Challenges and Opportunities</i>. Springer. ISBN: 9783030428730. 4. Schweitzer, P.A., & Stepanov, P. (2020). <i>Sustainable Water Resources Management in Urban Areas</i>. CRC Press. ISBN: 9780367333415. 5. Edwards, J.D. (2018). <i>Industrial Wastewater Treatment – A Guidebook</i>. CRC Press. ISBN: 9781566701129. | | | |

| | Cosmetics Industry | 3 (3-0) | Major |
|---|--------------------|---------|-------|
| <p>Course Contents</p> <p>Historical development of cosmetic products, categories of cosmetics (skin care, hair care, color cosmetics, fragrances, etc.), legal status and regulations, raw materials in cosmetics (emollients, emulsifiers, surfactants, colorants, fragrances, silicones, thickeners, chelators, preservatives), natural vs synthetic ingredients, techniques in formulation and challenges (emulsions, gels, suspensions, powders), stability testing and shelf-life determination, skin cleansing products. skin moisturizing products, anti-aging products, sun care products, antiperspirants and deodorants, hair cleansing and conditioning products, hair coloring products, oral and dental care products and formulations, irritation, sensitization, and phototoxicity testing, GMP (Good Manufacturing Practices), overview of regulations: EU (Cosmetics Regulation), USA (FDA), Asia-Pacific.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Describe the major classes of cosmetic products and their chemical constituents. 2. Formulate basic cosmetic preparations using scientific principles, and evaluate cosmetic products for stability, efficacy, and safety. 3. Understand the regulatory landscape governing cosmetic products. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Wilkinson, J., & Moore, R. (2018). <i>Harry's Cosmeticology</i> (9th ed.). Allured Publishing Corporation. ISBN: 978-0896896304. 2. Draelos, Z.D. (2015). <i>Cosmetics and Dermatologic Problems and Solutions</i> (3rd ed.). CRC Press. ISBN: 978-1482230054. 3. Barel, A.O., Paye, M., & Maibach, H.I. (2014). <i>Handbook of Cosmetic Science and Technology</i> (3rd ed.). Informa Healthcare. ISBN: 9781420069631. 4. Robinson, R.K., & Downey, R.H. (2012). <i>Cosmeticology</i> (9th ed.). Chemical Publishing Co., Inc. ISBN: 978-0827379841. 5. Williams, D.F., & Schmitt, W.H. (2012). <i>Chemistry and Technology of the Cosmetics and Toiletries Industry</i> (2nd ed.). Springer Dordrecht. ISBN: 978075140334-3. | | | |

| | Petroleum Chemistry | 3 (3-0) | Major |
|---|---------------------|---------|-------|
| <p>Course Contents:</p> <p>Historical overview of petroleum use, origin and formation of fossil fuels, composition, properties, and classification of crude oils, oil shale and tar sands, petroleum refining processes with flow diagram, atmospheric and vacuum distillation, catalytic and thermal cracking, reforming and hydrocracking – catalysts, mechanisms, and operating parameters, hydroforming, desulfurization and other purification techniques, fuel quality parameters such as API gravity, octane/cetane numbers, and flash point, reformulated and alternative fuels, petrochemical feedstocks, oil spills: chemical composition and degradation, environmental impact of hydrocarbon emissions, mitigation strategies, global emission standards.</p> <p>Course Learning Outcomes:</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Understand the origin and chemical nature of petroleum. 2. Explain the principles and operations involved in petroleum refining and evaluate the chemical transformations in refining and petrochemical processes. 3. Assess environmental impacts and regulatory frameworks surrounding petroleum use. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Speight, J.G. (2023). Thermal and Catalytic Processing in Petroleum Refining Operations (1st ed.). CRC Press. ISBN: 9781032027203. 2. Coker, A.K. (2021). Petroleum Refining Design and Applications Handbook (1st ed.). Wiley. ISBN: 9781119476412. 3. Kaiser, M.J., de Klerk, A., Gary, J.H., & Handwerk, G.E. (2020). Petroleum Refining: Technology, Economics, and Markets (6th ed.). CRC Press. ISBN: 9781466563001. 4. Hunt, B.J. (2016). Introduction to Petroleum Chemistry (1st ed.). CRC Press. ISBN: 9781138199426. 5. Speight, J.G. (2014). The Chemistry and Technology of Petroleum (5th ed.). CRC Press. ISBN: 9781040060926. 6. Tissot, B.P., & Welte, D.H. (2013). Petroleum Formation and Occurrence (2nd ed.). Springer Berlin-Heidelberg. ISBN: 9783642878152. | | | |

| | Industrial Electrochemistry | 3 (3-0) | Major |
|---|------------------------------------|----------------|--------------|
| <p>Course Contents:</p> <p>Introduction to industrial electrochemistry, thermodynamics of electrochemical cells, kinetics of electrode reactions and mass transport, Butler-Volmer and Tafel equations, electrochemical cell design, electrochemical techniques and instrumentation, industrial electrolysis processes, electrolysis of water: hydrogen production, chlor-alkali process: diaphragm, membrane, and mercury cells, electroplating and electroforming, electrowinning and electrorefining of metals, batteries and fuel cells, electrocatalysis and energy conversion, electrochemical sensors and monitoring techniques.</p> <p>Course Learning Outcomes:</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Understand the theoretical foundation of electrochemical cells and processes, and design industrial electrochemical systems. 2. Understand environmental and economic considerations in electrochemical industries. 3. Apply electrochemical techniques for material treatment and evaluate the efficiency and sustainability of electrochemical operations. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Benvenuto, M.A. (2024). <i>De Gruyter Textbook of Industrial Chemistry</i> (2nd ed.). Walter de Gruyter Publisher. ISBN: 9783110671063. 2. Schlesinger, M., & Paunovic, M. (2010). <i>Modern Electroplating</i>. John Wiley & Sons, Inc. ISBN: 9780470167786. 3. Hamann, C.H., Hamnett, A., & Vielstich, W. (2007). <i>Electrochemistry</i> (2nd ed.). John Wiley & Sons, Inc. ISBN: 9783527310692. 4. Bard, A.J., & Faulkner, L.R. (2000). <i>Electrochemical Methods: Fundamentals and Applications</i> (2nd ed.). John Wiley & Sons, Inc. ISBN: 9780471043720. 5. Pletcher, D., & Walsh, F.C. (1993). <i>Industrial Electrochemistry</i> (2nd ed.). Springer Dordrecht. ISBN: 9780751401486. | | | |

| | Industrial Waste Treatment & Pollution Control | 3 (3-0) | Major |
|---|---|----------------|--------------|
| <p>Course Contents Classification of industries and associated waste streams, overview of pollution parameters (COD, BOD, TSS, pH, etc.), waste sampling protocols and statistical analysis of waste data, physical treatment methods: sedimentation, screening, filtration, adsorption (activated carbon, zeolites), flotation and membrane technologies (MF, UF, NF, RO), chemical treatment methods: coagulation-flocculation, oxidation-reduction processes (ozonation, Fenton, chlorination), advanced oxidation processes (AOPS), biological treatment methods: aerobic and anaerobic treatment systems, activated sludge process, trickling filters, biotowers, anaerobic digesters and bioreactors, integration of biotechnological solutions, sludge management and disposal: thickening, dewatering, digestion, thermal treatments: incineration, pyrolysis, land application, secure landfilling, air pollution control: gaseous pollutant types and sources, control devices: scrubbers, filters, electrostatic precipitators, VOC and odor control, solid and hazardous waste management: waste minimization and resource recovery, stabilization, solidification, incineration, hazardous waste regulations and transport, national environmental quality standards (NEQS), EPA guidelines.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to: Identify and classify major industrial waste streams, and key pollution parameters, and apply standardized protocols for waste sampling and statistical data analysis. Explain and evaluate physical, chemical, biological, and advanced treatment methods for industrial waste management. Understand integrated waste and pollution control strategies, including sludge handling, air and hazardous waste management, and compliance with NEQS and EPA regulatory frameworks.</p> <p>Recommended Books International Organization for Standardization (ISO). (2015). <i>ISO 9000:2015 Quality Management Systems - Fundamentals and Vocabulary</i>. ISO. ISBN: 9789267105884. Tchobanoglous, G., Stensel, H.D., Tsuchihashi, R., & Burton, F.L. (2013). <i>Wastewater Engineering: Treatment and Resource Recovery</i> (5th ed.). McGraw Hill. ISBN: 9780073401188. Woodard, F. (2006). <i>Industrial Waste Treatment Handbook</i> (2nd ed.). Butterworth-Heinemann Publisher. ISBN: 9780750679633. Mahajan, S. (2003). <i>Pollution Control in Process Industries</i>. McGraw Hill India. ISBN: 9780074517727. Kiely, G. (1996). <i>Environmental Engineering</i>. McGraw-Hill College. ISBN: 978077091279.</p> | | | |

| | Corrosion Science & Protection | 3 (3-0) | Major |
|--|---|----------------|--------------|
| <p>Course Contents: Definition and significance of corrosion, basic concepts and factors affecting corrosion, economic impact of corrosion, thermodynamics of corrosion, electrochemical cell potentials, Pourbaix diagrams (E-pH diagrams), Nernst equation and corrosion prediction, Butler- Volmer equation, Tafel slopes and polarization curves, mixed potential theory, overvoltage and Evans diagrams, factors affecting the rate of corrosion and passivity, types of corrosion, uniform and non-uniform corrosion, bimetallic corrosion, crevice corrosion, pitting corrosion, grain boundary corrosion, layer corrosion, stress corrosion cracking, cavitation corrosion, atmospheric, soil, and high-temperature corrosion hot gases, liquid metals, thermal fatigue, aqueous corrosion: recognizing the various forms of aqueous corrosion and understanding their basic mechanisms, selective leaching, erosion corrosion, hydrogen embrittlement, corrosion in specific materials and corrosion prevention and control, iron and steel, nickel, aluminum, titanium, superalloys, degradation in polymers and ceramics, protective coatings, inhibitors, cathodic and anodic protection, electroplating, corrosion testing, monitoring, and inspection, case studies in industry: oil and gas pipelines, bridges and infrastructure, aircraft and marine vessels, and nuclear reactors and desalination plants.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to: Understand the electrochemical basis and thermodynamic conditions for corrosion. Identify and characterize various forms of corrosion, and evaluate materials and environmental factors contributing to corrosion. Design and propose effective corrosion protection and mitigation strategies.</p> <p>Recommended Books</p> <p>Elayaperumal, K., & Raja, V.S. (2015). <i>Corrosion Failures – Theory, Case Studies, and Solutions</i>. Wiley. ISBN: 9780470455647. Revie, W. (2011). <i>Uhlig’s Corrosion Handbook</i> (3rd ed.). Wiley. ISBN: 9780470080320 Roberge, P.R. (2008). <i>Corrosion Engineering Principles and Practice</i>. McGraw-Hill. ISBN: 9780071482431. Ahmad, Z. (2006). <i>Principles of Corrosion Engineering and Corrosion Control</i>. Butterworth-Heinemann. ISBN: 9780750659246. Philip A., & Schweitzer P.E. (2006). <i>Corrosion Engineering Handbook</i>. CRC Press. ISBN: 9780429188084. Davis, J.R. (2000). <i>Corrosion: Understanding the Basics</i>. ASM International. ISBN: 9780871706416. Jones, D. (1995). <i>Principles and Prevention of Corrosion</i> (2nd ed.). Pearson. ISBN: 9780133599930.</p> | | | |

SPECIALIZATION: ORGANIC CHEMISTRY

Elective Courses

| SEMESTER 6 | | | |
|-------------------|-----------------------------|---------|-------|
| CHEM-5 <u>0</u> 3 | Stereochemistry | 3 (3-0) | Major |
| CHEM-5 <u>0</u> 4 | Synthetic Organic Chemistry | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-6 <u>0</u> 5 | Heterocyclic Chemistry | 3 (3-0) | Major |
| CHEM-6 <u>0</u> 6 | Reactive Intermediates | 3 (3-0) | Major |
| CHEM-6 <u>0</u> 7 | Organic Spectroscopy | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-6 <u>0</u> 8 | Natural Product Chemistry | 3 (3-0) | Major |
| CHEM-6 <u>0</u> 9 | Organic Electronics | 3 (3-0) | Major |

| | Stereochemistry | 3 (3-0) | Major |
|--|------------------------|----------------|--------------|
| <p>Course contents</p> <p>Introduction and importance of stereochemistry. Classification of isomers, structural and geometrical isomerism (<i>cis-trans</i> and <i>E-Z</i>). Conformational isomerism (acyclic and cyclic systems) and their energy profiles. Chirality and symmetry elements in organic molecules. Determination their absolute configuration based on the Cahn Ingold-Prelog rule (<i>R-S</i> system). Enantiomers, diastereomers, epimers & anomers. Optical isomerism. Chiral molecules that do not possess a chirality center (biphenyls, allenes, spiranes).</p> <p>Course Learning Outcomes:</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. To understand the basic concept of stereochemistry, Emphasis on different types of isomerism, Illustration of stereoisomers by Haworth and Fischer projections. 2. To critically analyze the chemistry of conformational isomerism. 3. To evaluate 3-D molecular structure of compounds. 4. Explicate <i>E, Z</i> convention and <i>cis-trans</i> isomerism compounds <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Carey, F. A. & Sundberg, R. J. (2007). <i>Advanced Organic Chemistry. Part B: Reactions and Synthesis</i> (5th ed.). Springer New York. ISBN 978-0-387-71481-3. 2. Solomons, Craig, T. W. G. & Fryhle, B. (2014). <i>Organic Chemistry</i> (11th ed.). John Wiley & Sons, Inc. New York. ISBN 978-047-183659-9. 3. Morrison, R. T. & Boyd, R. N. (2021). <i>Organic Chemistry</i> (6th ed.). Benjamin-Cummings Pub Co. ISBN: 978-013-643669-0. 4. Eliel, L. & Wilen, S.H. (2014). <i>Stereochemistry of Organic compounds</i> (1st ed.). John Wiley & Sons, Inc. New York. ISBN 978-047-101670-0. 5. Clayden, N. Greeves, S. Warren & P. Wothers, (2022). <i>Organic Chemistry</i> (2nd ed.). John Wiley & Sons, Inc. New York. ISBN 978-019-927029-3. 6. Current Literature and Reviews. | | | |

| | Synthetic Organic Chemistry | 3 (3-0) | Major |
|--|-----------------------------|---------|-------|
| Course Contents: | | | |
| Principles and importance of organic synthesis. Design, development and execution of organic reactions to construct complex molecules. Introduction to retrosynthesis and disconnection approach, one and two group carbon C-X disconnections, donor and acceptor synthons, C-C disconnections (1,2-, 1,3-, 1,4-, 1,5- and 1,6- di-functionalized compounds). Functional group transformations & functional group protection/de-protection strategies. Strategic planning of multistep synthesis. Carbon-carbon cross couplings, solid phase synthesis, green synthesis, phase-transfer catalysis. Synthetic applications of organic molecules in pharmaceuticals, polymers, materials science, and agrochemicals. | | | |
| Course Learning Outcomes: | | | |
| By the end of this course, the students will be able to: | | | |
| <ol style="list-style-type: none"> 1. Understand the use of different approaches to design molecules in organic chemistry. 2. Develop own synthetic pathways for the synthesis of unknown materials. 3. Compare different synthetic pathways for the targeted molecules and develop a synthetic route that is the easiest, economical and environmentally friendly. | | | |
| Recommended Books | | | |
| <ol style="list-style-type: none"> 1. Warren, S. and Wyatt, P. (2010). <i>Workbook for Organic Synthesis: The Disconnection Approach</i>. (2nd ed.). John-Wiley & Sons, Inc. ISBN: 978-1119965558. 2. Warren, S. and Wyatt, P. (2008). <i>Organic Synthesis: The Disconnection Approach</i>. (2nd ed.). John-Wiley & Sons, Inc. ISBN: 978-0470712368. 3. Warren, S. and Wyatt, P. (2013). <i>Organic Synthesis: Strategy and Control</i>. John-Wiley & Sons, Inc. ISBN: 978-1118-681442. 4. Zweifel, G. S., Nantz, M. H., Somfai, P. (2017) <i>Modern Organic Synthesis: An Introduction</i>. (2nd ed.). John-Wiley & Sons, Inc. ISBN: 9781119086536. 5. Starkey, L. S. (2018) <i>Introduction to Strategies for Organic Synthesis</i>. John-Wiley & Sons, Inc. ISBN: 9781119347248. 6. Keighley, N. (2024). <i>Introduction to Organic and Medicinal Chemistry</i>. CRC Press. ISBN: 9781040144862. 7. Fox, M. A. and Whitsell, J. K. (2004) <i>Organic Chemistry</i>. (3rd ed.). Jones & Bartlett Publishers. ISBN: 9780763721978. 8. Clayden, J., Greeves, N., and Warren, S. (2012). <i>Organic Chemistry</i>. (2nd ed.) Oxford University Press, New York. ISBN: 9780199270293. 9. Loudon, M. (2009). <i>Organic Chemistry</i>. (5th ed.). Roberts Company Publishers. ISBN: 978-0981519432. | | | |

14. Smith, J. G. (2010). *Organic Chemistry*. (3rd ed.). McGraw-Hill. ISBN: 9780071081863.
15. Norman, R. O. C. and Coxon, J. M. (1993). *Principles of Organic Synthesis*. (3rd ed.). CRC Press. ISBN: 9780748761623.
16. Current Literature and Reviews.

| | Heterocyclic Chemistry | 3 (3-0) | Major |
|--|-------------------------------|----------------|--------------|
| Course Contents: | | | |
| <p>Systematic nomenclature of heterocyclic compounds. Three, five and six membered heterocycles (structure, general properties, classification, aromaticity, stability, synthesis & reactivity). Electrophilic substitution reactions of pyrrole, furan and thiophene analogs. Facile synthesis of medicinally and industrially important heterocycles.</p> | | | |
| Course Learning Outcomes: | | | |
| <p>By the end of this course, the students will be able to:</p> | | | |
| <ol style="list-style-type: none"> 1. Explain reaction mechanisms, aromaticity and stability, synthesis of heterocyclic molecules. 2. Apply synthetic methods to design heterocyclic molecules relevant to modern applications. 3. Design organic synthesis with an emphasis on research. | | | |
| Recommended books | | | |
| <ol style="list-style-type: none"> 1. Carey, F. A. & Sundberg, R. J. (2007). Advanced Organic Chemistry. Part B: Reactions and Synthesis (5th ed.). Springer New York. ISBN 978-0-387-71481-3. 2. Solomons, Craig, T. W. G. & Fryhle, B. (2014). Organic Chemistry (11th ed.). John Wiley & Sons, Inc. New York. ISBN 978-047-183659-9. 3. Morrison, R. T. & Boyd, R. N. (2021). Organic Chemistry (6th ed.). Benjamin-Cummings Pub Co. ISBN: 978-013-643669-0. 4. Eliel, L. & Wilen, S.H. (2014). Stereochemistry of Organic compounds (1st ed.). John Wiley & Sons, Inc. New York. ISBN 978-047-101670-0. 5. Clayden, N. Greeves, S. Warren & P. Wothers, (2022). Organic Chemistry (2nd ed.). John Wiley & Sons, Inc. New York. ISBN 978-019-927029-3. 6. Current Literature and Reviews. | | | |

| | Reactive Intermediates | 3 (3-0) | Major |
|--|-------------------------------|----------------|--------------|
| Course Contents: | | | |
| <p>Introduction and evidences for the existence of reactive intermediates. Types of reactive intermediates. Stability, generation and salient reactions of carbocations, carbanions, free radicals, carbenes, nitrenes, benzyne and arynes. Singlet and triplet states of carbenes, nitrenes and benzyne. Alpha C–H acidity of carbonyl compounds. Generation of Enolates and Enols. Kinetic versus thermodynamic control for enolization. Reactions of enols and enolates including α-Halogenation, α-alkylation and condensation reactions. Synthetic applications of reactive intermediates.</p> | | | |
| Course Learning Outcomes: | | | |
| By the end of this course, the students will be able: | | | |
| <ol style="list-style-type: none"> 1. To acquire knowledge regarding the generation, stability and salient reactions of reactive intermediates. 2. To comprehend and corroborate the reactivity of enolates and enols. 3. To apply the underlying concepts to design the reactions involving reactive intermediates. | | | |
| Recommended Books | | | |
| <ol style="list-style-type: none"> 1. Clayden, J., Greeves, N. and Warren, S. (2012). Organic Chemistry, (2nd ed.). Oxford University Press. 2. Coxon, J. M. and Norman, R.O.C. (1993). Principles of Organic Synthesis, (3rd ed.). Chapman and Hall, UK. 3. Brown, W. H., Fotte, C. S., Iverson, B. L. and Anslyn, E. V. (1992). Organic Chemistry, (6th ed.). Brooks/Cole Learning. 4. John, E. M., (2012). Organic Chemistry, (8th ed.). Brooks/Cole Publishing Co., USA, 5. Robert, T. M. and Robert, N. B. (1992). Organic Chemistry, (6th ed.). Prentice Hall, New Jersey. 6. Current Literature and Reviews | | | |

| | Organic Spectroscopy | 3 (3-0) | Major |
|---|----------------------|---------|-------|
| <p>Course Contents</p> <p>UV-Visible: Basic concepts, electronic transitions, Lambert-Beer's law, factors influencing the lambda max (λ_{max}) values, Woodward rules for calculation of wavelength values. IR spectroscopy: Basic concepts, absorption mechanisms, functional group determination and factors affecting the absorption frequencies. ¹H-NMR and ¹³C-NMR: Chemical shift, factors affecting chemical shift, spin relaxation, spin-spin coupling, coupling constants, nuclear overhauser effect, 2-D NMR, COSY and HETCOR. Mass Spectrometry: Basic concepts; mass spectrometers, ionization techniques, different fragmentation patterns and structure elucidation, combined usage of IR, UV, NMR and Mass spectrometric data for structure elucidation of organic compounds having medium complexity</p> <p>Course Learning Outcomes:</p> <p>By the end of this course, the students will be able:</p> <ol style="list-style-type: none"> 1. To acquire an adequate knowledge about fundamental and instrumental aspects of different spectroscopic techniques. 2. To elucidate structure of organic compounds using spectral data. 3. To write spectral data in research papers and capstone. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Mohan, J. (2003). <i>Organic Analytical Chemistry: Theory and Practice</i>, (1st ed.). Alpha Science Int.Ltd. 2. Kalsi, P. S. (2003). <i>Spectroscopy of Organic Compounds</i>, (6th ed.). New Age International, New Delhi, India. 3. Yadav, L. D. S. (2005). <i>Organic Spectroscopy</i>, Springer, UK. 4. Kemp, W. (1991). <i>Organic Spectroscopy</i>, (3rd ed.). W. H. Freeman & Company, New York, USA. 5. Younas, M. (2006). <i>Organic Spectroscopy</i>, Ilmi Kitab Khana, Urdu Bazar Lahore, Pakistan. 6. Hollas, J. M. (2004). <i>Modern Spectroscopy</i>, (4th ed.). John-Wiley & Sons, Inc. 7. Pavia, D. L., Lampman, G. M., Kriz, G. S. and Vyvyan, J. R. (2009). <i>Introduction to Spectroscopy</i>, (4th ed.). Brooks/ Cole Cengage Learning. 8. Silverstein, R. M., Webster, F. X. and Kiemle, D. (2005). <i>Spectrometric Identification of Organic Compounds</i>, (7th ed.). John-Wiley & Sons, Inc. 9. Williams, D. H. and Fleming, I. (2008). <i>Spectroscopic Methods in Organic Chemistry</i>, (6th ed.). McGraw-Hill Higher Education. 10. Current Literature and Reviews | | | |

| | Natural Product Chemistry | 3 (3-0) | Major |
|---|---------------------------|---------|-------|
| <p>Course Contents</p> <p>Alkaloids: Introduction, classification, isolation methods, structure elucidation and discussion with particular reference to structure and synthesis and biosynthesis of typical alkaloids such as ephedrine, nicotine, atropine, quinine, papaverine and morphine. Terpenoids: Introduction, classification, isolation techniques and discussion with particular reference to structure and synthesis and biosynthesis of typical terpenoids such as citral, α-terpineol, α-pinene, camphor and α-cadinene. Steroids: Study of cholesterol and steroidal hormones with emphasis on their structure and biosynthesis. Flavonoids: Introduction and classification of flavonoids, general biosynthetic pathway, synthesis of flavone, flavonol and cyanidin.</p> <p>Course Learning Outcomes:</p> <p>By the end of this course, the students will be able:</p> <ol style="list-style-type: none"> 1. To acquire knowledge about different types of natural products with emphasis on their structure determination. 2. To understand classification, extraction and biosynthesis of different natural products. 3. To apply the chemistry of natural products in daily life endeavors. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Dewick, P. M. (2009). <i>Medicinal Natural Products: A Biosynthetic Approach</i>, (3rd ed.). Medicinal Natural Products, John-Wiley & Sons, Ltd. 2. Sell, C. S. A. (2003). <i>Fragrant Introduction to Terpenoid Chemistry</i>, The Royal Society of Chemistry, UK. 3. De la Rosa, L. A., Parrilla, E. A. and Aguitar, G. A. G. (2009). <i>Fruit and Vegetable Phytochemicals: Chemistry, Nutritional Value and Stability</i>, Wiley-Blackwell. 4. Shahidi, F. and Naczki M. (2004). <i>Phenolics in Food and Nutraceuticals</i>, CRC Press 5. Oyvind, M. A., and Kenneth, R. M. (2010). <i>Flavonoids: Chemistry, Biochemistry and Applications</i>, CRC, Taylor & Francis, New York. 6. Finar, I. L. Organic Chemistry, (2008). <i>Stereochemistry and the Chemistry of Natural Products</i>, (5th ed.). Pearson Education Ltd., Delhi 7. Hesse, M., (1981). <i>Alkaloid Chemistry</i>, John-Wiley & Sons, New York 8. Bhat, S. V., Nagasampagi, B. A. and Sivakumar, M. (2005). <i>Chemistry of Natural Products</i>, Narosa Publishing House. | | | |

| | Organic Electronics | 3 (3-0) | Major |
|---|---------------------|---------|-------|
| <p>Course Contents</p> <p>Introduction to principles and applications of organic electronic materials. Design and synthesis of organic semiconductors (small molecules and polymers). Optical and electrochemical properties of organic semiconductors. Use of these materials in applications ranging from organic light-emitting diodes (OLEDs) to organic photovoltaics (OPVs), organic field-effect transistors (OFETs), photodetectors, flexible displays, sensors, wearable devices, and bioelectronics. To understand and develop molecular design strategies for optimizing performance, the role of structural order and disorder in device efficiency, and current challenges in stability and scalability. Industrial applications of organic semiconductor technology and comparison to current technologies.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Understand design, synthesis and characterization of materials used in organic electronics 2. Analyze Optoelectronic and electrochemical properties of materials used in organic electronic, Device architecture and performance factors. 3. Evaluate trends in electronics including next-generation solar cells, transistors, OLED displays, future market potential and applications of Organic Electronics. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Forrest, S. R. (2025). <i>Concepts in Organic Electronics</i>. Oxford University Press. ISBN: 978-0192845344. 2. Ogawa, Shuichiro, (Ed.) (2024) <i>Organic Electronics Materials and Devices</i> (2nd ed.). Springer. ISBN 978-4431569350. 3. Bernards, D. A., Malliaras, G. G., Owens, R. M. (Eds.) (2008). <i>Organic Semiconductors in Sensor Applications</i>. Springer. ISBN: 978-3540763147. 4. Li, Y. (Ed.) (2015). <i>Organic Optoelectronic Materials</i>. Springer. ISBN: 978-3319168623. 5. Ogawa, S. (2024). <i>Organic Electronics Materials and Devices</i>. Springer. ISBN: 978-4431569350. 6. Chujo, Y. (Ed.) (2010). <i>Conjugated Polymer Synthesis: Methods and Reactions</i>. Wiley. ISBN: 9783527322671. 7. Current Literature and Reviews. | | | |

SPECIALIZATION: INORGANIC CHEMISTRY

Elective Courses

| SEMESTER 6 | | | |
|-------------------|------------------------------|---------|-------|
| CHEM-593 | Coordination Compounds | 3 (3-0) | Major |
| CHEM-594 | Inorganic Reaction Mechanism | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-695 | Inorganic Polymers | 3 (3-0) | Major |
| CHEM-696 | Organometallics | 3 (3-0) | Major |
| CHEM-697 | Group Theory | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-698 | Bio-Inorganic Chemistry | 3 (3-0) | Major |
| CHEM-699 | Radio And Nuclear Chemistry | 3 (3-0) | Major |

| CHEM- | COORDINATION COMPOUNDS | 3 (3-0) | Major |
|---|------------------------|---------|-------|
| <p>Course contents</p> <p>Historical developments, preparation, and reactions of coordination compounds in aqueous and non-aqueous solvents, thermal dissociation of solid complexes. Complex stability: factors, thermodynamics, and stability constant. Kinetics and mechanisms: basic kinetic parameters, inert and labile complexes of coordination compounds. Mechanisms of substitution reactions: Dissociation, association, and interchange reaction pathways. Octahedral substitution reactions: Dissociation, associative, the conjugate base mechanisms. Kinetic chelating effect. Square planar substitution reaction: Stereochemistry, <i>trans</i> effect. Oxidation-reduction reactions: Inner and outer sphere reaction mechanisms. Organometallics and their role in catalysis, comparative studies of coordination compounds belonging to main group and transition elements with reference to synthesis and stability. Intermetallic compounds.</p> <p>Learning Outcomes</p> <p>Upon completing this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Analyze the stability and reactivity of coordination compounds by evaluating thermodynamic and kinetic parameters. 2. Compare substitution and redox mechanisms in coordination compounds/complexes. 3. Learn synthetic strategies for organometallic compounds, correlating structure-property relationships to their catalytic and industrial applications. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Cotton, F. A., Wilkinson, G., Murillo, C. A. and Bochmann, M., Advanced Inorganic Chemistry, 6th ed., Wiley-Interscience, (1999). 2. Housecraft, C. Sharpe, A. G., Inorganic Chemistry, 5th ed., Prentice Hall, (2018). 3. Miessler, G. L.; Tarr, D.A., Inorganic Chemistry, 6th ed., Pearson-Prentice Hall International, (2022). 4. Douglas, B., McDaniel, D., Alexander, J., Concepts and Models of Inorganic Chemistry, 3rd ed., John-Wiley & Sons, New York, (1994). 5. Shriver, D. and Atkins, P., Inorganic Chemistry, 5th ed., W. H. Freeman & Company, (2010). 6. Lee, J. D., Concise Inorganic Chemistry, 5th ed., Blackwell Science Ltd., (1996). 7. Atkins, P. and Jones, L., Chemicals Principles, 5th ed., W. H. Freeman & Company, (2010). | | | |

8. Roden, B. S., *Mechanisms of Inorganic Reactions*, 2nd ed., University Science Books, (2020)
1. Huheey, J. E., Keiter, E. A.; Keiter, R. L., *Inorganic Chemistry: Principles of Structure and Reactivity*, 4th ed., Prentice Hall, (1997).
2. Müller, U., *Inorganic Structural Chemistry*, 2nd ed., John-Wiley & Sons, Ltd., (2006).
3. Marusak R. A., Doan K., Cummings S. D., *Integrated Approach to Coordination Chemistry*, 1st ed., John-Wiley & Sons, (2007).

Richens, D. T., *The Chemistry of Aqua Ions: Synthesis, Structure and Reactivity: A Tour Through the Periodic Table of the Elements*, **John Wiley & Sons, (1997).**

| CHEM- | INORGANIC REACTION MECHANISM | 3 (3-0) | Major |
|--|------------------------------|---------|-------|
| <p>Course Contents</p> <p>Classification of reaction mechanisms; rate laws; steady state approximation; inert and labile complexes; substitution reactions in octahedral complexes and square planar complexes, acid hydrolysis, base hydrolysis, steric effects of inert ligands, nucleophilic reactivity, trans-effect, cis-effect, racemization reactions. Mechanism of electron transfer reactions, oxidation reduction reactions of metal ions, outer and inner sphere mechanisms, factors affecting rate of electron transfer reactions, two electrons transfer reactions, complementary or non-complementary electron transfer reactions, oxidative addition, addition of oxygen, hydrogen, HX, organic halides and bimetallic species, Reductive Elimination Reactions.</p> <p>Learning Outcomes</p> <p>Upon successful completion of this course, students will be able to:</p> <ul style="list-style-type: none"> • Learn reaction mechanisms in coordination complexes using kinetic principles and ligand effects. • Learn to differentiate between inner-sphere and outer-sphere electron transfer mechanisms and assess factors that control their rates. <p>Predict reactivity in organometallic systems by applying concepts of oxidative addition, reductive elimination, and bimetallic reactions to catalytic and stoichiometric transformations.</p> <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Huheey, J. E., Keiter, E. A., Keiter, R. L., Inorganic Chemistry: Principles of Structure and Reactivity, 4th ed., Prentice Hall, (1997). 2. Wilkins, R. G., Kinetics and Mechanism of Reactions of Transition Metal Complex, 2nd ed., (Rev.), Wiley-VCH, (1991). 3. Jordan, R. B., Reaction Mechanisms of Inorganic and Organometallic Systems, 3rd ed., Oxford University Press, (2007). 4. Atwood, J. D., Inorganic and Organometallic Reaction Mechanisms, 2nd ed., Wiley-VCH, Inc., (1997). | | | |

5. Sharma, R. K., *Inorganic Reaction Mechanisms*, Discovery Publishing House, (2007). BS 4th ed. Miessler, G. L., Fischer, P. J., & Tarr, D. A., *Inorganic Chemistry*, 6th ed., Pearson Education, (2022).
6. Housecroft, C. E., & Sharpe, A. G., *Inorganic Chemistry*, 5th ed., Pearson Education, (2018).
7. Wilkins, R. G., *Kinetics and Mechanism of Reactions of Transition Metal Complexes*, 2nd ed., Wiley-VCH, (1991).
8. Espenson, J. H., *Chemical Kinetics and Reaction Mechanisms*, 2nd ed., McGraw-Hill, (1995).
9. Crabtree, R. H., *The Organometallic Chemistry of the Transition Metals*, 7th ed., John Wiley & Sons, (2019).
10. Hartwig, J. F., *Organotransition Metal Chemistry: From Bonding to Catalysis*, University Science Books, (2010).
11. Roden, B. S., *Mechanisms of Inorganic Reactions*, 2nd ed., University Science Books, (2020).

| CHEM- | INORGANIC POLYMERS | 3 (3-0) | Major |
|---|---------------------------|----------------|--------------|
| <p>Course Contents</p> <p>Introduction to homoatomic and heteroatomic inorganic polymers, silicon-based (polysiloxanes, polysilanes), phosphorus-based (polyphosphazenes), boron-nitrogen, and sulfur-containing polymers, hybrid inorganic-organic based polymers. Synthesis methods (condensation, sol-gel, ring-opening polymerization) and characterization techniques (spectroscopy, thermal analysis, microscopy), properties and applications, Polyionic species, Isopoly and heteropoly, anions of transition metals. Emerging trends such as green synthesis, nanocomposites and sustainability.</p> <p>Learning Outcomes</p> <p>Upon successful completion of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Classify and compare key inorganic polymers and hybrid materials, correlating their structures with properties and applications. 2. Apply synthetic methods and characterization techniques to design and evaluate inorganic polymeric materials. 3. Critically assess emerging trends and poly-ionic species for advanced material development. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Chandrasekhar, V., Inorganic and Organometallic Polymers, Springer International Publishing, (2018). 2. Manners, I., Synthetic Metal-Containing Polymers, Wiley-VCH, (2004). 3. Kickelbick, G., Hybrid Materials: Synthesis, Characterization, and Applications, Wiley-VCH, (2007). 4. Andrianov, A. K., Polyphosphazenes for Biomedical Applications, Wiley, (2009). 5. Dvornic, P. R., Lenz, R. W., High Temperature Siloxane Elastomers, Hüthig & Wepf Verlag, (1990). 6. Billmeyer, F. W., A Textbook of Polymer Science, 3rd ed., John Wiley and Sons, (2003). 7. Miessler, G. L., Tarr, D. A., Inorganic Chemistry, 5th ed., Pearson Education, (2013). 8. Crabtree, R. H., The Organometallic Chemistry of the Transition Metals, 7th ed., John Wiley and Sons, (2019). | | | |

9. Cotton, F. A., Wilkinson, G., Murillo, C. A. and Bochmann, M., *Advanced Inorganic Chemistry*, 6th ed., Wiley-Interscience, (1999).
 10. Mark, J. E., et al. (Eds.), *Inorganic Polymers*, 2nd ed., Oxford University Press, (2005).
 11. Atkins, P. and Jones, L., *Chemicals Principles: The Quest for Insight*, 5th ed., W. H. Freeman, (2010).
 12. Yamamoto, A., *Organotransition Metal Chemistry*, Prentice Hall, (1992).
 13. Billmeyer, F. W., *A Text Book of Polymer Science*, 3rd, John-Wiley and Sons, (2003).
- Malmcoim, P.S., *Polymer Chemistry: An Introduction*, 3rd ed., Oxford University Press, (2005).

| CHEM- | ORGANOMETALLICS | 3 (3-0) | Major |
|--|-----------------|---------|-------|
| <p>Course Contents</p> <p>Fundamentals of organometallic compounds, the 18-electron rule, types of bonding in organometallics, single, double and triple bonds to carbon (compound types, acyls, alkylidene complexes and alkylidyne complexes), delocalized hydrocarbon systems (alkenes, allyl, butadienes and arenes), alkyne complexes, cyclic π-complexes, metal-carbon multiple bonds, and main group organometallics. Fundamental reaction mechanisms including ligand substitution, oxidative addition, reductive elimination, insertion and elimination reactions, and nucleophilic/electrophilic attack on coordinated ligands. Homogeneous catalytic hydrogenation, dimerization, oligomerization, polymerization, hydroformylation of olefins, catalytic polymerization of acetylenes, olefin metathesis, cross-coupling reactions, and C-H activation and applications.</p> <p>Learning Outcomes</p> <p>Upon completing this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Classify organometallic compounds based on bonding modes and ligand types. 2. Analyze homogeneous catalytic processes and insertion reactions to predict reaction mechanisms and synthetic applications. 3. Optimize organometallic-catalyzed reactions for organic synthesis and industrial processes by using metal-ligand interactions and mechanistic principles. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Powell, P., Principles of Organometallics Chemistry, 2nd ed., Springer, (1998). 2. Yamamoto A., Organotransition Metal Chemistry: Fundamental Concepts and Applications, 1st ed., John-Wiley & Sons, Inc., (1986). 3. Douglas, B., McDaniel, D. and Alexander, J., Concepts and Models of Inorganic Chemistry, 3rd ed., John-Wiley & Sons, Inc., (1994). 4. Haiduc, I.; Zuckerman, J. J., Basic Organometallic Chemistry, Walter De Gruyter Inc., (1985). 5. Crabtree, R. H., The Organometallic Chemistry of the Transition Metals, 7th ed., John Wiley & Sons, (2019). 6. Hartwig, J. F., Organo-transition Metal Chemistry: From Bonding to Catalysis, University Science Books, (2010). 7. Elschenbroich, C., Organometallics, 6th ed., Wiley-VCH, (2016). 8. Maitlis, P. M., & De Vries, A., The Organic Chemistry of the Transition Metals: A Guide to Reactions and Mechanisms, Wiley, (2014). 9. Yamamoto, A., Organotransition Metal Chemistry: Fundamental Concepts and Applications, 1st ed., John Wiley & Sons, Inc., (1986). | | | |

10. Miessler, G. L., Fisher, P. J., and Tarr, D. A., *Inorganic Chemistry*, 6th ed., Pearson Education, (2022).

Cotton, F. A., Wilkinson, G., Murillo, C. A., and Bochmann, M., *Advanced Inorganic Chemistry*, 6th ed., Wiley-Interscience, New York, (1999).

| CHEM- | Group Theory | 3 (3-0) | Major |
|--|--------------|---------|-------|
| <p>Course Contents</p> <p>Symmetry; operations & elements, point groups, crystallographic and non-crystallographic point groups, assigning point groups, definition and properties of a group, subgroups, group multiplication table, matrix representation of a group, character tables. The great orthogonality theorem, rules derived from the theorem, developing of character tables for various point groups, matrices, matrix multiplication, character of a matrix, reducible representations and their reduction, symmetry and physical properties of molecules. Application of group theory: to valence bond theory and hybrid orbitals, crystal field theory and Jahn-Teller distortion, MX_n molecules with pi-bonding, pi-bonding in aromatic ring systems, vibrational spectroscopy, molecular vibrations using internal coordinates, bonding modes, geometric isomers, infrared and Raman active vibrations, exclusion rule, molecular orbital diagrams, metal sandwich compounds and AB_n molecules.</p> <p>Course Learning Outcomes</p> <p>Upon completing this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Classify molecules using point groups and predict properties <i>via</i> character tables. 2. Analyze bonding in complexes/aromatics using MO diagrams and symmetry. 3. Interpret vibrational spectra with selection rules and normal mode analysis <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. K.C. Molloy, Theory for Chemists: Fundamental Theory and Applications, 2nd ed., Woodhead Publishing in Materials (2011). 2. Carter, L.R., Molecular Spectrometry and Group Theory, John Wiley and Sons (2004). 3. Vincent, A., Molecular Symmetry and Group Theory, 2nd ed., Wiley (2000). 4. Cotton, F.A., Chemical Applications of Group Theory, 3rd ed., Wiley India (2008). 5. Lever, A.B.P., Introduction to Electronic Spectroscopy, 2nd ed., Elsevier, Amsterdam (1984) 6. Cotton, F. A., Chemical Applications of Group Theory, 3rd ed., Wiley-Interscience, (2008). 7. Housecraft, C. and Sharpe, A. G., Inorganic Chemistry, 4th ed., Prentice Hall, (2012). 8. Miessler, G. L. and Tarr, D.A., Inorganic Chemistry, 4th ed., Pearson Prentice Hall International, (2010). 9. Vincent, A., <i>Molecular Symmetry and Group Theory: A Programmed Introduction to Chemical Applications</i>, 2nd ed., John Wiley & Sons, Ltd., (2001). | | | |

10. Atkins, P. W., de Paula, J., & Friedman, R. G., *Quanta, Matter, and Change: A Molecular Approach to Physical Chemistry*, 2nd ed., Oxford University Press, (2023).

Harris, D. C., & Bertolucci, M. D., *Symmetry and Spectroscopy: An Introduction to Vibrational and Electronic Spectroscopy*, Dover Publications, (1989).

| | | | |
|--|--------------------------------|----------------|--------------|
| CHEM- | BIO-INORGANIC CHEMISTRY | 3 (3-0) | Major |
| <p>Course Contents</p> <p>Development and importance of bio-inorganic chemistry. Metals and Complexes: Metals of biological importance. Function of metals in enzyme catalysis. Metalloproteins and enzymes containing a transition metal -centre at their active site. Biochemistry of iron. Oxygen carriers; uptake and transport activation and utilization; synthetic dioxygen carriers; nitrogen fixation; vitamin B6 and B12. Biochemistry of selenium, Bio Chemistry of Organo selenium Compounds, Antioxidant, Activity of Organoselenium compounds, Toxicology of Organoselenium Compounds, the biochemistry of Zn, Cu. Co, Mg, F₂, I₂ and alkali and Alkaline earth metals. Importance of nonmetals in biological systems. Metal ions and chelating agents in biological systems. Metal-based drugs. The harmful effects of heavy metals, Future perspectives.</p> <p>Learning Outcomes</p> <p>Upon successful completion of this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Explain the critical role of metal ions in biological systems by analyzing the structure-function relationships of metalloenzymes, oxygen carriers. 2. Evaluate the biochemical mechanisms of essential metal ions and nonmetals in metabolic pathways, and their implications in health and disease. 3. Apply bioinorganic principles to rationalize the design of metal-based drugs and chelation therapies, connecting molecular interactions to therapeutic outcomes. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Crichton, R. R. <i>Biological Inorganic Chemistry: A New Introduction to Molecular Structure and Function</i> (3rd ed.). Academic Press (Elsevier), (2018). 2. Lippard, S. J., Berg, J. M., <i>Principles of Bioinorganic Chemistry</i>, University Science Books, (1994). 3. Fraústo da Silva, J. J. R., & Williams, R. J. P., <i>The Biological Chemistry of the Elements: The Inorganic Chemistry of Life</i>, 2nd ed., Oxford University Press, (2013). 4. Sigel, A., Sigel, H., Sigel, R. K. O. (Eds.), <i>Metallo-Drugs: Development and Action of Anticancer Agents</i>, De Gruyter, (2018). 5. Aldrich-Wright, J., Vilar, R. (Eds.), <i>Medicinal Applications of Coordination Chemistry</i>, Royal Society of Chemistry, (2023). 6. Sessler, J. L., Doctrow, S. R., McMurry, T. J., & Lippard, S. J., <i>Medicinal Inorganic Chemistry</i>, American Chemical Society, (2005). 7. Storr, T. (Ed.), <i>Ligand Design in Medicinal Inorganic Chemistry</i>, John Wiley & Sons, (2014). 8. Kaim, W., Schwederski, B., Klein, A. <i>Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life</i> (2nd ed.). Wiley-VCH. (2021). | | | |

9. Fraústo da Silva, J. J. R., & Williams, R. J. P.
The Biological Chemistry of the Elements: The Inorganic Chemistry of Life (*2nd ed.*).
Oxford University Press, (2013).
10. Hay, R. W., *Bioinorganic Chemistry*, Ellis Horwood, London (1984).
11. Keppler, B.K., *Metal Complexes in Cancer Chemotherapy*, VCH, Weinheim (1993).
12. Gielen, M. F. *Metal Based Anti-tumor Drugs*, Freund Publishing House Ltd. London (1988).

| CHEM- | RADIO AND NUCLEAR CHEMISTRY | 3 (3-0) | Major |
|--|-----------------------------|---------|-------|
| <p>Course Contents</p> <p>Fundamentals and applied aspects of radioactivity and nuclear chemistry. Types and characteristics of nuclear radiation, structure of nucleus, half -life, nuclear binding energy, and artificial radioactivity, radioactive decay, Effect of radiations on biological system, fission and fusion reactions, and acceleration of charged particles and applications of radioisotopes. Radiotracer techniques, choice of radiotracers, factors affecting choice of radiotracers, isotope dilution analysis Radiation detection and measurement techniques, Radiochemical separation methods, environmental radiochemistry, radioactive waste management. Radiation safety and Regulations.</p> <p>Learning Outcomes</p> <p>Upon completing this course, students will be able to:</p> <ol style="list-style-type: none"> 1. Explain nuclear stability, radiation interactions by analyzing half-life, binding energy, and biological effects to assess risks and safety measures. 2. Compare fission, fusion, and particle acceleration techniques, evaluating their applications in energy production, medicine, and industry. 3. Apply radioisotope methodologies in real-world contexts with ethical and environmental consideration. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Friedlander, G., Kennedy, J. W., Miller, J. M. and Maciuas, E. S., Nuclear and Radiochemistry, 3rd ed., John-Wiley & Sons, Inc., (1981). 2. Choppin, G. R., Rydberg, J., Liljenzin, J., Radiochemistry and Nuclear Chemistry, 3rd ed., Butterworth-Heinemann Ltd., (2002). 3. Arnikaar, H. J., Essentials of Nuclear Chemistry, 4th ed., New Age International Pvt. Ltd. Publishers, (1996). 4. Friedlander, G., Kennedy, J. W., Miller, J. M. and Maciuas, E. S., Nuclear and Radiochemistry, 3rd ed., John-Wiley & Sons, Inc., (1981). 5. Choppin, G. R., Rydberg, J., Liljenzin, J., Radiochemistry and Nuclear Chemistry, 3rd ed., Butterworth-Heinemann Ltd., (2002). 6. Arnikaar, H. J., Essentials of Nuclear Chemistry, 4th ed., New Age International Pvt. Ltd. Publishers, (1996). 7. Naqvi, I. I. and Farrukh, M. A., Radiotracers in Chemical Applications VDM Verlag Dr. Müller, Germany, (2010). 8. Loveland, W., Morrissey, D. J. and Seaborg, J. T., Modern Nuclear Chemistry, John Wiley and Sons, Inc., (2006). | | | |

SPECIALIZATION: PHYSICAL CHEMISTRY

Elective Courses

| SEMESTER 6 | | | |
|-------------------|--------------------------------|---------|-------|
| CHEM-5 <u>2</u> 3 | Colloids & Surfactants | 3 (3-0) | Major |
| CHEM-5 <u>2</u> 4 | Materials Science | 3 (3-0) | Major |
| SEMESTER 7 | | | |
| CHEM-6 <u>2</u> 5 | Physical Chemistry of Polymers | 3 (3-0) | Major |
| CHEM-6 <u>2</u> 6 | Surface Chemistry | 3 (3-0) | Major |
| CHEM-6 <u>2</u> 7 | Chemical Thermodynamics | 3 (3-0) | Major |
| SEMESTER 8 | | | |
| CHEM-6 <u>2</u> 8 | Nuclear & Radiation Chemistry | 3 (3-0) | Major |
| CHEM-6 <u>2</u> 9 | Photochemistry | 3 (3-0) | Major |

| | Colloids & Surfactants | 3 (3-0) | Major |
|--|-----------------------------------|----------------|--------------|
| <p>Course contents</p> <p>Colloidal solutions, catalyst preparation methods, industrial catalysts, surfactant, nanoscale chemistry, nanomaterials and their applications, dimensional control in nanostructures, macromolecular surface films, characterization methods and applications.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Acquire knowledge about the important physical and chemical aspects of nano and colloidal systems and the basics of thermodynamically and kinetically stabilized nanoparticles and colloidal solutions. 2. Learn about the surfactant chemistry, characterization methods and applications of nanoparticles and colloidal solutions. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Schmid, G. <i>Nanoparticles: From Theory to Application</i>, 2nd ed.; Wiley-VCH: Weinheim, Germany, 2010. Covers nanoscale chemistry, nanomaterials, and their applications with emphasis on synthesis and dimensional control. 2. Shaw, D. J. <i>Introduction to Colloid and Surface Chemistry</i>, 4th ed.; Butterworth-Heinemann: Oxford, UK, 1992. A foundational text on colloidal solutions, surfactants, and macromolecular surface films. 3. Somorjai, G. A.; Li, Y. <i>Introduction to Surface Chemistry and Catalysis</i>, 2nd ed.; Wiley: Hoboken, NJ, 2010. Explores catalyst preparation, industrial catalysis, and surface interactions at the nanoscale. 4. Binns, C. <i>Introduction to Nanoscience and Nanotechnology</i>; Wiley: Chichester, UK, 2010. Provides a broad overview of nanoscience, including nanostructure control and characterization methods. 5. Skoog, D. A.; Holler, F. J.; Crouch, S. R. <i>Principles of Instrumental Analysis</i>, 7th ed.; Cengage Learning: Boston, MA, 2017. Essential for understanding spectroscopic and microscopic characterization techniques used in materials and nanochemistry. | | | |

| | Materials Science | 3 (3-0) | Major |
|---|--------------------------|----------------|--------------|
| <p>Course Contents</p> <p>Materials, Structure of materials: metals, alloys, ceramics, polymers, composite materials and their classification, matrices and reinforcements for materials, Properties of materials (thermal, morphological, mechanical, electrical, magnetic and optical). Applications of materials, Characterization techniques use in materials, Spectroscopic and microscopic analysis.</p> <p>Course Learning Outcomes By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Explain fundamental principles of nano-chemistry, including nanoscale properties, quantum 2. Learn about the effects, and surface-to-volume ratio implications. 3. Identify and describe various synthesis methods and characterization techniques used in nanomaterials, <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Callister, W. D.; Rethwisch, D. G. <i>Materials Science and Engineering: An Introduction</i>, 10th ed.; Wiley: Hoboken, NJ, 2021. 2. Askeland, D. R.; Wright, W. J. <i>The Science and Engineering of Materials</i>, 7th ed.; Cengage Learning: Boston, MA, 2019. 3. Smith, W. F.; Hashemi, J. <i>Foundations of Materials Science and Engineering</i>, 5th ed.; McGraw-Hill Education: New York, NY, 2010. 4. Van Vlack, L. H. <i>Elements of Materials Science and Engineering</i>, 6th ed.; Addison-Wesley: Reading, MA, 1989. 5. Cullity, B. D.; Stock, S. R. <i>Elements of X-ray Diffraction</i>, 3rd ed.; Pearson: Upper Saddle River, NJ, 2011. | | | |

| CHEM- | Physical Chemistry of Polymers | 3 (3-0) | Major |
|--|-----------------------------------|---------|-------|
| <p>Course Contents</p> <p>Introduction to Polymers, step-growth polymerization, polymer chain growth, kinetics of polymer chain growth, co-polymerization, emulsion polymerization, natural and inorganic polymers, physical aspects of polymers, molecular weight of polymers, distribution, averages, and methods of determination, viscosity, osmometry, light scattering method, diffusion, sedimentation, optical rotation method, structure of polymer chain, introduction to chain isomerism, stereochemistry, configurations, and conformations (not in Hiemenz), amorphous state of polymers, in-depth examination of polymer conformation, microstructure, and dynamics in the amorphous state, polymer viscoelasticity, stress relaxation, mechanical models of polymer behavior, time-temperature superposition, polymer rheology, crystalline state of polymers, crystallization and kinetics, crystalline structures, experimental methods, polymer solutions and blends.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Students will learn the fundamental principles of polymerization, synthesis methods and reaction mechanisms, thermodynamic and kinetic aspects of the polymerization, and physical and mechanical properties of polymers. 2. Students will also know about the polymer characterization techniques and various applications of polymers. <p>Recommended Books:</p> <ol style="list-style-type: none"> 1. Sperling, L. H. Introduction to Physical Polymer Science, 4th ed., Wiley-Interscience, New York, USA, (2006). 2. Boyd, R. H. and Phillips, P. J., The Science of Polymer Molecules, Cambridge, UK, (1993). 3. Odian, G., Principles of Polymerization, 4th ed., Wiley Interscience, (2004). 4. Carraher Jr, C. E., Carraher's, Polymer Chemistry, 8th ed., CRC Press, Inc., (2010). 5. Ravve, A., Principles of Polymer Chemistry, 3rd ed., Springer, (2012). 6. Stevens, M. P., Polymer Chemistry: An Introduction, 3rd ed., Oxford University Press, (1998). 7. Allcock, H., Lampe, F. and Mark, J., Contemporary Polymer Chemistry, 3rd ed., Prentice Hall, (2003). 8. Flory, J., Principles of Polymer Chemistry, Cornell University Pres (1953) | | | |

| CHEM- | Surface Chemistry | 3 (3-0) | Major |
|--|-------------------|---------|-------|
| <p>Course Contents Definition, adsorption, Types of adsorptions, Adsorption isotherm, adsorption at liquid surfaces, chemisorption, physisorption, Interface, Solid-liquid surfaces, gas solid interface, surface structures, thermodynamics of adsorption, Catalysis, Classification, characteristics of catalyst, homogenous and heterogeneous catalysis, industrial catalysts, enzymatic catalysis, kinetic and mechanisms of catalyzed reactions, catalyst synthesis and characterization</p> <p>Learning Outcomes By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Know the basic concept of adsorption, adsorption phenomenon and application of adsorption. 2. The students will be able to remove the pollutants from water using different adsorbent. They will also able to learn different characterization techniques. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Somorjai, G. A.; Li, Y. <i>Introduction to Surface Chemistry and Catalysis</i>, 2nd ed.; Wiley: Hoboken, NJ, 2010. A foundational text covering surface phenomena, adsorption, catalysis, and surface analytical techniques. 2. Birdi, K. S. <i>Surface Chemistry Essentials</i>; CRC Press: Boca Raton, FL, 2013. Offers a concise yet comprehensive introduction to surface tension, wetting, surfactants, and colloidal systems. 3. Adamson, A. W.; Gast, A. P. <i>Physical Chemistry of Surfaces</i>, 6th ed.; Wiley-Interscience: New York, NY, 1997. A classic reference on interfacial phenomena, adsorption isotherms, and thermodynamics of surfaces. 4. Israelachvili, J. N. <i>Intermolecular and Surface Forces</i>, 3rd ed.; Academic Press: San Diego, CA, 2011. Explores the fundamental forces at play in surface interactions, with applications in biology, materials, and nanoscience. 5. Atkins, P.; de Paula, J. <i>Atkins' Physical Chemistry</i>, 11th ed.; Oxford University Press: Oxford, UK, 2018. Includes detailed chapters on surface chemistry, adsorption, and thermodynamics, suitable for advanced undergraduates. | | | |

| CHEM- | Chemical Thermodynamics | 3 (3-0) | Major |
|--|-------------------------|---------|-------|
| <p>Course Contents Fundamentals of thermodynamics, Thermodynamic properties, Enthalpy, entropy, Gibbs free energy and their relationship. Heat capacities, their dependence on temperature, pressure and volume, ideal and real gases, the virial equation and the van der Waals equation for real gases, critical phenomena and critical constants, laws of thermodynamics and their applications, reversible and non-reversible processes, spontaneous and non-spontaneous processes, relations of entropy and Gibbs free energy with equilibrium constant, Gibbs Helmholtz equation, fugacity and activity.</p> <p>Learning Outcomes By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Know the basic concept of thermodynamics, thermodynamic properties and application of thermodynamics in daily life. 2. The students will also learn about the laws of thermodynamics and their applications in practical life. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Atkins, P.; de Paula, J. <i>Atkins' Physical Chemistry</i>, 11th ed.; Oxford University Press: Oxford, UK, 2018. — A comprehensive text covering thermodynamic principles, equations of state, phase equilibria, and chemical potentials. 2. Smith, J. M.; Van Ness, H. C.; Abbott, M. M. <i>Introduction to Chemical Engineering Thermodynamics</i>, 8th ed.; McGraw-Hill Education: New York, NY, 2017. — Widely used in engineering programs, this book emphasizes real-world applications and phase behavior. 3. Engel, T.; Reid, P. <i>Thermodynamics, Statistical Thermodynamics, and Kinetics</i>, 3rd ed.; Pearson: Boston, MA, 2012. — Integrates classical and statistical thermodynamics with chemical kinetics, ideal for chemistry majors. 4. Alberty, R. A. <i>Thermodynamics of Biochemical Reactions</i>, 1st ed.; Wiley-Interscience: Hoboken, NJ, 2003. Alberty, R. A. <i>Thermodynamics of Biochemical Reactions</i>, 1st ed.; Wiley-Interscience: Hoboken, NJ, 2003. — Focuses on thermodynamics in biological systems, including biochemical equilibria and energy transformations. 5. Denbigh, K. <i>The Principles of Chemical Equilibrium: With Applications in Chemistry and Chemical Engineering</i>, 4th ed.; Cambridge University Press: Cambridge, UK, 1981. — A classic reference that delves into equilibrium thermodynamics and its theoretical foundations. | | | |

| CHEM- | Nuclear & Radiation Chemistry | 3 (3-0) | Major |
|--|-------------------------------|---------|-------|
| <p>Course Contents Course Contents:</p> <p>Radioactivity, Nuclear structure and properties. Radioactive decay, nuclear reactions, radiation dosimetry, Fricke dosimeter, dosimetry in pulse radiolysis, energy states in radiation chemistry, excited states, fragmentation, pre-dissociation. Development and advancement in radiation chemistry, Effect of radiation on biological systems. photochemical decay, ions and electrons, radiolysis of gases, liquids, solids, frozen liquids and ions in radiation chemistry, recent application of radiation chemistry. Applications of radioactivity in various fields.</p> <p>Course Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Learn about the mechanisms of radiation, radiation dosimetry and applications of the radiation chemistry. They will also learn about radioactive decays, and how radioisotopes are produced. 2. Students will be able to understand the principles of fluorescence, phosphorescence and other photochemical processes, and their applications. <p>Recommended Books</p> <ol style="list-style-type: none"> 1. Spinks, J. W. T. and Woods, R. J., An introduction to Radiation Chemistry, 3rd ed., Wiley Inter Si. Pub., USA, (1990). 2. Aziz, F. and Rodgers, M. A. J., Radiation Chemistry Principles and Applications, 1st ed., VCH Publishers, Inc., (1987). 3. Choppin, G., Liljenzin, J-O., Rydberg, J., Radiochemistry and Nuclear Chemistry, 3rd ed., Butterworth-Heinemann, (2002). 4. Mostafavi, M., Douki, T., Radiation Chemistry: From Basic to Applications in Material and Life Sciences, EDP Science, (2008). 5. Dunkin, I., Photochemistry, Vol. 36, RSC Publishing, (2007). 6. Dickson, D. P. E., Berry, F. J., Mossbauer Spectroscopy, Cambridge University Press, (1986). 7. Scaglia, B., The Fundamentals: An Understanding of Photochemistry, Biblio Bazaar, (2011). 8. Konya, J. and Nagy, N. M., Nuclear and Radiochemistry, 1st ed., Elsevier, (2012). | | | |

| CHEM- | Photochemistry | 3 (3-0) | Major |
|--|----------------|---------|-------|
| <p>Course Contents</p> <p>Fundamentals: Light and nature of electromagnetic radiations, Principles of photochemistry, laws of photochemistry, Einstein's law of photochemical equivalence, rates of intramolecular processes, photochemical reactions in gas and in solutions phase and quantum yields with examples, energy transfer in photochemical reaction. (Fluorescence, phosphorescence, inter-system crossing, internal conversion, quenching) and Stern-Volmer reactions, photosensitized reactions.</p> <p>Learning Outcomes</p> <p>By the end of this course, the students will be able to:</p> <ol style="list-style-type: none"> 1. Students will be able to understand the principles of fluorescence, phosphorescence and other photochemical processes, and their applications. 2. Moreover, they will understand about the laws of photochemistry, photosensitized reactions. <p>RECOMMENDED BOOKS</p> <ol style="list-style-type: none"> 1. Turro, N. J.; Ramamurthy, V.; Scaiano, J. C. <i>Principles of Molecular Photochemistry: An Introduction</i>; University Science Books: Sausalito, CA, 2009. — A widely respected introduction to photochemical principles, excited states, and reaction pathways. 2. Gilbert, A.; Baggott, J. <i>Essentials of Molecular Photochemistry</i>; CRC Press: Boca Raton, FL, 1991. — Covers the basics of photophysical processes and photochemical reactions with clear illustrations. 3. Coxon, J. M.; Halton, B. <i>Organic Photochemistry</i>; Cambridge University Press: Cambridge, UK, 1987. — Focuses on organic photochemical transformations and mechanisms. 4. Wayne, R. P. <i>Photochemistry</i>, 2nd ed.; Oxford University Press: Oxford, UK, 1996. — Offers a broad overview of photochemistry in atmospheric, environmental, and biological contexts. 5. Montalti, M.; Credi, A.; Prodi, L.; Gandolfi, M. T. <i>Handbook of Photochemistry</i>, 3rd ed.; CRC Press: Boca Raton, FL, 2006. — A practical reference with data on quantum yields, lifetimes, and photochemical properties of compounds. | | | |

(Allied courses)

To be opted from among the pool of available subject teachers in university and affiliated colleges