Learning Outcomes based Curriculum Framework (LOCF) for
(B.Sc. with Chemistry)
Undergraduate Programme: A Template
2019
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Preamble

Over the past decades the higher education system of our country has undergone substantial structural and functional changes resulting in both quantitative and qualitative development of the beneficiaries. Such changes have gained momentum with the introduction of Choice Based Credit System (CBCS) which further expects learning outcome based curriculum in order to maximize the benefits of the newly designed curriculum. The learning outcome based curriculum in general and in Chemistry in particular will definitely help the teachers of the discipline to visualize the curriculum more specifically in terms of the learning outcomes expected from the students at the end of the instructional process. It is pertinent to mention here that the purpose of education is to develop an integrated personality of the individual and the educational system provides all knowledge and skills to the learner for this.

The Learning outcome-based curriculum framework (LOCF) has been prepared to support designing uniform, advanced and effective Chemistry curriculum for undergraduate studies in Chemistry. The recommendations related to curriculum development is applicable for college/university education system which includes heads of schools/departments, practising teachers, parents, employers, academics from tertiary institutions, professionals from related fields or related bodies and representatives from university/college examinations authorities. The LOCF guides are based on the consultation documents on curriculum framework of University Grants Commission and MOOCs. The concerns, needs and interests of students, teachers as well as societal expectations has been taken into consideration while developing these framework structure. Each subject content aims to present a curriculum framework, specifying the curriculum aims, learning targets and objectives, and thus providing suggestions regarding curriculum planning, learning and teaching strategies, assessment and resources. In addition, the curriculum framework also provides examples of effective learning, teaching and assessment practices. A coherent understanding of the whole-undergraduate chemistry (major and pass) curriculum planning and the planning of student learning ability at subject levels can be established. Curriculum development is a collaborative and an on-going enhancement process, therefore, the same shall be updated and improved from time to time to meet new needs of students, teachers and society at large.
The template as developed has the provision of ensuring the integrated personality of the students in terms of providing opportunity for exposure to the students towards core courses, discipline specific courses, generic elective courses, ability enhancement courses and skill enhancement courses with special focus on technical, communication and subject specific skills through practical and other innovative transactional modes to develop their employability skills. The template of learning outcome based curriculum has categorically mentioned very well defined expected outcomes for the programme like core competency, communication skills, critical thinking, affective skills, problem-solving, analytical, reasoning, research-skills, teamwork, digital literacy, moral and ethical awareness, leadership readiness and so on along with very specific learning course outcomes at the starting of each course. Therefore, this template on Learning Outcomes based Curriculum Framework (LOCF) for B.Sc. with Chemistry/Chemistry Honors will definitely be a landmark in the field of outcome based curriculum construction.
Introduction

Academics and research in India is a priority which depends upon the quality of education. Quality higher education include innovations that can be useful for efficient governance of higher education institutions, systems and society at large. Thus, fundamental approach to learning outcome-based curriculum framework emphasizes upon demonstration of understanding, knowledge, skills, attitudes and values in particular programme of study. The LOCF based programme intended to follow flexibility and innovation in design of the programme, its assessment, and expect graduate attributes demonstrating the level of learning outcome. It is further expected to provide effective teaching – learning strategies including periodic review of the programme and its academic standard. The learning outcome-based curriculum framework for B.Sc. degree in Chemistry is intended to provide a broad framework and hence designed to address the needs of the students with chemistry as the core subject of study. The framework is expected to assist in the maintenance of the standard of chemistry degrees/programmes across the country and periodic programme review within a broad framework of agreed/expected graduate attributes, qualification descriptors, programme learning outcomes and course-level learning outcomes. The framework is intended to allow flexibility and innovation in programme design, syllabi development, teaching-learning process and quality assessment of students learning levels.

This curriculum framework for the bachelor-level program in Chemistry is developed keeping in view of the student centric learning pedagogy, which is entirely outcome-oriented and curiosity-driven. To avoid rote-learning approach and foster imagination, the curriculum is more leaned towards self-discovery of concepts. The curriculum framework focuses on pragmatist approach whereby practical application of theoretical concepts is taught with substantial coverage of practical and field works. The platform aims at equipping the graduates with necessary skills for Chemistry-related careers, careers with general graduate-level aptitude and for higher education in Chemistry and allied subjects. Augmented in this framework are graduate attributes including critical thinking, basic psychology, scientific reasoning, moral ethical reasoning and so on, qualification descriptors that are specific outcomes pertinent to the discipline of chemistry, learning outcomes for the two programmes these frameworks have been
developed, learning outcomes for individual courses, pedagogical methods and assessment methods. While designing these frameworks, emphasis is given on the objectively measurable teaching-learning outcomes to ensure employability of the graduates. In line with recent trends in education section, these frameworks foster implementation of modern pedagogical tools and concepts such as flip-class, hybrid learning, MOOCs and other e-learning platforms. In addition, the framework pragmatic to the core; it is designed such a way to enable the learners implementing the concepts to address the real world problems. A major emphasis of these frameworks is that the curriculum focuses on issues pertinent to India and also of the west; for example, green chemistry and biomaterials etc. Above all, these frameworks are holistic and aim to mould responsible Indian citizen to have reflective thinking, scientific temper, and digital literacy in order to acquire requisite skill to be self employed entrepreneurial.

Aims:

2. To transform curriculum into outcome-oriented scenario
3. To develop the curriculum for fostering discovery-learning
4. To equip the students in solving the practical problems pertinent to India
5. To adopt recent pedagogical trends in education including e-learning, flipped class, hybrid learning and MOOCs
6. To mold responsible citizen for nation-building and transforming the country towards the future
1. Learning Outcome Based Curriculum Vis- A -Vis Objective Based Curriculum:

Curriculum is the heart of any educational system. It can be focused either to achieve the objectives of each course of the programme or on the expected learning outcomes from each course. The objective based curriculum refers to the overall targets to be achieved through curriculum which may be long term or immediate. On the other hand, the learning outcome based curriculum is very specific in nature in terms of changes in the cognitive, affective and psychomotor behavior of the students as a result of their exposure to the curriculum. The outcome based curriculum provides the teacher very specific targets which he can achieve through the selected instructional process as compared to the objective based curriculum which provides general outcomes.

The learning outcome based curriculum has very close relationship with the learning of the students whereas objective based curriculum focusses on only providing knowledge to the students. In other words, higher cognitive skills are developed through learning outcome based curriculum. Hence, it is preferred to develop learning outcome based curriculum which will provide specific directions to the teacher with respect to the transaction process and expected changes in the behavior of the students as well.

a. Nature and extent of the B.Sc Chemistry Programme

Chemistry is referred to as the science that systematically study the composition, properties, and reactivity of matter at atomic and molecular level. The scope of chemistry is very broad. The key areas of study of chemistry comprise Organic chemistry, Inorganic Chemistry, Physical Chemistry and Analytical Chemistry. Organic chemistry deals with study of substances containing carbon mostly; inorganic chemistry deals with study of all other elements/compounds/substances and their chemical properties. Physical chemistry deals with applications of concepts, laws to chemical phenomena. Analytical chemistry, in general, deals with identification and quantification of materials. Development of new interdisciplinary subjects like nano-materials, biomaterials, etc. and their applications from chemistry point of view added new dimension to materials chemistry. Thus, the degree programme in chemistry also intended to cover overlapping areas of chemistry with physics, biology, environmental
sciences. Further, a broad range of subjects such as materials chemistry, biomaterials, nanomaterials, environmental chemistry, etc., has also been introduced which can be helpful for students/faculty members to broaden the scope of their studies and hence applications from job prospective point of view. Therefore, as a part of efforts to enhance employability of graduates of chemistry, the curricula also include learning experience with industries and research laboratories as interns. In addition, industrial visits/industrial projects are encouraged and added to the curriculum in order to enhance better exposure to jobs/employment opportunities in industries, scientific projects and allied sectors.

This modified syllabus has been drafted to enable the students to equip for national level competitive exams that they may attempt in future. To ensure implementation of a holistic pedagogical model, several allied disciplines are covered/introduced in this framework, including Physics, Mathematics, Biology and a number of generic, and ability enhancement electives. In addition, employability of B.Sc. Chemistry graduate is given due importance such that their core competency in the subject matter, both theoretical and practical, is ensured. To expand the employability of graduates, a number of skill development courses are also introduced in this framework.

b. Aims of Bachelor’s degree programme in Chemistry

The broad aims of bacheleors degree programme in Chemistry are:

The aim of bachelor’s degree programme in chemistry is intended to provide:
(i). Broad and balance knowledge in chemistry in addition to understanding of key chemical concepts, principles and theories.
(ii). To develop students’ ability and skill to acquire expertise over solving both theoretical and applied chemistry problems.
(iii). To provide knowledge and skill to the students’ thus enabling them to undertake further studies in chemistry in related areas or multidisciplinary areas that can be helpful for self-employment/entrepreneurship.
(iv). To provide an environment that ensures cognitive development of students in a holistic manner. A complete dialogue about chemistry, chemical equations and its significance is fostered in this framework, rather than mere theoretical aspects.
(v). To provide the latest subject matter, both theoretical as well as practical, such a way to foster their core competency and discovery learning. A chemistry graduate as envisioned in this framework would be sufficiently competent in the field to undertake further discipline-specific studies, as well as to begin domain-related employment.

(vi). To mould a responsible citizen who is aware of most basic domain-independent knowledge, including critical thinking and communication.

(vii). To enable the graduate prepare for national as well as international competitive examinations, especially UGC-CSIR NET and UPSC Civil Services Examination.
2. Program Learning Outcomes

The student graduating with the Degree B.Sc (Honours) Chemistry should be able to acquire

- **Core competency**: Students will acquire core competency in the subject Chemistry, and in allied subject areas.

  (i). Systematic and coherent understanding of the fundamental concepts in Physical chemistry, Organic Chemistry, Inorganic Chemistry, Analytical Chemistry and all other related allied chemistry subjects.
  
  (ii). Students will be able to use the evidence based comparative chemistry approach to explain the chemical synthesis and analysis.
  
  (iii). The students will be able to understand the characterization of materials.
  
  (iv). Students will be able to understand the basic principle of equipments, instruments used in the chemistry laboratory.
  
  (v). Students will be able to demonstrate the experimental techniques and methods of their area of specialization in Chemistry.
  
  (vi). **Disciplinary knowledge and skill**: A graduate student is expected to be capable of demonstrating comprehensive knowledge and understanding of both theoretical and experimental/applied chemistry knowledge in various fields of interest like Analytical Chemistry, Physical Chemistry, Inorganic Chemistry, Organic Chemistry, Material Chemistry, etc. Further, the student will be capable of using of advanced instruments and related soft-ware for in-depth characterization of materials/chemical analysis and separation technology.
  
  (vii). **Skilled communicator**: The course curriculum incorporates basics and advanced training in order to make a graduate student capable of expressing the subject through technical writing as well as through oral presentation.
  
  (viii). **Critical thinker and problem solver**: The course curriculum also includes components that can be helpful to graduate students to develop critical thinking ability by way of solving problems/numerical using basic chemistry knowledge and concepts.
  
  (ix). **Sense of inquiry**: It is expected that the course curriculum will develop an inquisitive characteristics among the students through appropriate questions, planning and reporting experimental investigation.
(x). **Team player**: The course curriculum has been designed to provide opportunity to act as team player by contributing in laboratory, field based situation and industry.

(xi). **Skilled project manager**: The course curriculum has been designed in such a manner as to enabling a graduate student to become a skilled project manager by acquiring knowledge about chemistry project management, writing, planning, study of ethical standards and rules and regulations pertaining to scientific project operation.

(xii). **Digitally literate**: The course curriculum has been so designed to impart a good working knowledge in understanding and carrying out data analysis, use of library search tools, and use of chemical simulation software and related computational work.

(xiii). **Ethical awareness/reasoning**: A graduate student requires to understand and develop ethical awareness/reasoning which the course curriculum adequately provide.

(xiv). **Lifelong learner**: The course curriculum is designed to inculcate a habit of learning continuously through use of advanced ICT technique and other available techniques/books/journals for personal academic growth as well as for increasing employability opportunity.
3. Course Learning Outcomes

The course learning outcomes are aligned with program learning outcomes but these are specific-to-specific courses offered in a program. The course level learning shall be reflected as program level learning. The core courses shall be the backbone of this framework whereas discipline electives, generic electives and skill enhancement courses would add academic excellence in the subject together with multi-dimensional and multidisciplinary approach.

In course learning outcomes, the student will attain subject knowledge in terms of individual course as well as holistically. The example related to core courses and their linkage with each other is stated below:

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<thead>
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<th>Programme Outcomes</th>
<th>CC1</th>
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<th>CC5</th>
<th>CC6</th>
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<tr>
<td>CC1 CC2 CC3 CC4 CC5 CC6 CC7 CC8 CC9 CC10 CC11 CC12 CC13 CC14</td>
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<tr>
<td>Discipline elective Courses (DEC)/Discipline Specific Elective (DSE)</td>
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<tr>
<td>Programme Outcomes</td>
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<tr>
<td>Additional Academic Knowledge</td>
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<td>Problem-solving</td>
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<td>Additional analytical skills</td>
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<td>Additional Research skills</td>
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Generic Elective Courses (GEC)

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<tr>
<th>Programme Outcomes</th>
<th>GEC-1</th>
<th>GEC-2</th>
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<td>Academic Knowledge</td>
<td>Exposure beyond discipline</td>
<td>Problem-solving</td>
<td>Analytical reasoning</td>
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<td>Programme Outcomes</td>
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<td>Additional Academic Knowledge</td>
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<td>Psychological skills</td>
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<td>Problem-solving</td>
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<td>Programme Outcomes</td>
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<td></td>
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<tr>
<td>Additional Knowledge enhancement</td>
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<tr>
<td>Exposure beyond discipline</td>
</tr>
<tr>
<td>Analytical reasoning</td>
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<tr>
<td>Digital Literacy</td>
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<tr>
<td>Moral and ethical awareness</td>
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The core courses would fortify the students with in-depth subject knowledge concurrently; the discipline specific electives will add additional knowledge about applied aspects of the program as well as its applicability in both academia and industry. Generic electives will introduce integration among various interdisciplinary courses. The skill enhancement courses would further add additional skills related to the subject as well as other than subject. In brief the student graduated with this type of curriculum would be able to disseminate subject knowledge along with necessary skills to suffice their capabilities for academia, entrepreneurship and Industry.
4. Teaching Learning Outcomes

The learning outcomes based course curriculum framework of Chemistry is designed to persuade the subject specific knowledge as well as relevant understanding of the course. The academic and professional skills required for Chemistry-based professions and jobs are also offered by same course in an extraordinary way. In addition, the learning experiences gained from this course should be designed and implemented for cognitive development in every student. The practical associated with this course helps to develop an important aspect of the teaching-learning process. Various types of teaching and learning processes will need to be adopted to achieve the same. The important relevant teaching and learning processes involved in this course are;

- Class lectures
- Seminars
- Tutorials
- Group discussions and Workshops
- Peer teaching and learning
- Question preparation
- Subjective type
- Long answer
- Short answer
- Objective type
  - Multiple choice questions
  - One answer/two answer type questions
  - Assertion and reasoning
- Practicum, and project-based learning
- Field-based learning
- Substantial laboratory-based practical component and experiments
- Open-ended project work,
- Games
- Technology-enabled learning
- Internship in industry, and research establishments.
The effective teaching strategies will also need to be adopted to develop problem-solving skills, higher-order skills of reasoning and analysis. The designed course also encourages fostering the social values/responsibility for maintaining and protecting the surrounding environment for improved living conditions. A learner centric and active participatory pedagogy shall be introduced in this framework.
5. Learning outcomes-based curriculum framework for B.Sc. Chemistry and B.Sc. Chemistry (Honours)

a) Attributes of a Chemistry Graduate
Attributes of chemistry graduate under the outcome-based teaching-learning framework may encompass the following:

- **Core competency:** The chemistry graduates are expected to know the fundamental concepts of chemistry and applied chemistry. These fundamental concepts would reflect the latest understanding of the field, and therefore, are dynamic in nature and require frequent and time-bound revisions.

- **Communication skills:** Chemistry graduates are expected to possess minimum standards of communication skills expected of a science graduate in the country. They are expected to read and understand documents with in-depth analyses and logical arguments. Graduates are expected to be well-versed in speaking and communicating their idea/finding/concepts to wider audience.

- **Critical thinking:** Chemistry graduates are expected to know basics of cognitive biases, mental models, logical fallacies, scientific methodology and constructing cogent scientific arguments.

- **Psychological skills:** Graduates are expected to possess basic psychological skills required to face the world at large, as well as the skills to deal with individuals and students of various sociocultural, economic and educational levels. Psychological skills may include feedback loops, self-compassion, self-reflection, goal-setting, interpersonal relationships, and emotional management.

- **Problem-solving:** Graduates are expected to be equipped with problem-solving philosophical approaches that are pertinent across the disciplines.

- **Analytical reasoning:** Graduates are expected to acquire formulate cogent arguments and spot logical flaws, inconsistencies, circular reasoning etc.

- **Research-skills:** Graduates are expected to be keenly observant about what is going on in the natural surroundings to awake their curiosity. Graduates are expected to design a scientific experiment through statistical hypothesis testing and other *a priori* reasoning including logical deduction.
- **Teamwork**: Graduates are expected to be team players, with productive co-operations involving members from diverse socio-cultural backgrounds.

- **Digital Literacy**: Graduates are expected to be digitally literate for them to enroll and increase their core competency via e-learning resources such as MOOC and other digital tools for lifelong learning. Graduates should be able to spot data fabrication and fake news by applying rational skepticism and analytical reasoning.

- **Moral and ethical awareness**: Graduates are expected to be responsible citizen of India and be aware of moral and ethical baseline of the country and the world. They are expected to define their core ethical virtues good enough to distinguish what construes as illegal and crime in Indian constitution. Emphasis be given on academic and research ethics, including fair Benefit Sharing, Plagiarism, Scientific Misconduct and so on.

- **Leadership readiness**: Graduates are expected to be familiar with decision-making process and basic managerial skills to become a better leader. Skills may include defining objective vision and mission, how to become charismatic inspiring leader and so on.

b) **Qualification Descriptors**

i. **B.Sc. Chemistry (Honours)**

The qualification descriptors for a Bachelor’s degree in Chemistry (Honours) may include following:

(i). Systematic and fundamental understanding of chemistry as a discipline.

(ii). Skill and related developments for acquiring specialization in the subject.

(iii). Identifying chemistry related problems, analysis and application of data using appropriate methodologies.

(iv). Applying subject knowledge and skill to solve complex problems with defined solutions.

(v). Finding opportunity to apply subject-related skill for acquiring jobs and self-employment.

(vi). Understanding new frontiers of knowledge in chemistry for professional development.

(vii). Applying subject knowledge for solving societal problems related to application of chemistry in day to day life.
(ix). Applying subject knowledge for sustainable environment friendly green initiatives.
(x). Applying subject knowledge for new research and technology.

**ii. B.Sc. Chemistry (H) & Chemistry (Pass)**
The qualification descriptors for a Bachelor’s degree in Chemistry may also include following:

(i). To demonstrate a systematic, extensive and coherent knowledge and understanding of academic fields of study as a whole and its applications and links to disciplinary areas of the study; including critical understanding of the established theories, principles and concepts of a number of advanced and emerging issues in the field of chemistry;
(ii). To demonstrate procedural knowledge that creates different types of professionals in the field of chemistry. Further application of knowledge can enhance productivity of several economically important product. Knowledge of Chemistry is also necessary for the development and management of industry, manufacturing of fine chemicals, etc.
(iii) Developing skills and ability to use knowledge efficiently in areas related to specializations and current updates in the subject
(iv). Demonstrate comprehensive knowledge about chemistry, current research, scholarly and professional literature of advanced learning areas of Chemistry
(v). Use knowledge understanding and skills for critical assessment of wide range of ideas and problems in the field of Chemistry.
(vi). Communicate the results of studies in the academic field of Chemistry using main concepts, constructs and techniques
(vii). Apply one’s knowledge and understanding of Chemistry to new/unfamiliar contexts and to identify problems and solutions in daily life.
(viii). To think any apply understanding of the subject of Chemistry, Chemical Sciences sciences in identifying the problems which can be solved through the use of chemistry knowledge.
(ix). To think of the adopting expertise in chemical sciences and solve the problems of environment, green chemistry, ecology, sustainable development, hunger, etc.
**c) Distribution of different types of courses with their credits for B.Sc. Chemistry (Pass Course) (PCM & PCB)**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Core Courses (CC)</th>
<th>Ability Enhancement Courses (AEC)</th>
<th>Skill Enhancement Electives (SEC)</th>
<th>Discipline Specific Elective (DSE)</th>
<th>Credit hour load</th>
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<tbody>
<tr>
<td>1.</td>
<td>CC-IA CC-IB CC-IC</td>
<td>AEC-1</td>
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<td>AEC-2</td>
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<td>3.</td>
<td>CC-III-A CC-III-B CC-III-C</td>
<td>SEC-1A SEC-2B</td>
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<td>4.</td>
<td>CC-IVA CC-IVB CC-IVC</td>
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<td>5.</td>
<td>- -</td>
<td>SEC-2B SEC-2C</td>
<td>DSE-IA DSE-IB DSE-IC</td>
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<td>6.</td>
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<td>Any 02 SEC courses from</td>
<td>DSE-IIA DSE-IIB</td>
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**d) Distribution of different types of courses with their credits for B.Sc. Chemistry (Honors)**

<table>
<thead>
<tr>
<th>Semester</th>
<th>Core Courses (CC)</th>
<th>Ability Enhancement Electives (AEC)</th>
<th>Skill Enhancement Electives (SEC)</th>
<th>Discipline Specific Elective (DSE)</th>
<th>Generic Elective (GEC)</th>
<th>Credit hour load</th>
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<tbody>
<tr>
<td>1.</td>
<td>CC-I, CC-II</td>
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<td>DSE-1, DSE-2</td>
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<td>6.</td>
<td>CC-XIII, CC-XIV</td>
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<td>08</td>
<td>08</td>
<td>16+8 (P)=24</td>
<td>16+8(P)=24</td>
<td>148</td>
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</table>

Note: 14 CC are available. All courses are compulsory 6 credits each.

NOTE: 12 DSE are available. Choose any 4 having 6 credits each (PCM/PCB combination).

Credit: 56+28 (P)=84 08 08 16+8 (P)=24 16+8(P)=24 148
## Course Structure at a Glance

### 6. Core Courses (CC)

<table>
<thead>
<tr>
<th>Sr. No.</th>
<th>Name of the course</th>
<th>Type of course</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Credits</th>
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<tbody>
<tr>
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## 7. Discipline Specific Elective (DSE) Course

<table>
<thead>
<tr>
<th>Sr No</th>
<th>Name of the course</th>
<th>Type of course</th>
<th>L</th>
<th>T</th>
<th>P</th>
<th>Credits</th>
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<tbody>
<tr>
<td>1</td>
<td>Medicinal Chemistry</td>
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<td>Electrochemistry</td>
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<td>Polymer Chemistry</td>
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<td>7</td>
<td>Nuclear &amp; Radiation Chemistry</td>
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8. **Generic Elective Courses (GEC) (for PCM & PCB combination)**

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<th>Sr. No.</th>
<th>Name of the course</th>
<th>Type of course</th>
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<th>T</th>
<th>P</th>
<th>Credits</th>
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### 9. Ability Enhancement Courses

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## 10. Skill Enhancement Courses

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e) Assessment Methods

Academic performance in various courses i.e. core, discipline electives, generic electives and skill enhancement courses are to be considered as parameters for assessing the achievement of students in Chemistry. A number of appropriate assessment methods of Chemistry will be used to determine the extent to which students demonstrate desired learning outcomes. Following assessment methodology should be adopted;

- The oral and written examinations (Scheduled and surprise tests),
- Closed-book and open-book tests,
- Problem-solving exercises,
- Practical assignments and laboratory reports,
- Observation of practical skills,
- Individual and group project reports,
- Efficient delivery using seminar presentations,
- *Viva voce* interviews are majorly adopted assessment methods for this curriculum.
- The computerized adaptive testing, literature surveys and evaluations, peers and self-assessment, outputs form individual and collaborative work are also other important approaches for assessment purposes.
A continuous assessment method throughout the programme shall inculcate regular reading habit in the students’ and continuous observation about weaker aspect of the students’.

f) **Suggested List of Seminar Topics (not limited to)**

1. Carbon dating
2. Carbohydrate chemistry
3. Aliphatic Compounds
4. Biodiversity and climate change
5. Current Developments in Analytical Techniques
6. Boron Chemistry
7. Role of DNA sequencing in chemical analysis.
8. Catalytic converter
9. Chemistry of diamonds
10. DNA markers and Genetic diversity
11. Biomaterials
12. Polymers in drug delivery system
13. Hydrogels in medical applications
14. Adsorption techniques in industry
15. Chiral molecules
16. Water conservation
17. Renewable energy for sustainable developments
18. Fluoride in water.
19. Arsenic and its remediation.
20. Paint chemistry
21. Exotic molecules
22. Hybridization
23. Fuel chemistry
24. Nanomedicine
25. Advances in Supramolecular Chemistry
26. Functional materials
27. Quazi crystals
g) Suggested List of Topics for Group Discussion (not limited to)

1. Smart materials
2. Solid oxide fuels
3. Desalination technology
4. Surfactants, colloids and its applications in industry.
5. Water based polymers
6. Molecular spectroscopy and is application.
7. Explosive chemistry
8. CO₂ capture
9. Green house effects.
10. Chemistry and Biotechnology; Past present and Future
11. Mesoporous materials
12. CNT and its applications in future
13. Fullerene
14. Recent advances in atomic layer deposition
15. Thermoelectric materials
16. Origin of seeds
17. Chemistry of separation of small and complex molecules
18. Environmental Nanotoxicology
19. Bioconjugate chemistry
20. Intelligent molecules in biomedical applications
21. Chemical neuroscience
22. Atmospheric physical chemistry
23. Organic electronics
24. Climate change- a solution through application of Chemistry
26. Good ozone vs. bad ozone
27. Air pollution and climate change
28. Biodiversity under climate changing scenarios
29. Inorganic reaction mechanism
30. Solution Chemistry
31. Biomolecular chemistry
32. Boron chemistry and its application in medical science and technology
33. Chemistry of wine and coffee.
34. Graphene – recent advancement.
35. Hydrogen storage.
36. Food chemistry

h) Suggested Topics for Individual/Team Projects (not limited to)

2. Finding EMF of electrochemical cells.
3. Preparation of biodiesel.
4. Study of chemistry of photography.
5. Water analysis of nearby areas; finding out the toxic/heavy metals, anions and purification of water using simple available lab technology.
7. Forensic analysis of given species.
**CORE COURSES**

These are 12 courses. All courses are compulsory. These courses have the following credit pattern.

For Theory papers:

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For Practical based papers:

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1. **Inorganic Chemistry-I:**

On completion of this course, the students will be able to understand:

**Learning objective:**

2. Learning scientific theory of atoms, concept of wave function.
3. Elements in periodic table; physical and chemical characteristics, periodicity.
4. To predict the atomic structure, chemical bonding, and molecular geometry based on accepted models.
5. To understand atomic theory of matter, composition of atom.
6. Identity of given element, relative size, charges of proton, neutron and electrons, and their assembly to form different atoms.
7. Defining isotopes, isobar and isotone.
8. Physical and chemical characteristics of elements in various groups and periods according to ionic size, charge, etc. and position in periodic table.
9. Characterize bonding between atoms, molecules, interaction and energetics (ii) hybridization and shapes of atomic, molecular orbitals, bond parameters, bond- distances and energies.
10. Valence bond theory incorporating concepts of hybridization predicting geometry of molecules.
11. Importance of hydrogen bonding, metallic bonding.

**Self-study:**

1. Electronic configuration of various elements in periodic table
2. Predicting structure of molecules
3. How hydrogen bonding, metallic bonding is important in common materials’ scientific applications to material fabrication

**Atomic Structure: (10 classes of 60 minutes each)**

**Periodicity of Elements: (10 classes of 60 minutes each)**
s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to s and p-block.
(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.
(b) Atomic radii (van’der Waals)
(c) Ionic and crystal radii.
(d) Covalent radii (octahedral and tetrahedral)
(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.
(f) Electron gain enthalpy, trends of electron gain enthalpy.
Chemical Bonding: (14 classes of 60 minutes each)

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

(ii) Covalent bond: Lewis structure, Valence Shell Electron Pair Repulsion Theory (VSEPR), Shapes of simple molecules and ions containing lone-and bond-pairs of electrons multiple bonding, sigma and pi-bond approach, Valence Bond theory, (Heitler-London approach). Hybridization containing s, p and s, p, d atomic orbitals, shapes of hybrid orbitals, Bents rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of simple homonuclear and heteronuclear diatomic molecules, MO diagrams of simple tri and tetra-atomic molecules, e.g., N₂, O₂, C₂, B₂, F₂, CO, NO, and their ions; HCl, BeF₂, CO₂, HCHO, (idea of s-p mixing and orbital interaction to be given). Covalent character in ionic compounds, polarizing power and polarizability. Fajan rules, polarization. Ionic character in covalent compounds: Bond moment and dipole moment. ionic character from dipole moment and electronegativities.

Metallic bonding and Weak chemical forces: (6 classes of 60 minutes each)

(iii) Metallic Bond: Qualitative idea of free electron model, Semiconductors, Insulators.

(iv) Weak Chemical Forces: van’der Waals, ion-dipole, dipole-dipole, induced dipole dipole-induced dipole interactions, Lenard-Jones 6-12 formula, hydrogen bond, effects of hydrogen bonding on melting and boiling points, solubility, dissolution.

Recommended Books/References:
1.1. Inorganic Chemistry Practical

(A) Titrimetric Analysis
(i) Calibration and use of apparatus.
(ii) Preparation of solutions of different Molarity/Normality of titrants.
(iii) Use of primary and secondary standard solutions.

(B) Acid-Base Titrations
(i) Estimation of carbonate and hydroxide present together in mixture.
(ii) Estimation of carbonate and bicarbonate present together in a mixture.
(iii) Estimation of free alkali present in different soaps/detergents

(C) Oxidation-Reduction Titrimetry
(i) Estimation of Fe(II) and oxalic acid using standardized KMnO₄ solution.
(ii) Estimation of oxalic acid and sodium oxalate in a given mixture.
(iii) Estimation of Fe(II) with K₂Cr₂O₇ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books/References:
2. Core course: Organic Chemistry-I

On completion of this course, the students will be able to understand:

Learning objectives:

1. Basic of organic molecules, structure, bonding, reactivity and reaction mechanisms.
2. Stereochemistry of organic molecules – conformation and configuration, asymmetric molecules and nomenclature.
3. Aromatic compounds and aromaticity, mechanism of aromatic reactions.
4. Understanding hybridization and geometry of atoms, 3-D structure of organic molecules, identifying chiral centers.
5. Reactivity, stability of organic molecules, structure, stereochemistry.
6. Electrophile, nucleophiles, free radicals, electronegativity, resonance, and intermediates along the reaction pathways.
7. Mechanism of organic reactions (effect of nucleophile/leaving group, solvent), substitution vs. elimination.

Self-study:

1. Design and syntheses of organic molecules.
2. Structure identification through IR, NMR and Mass spectroscopic data.
3. Lab/Instrumentation techniques used for analyzing reaction mechanisms.
4. Advanced soft-wares/Models used for predicting stereochemistry/study of energy minimization of organic molecules.

Basics of Organic Chemistry: (10 classes of 60 minutes each)

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties. Electronic Displacements: Inductive, electromeric,
resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength. Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophilicity and basicity; Types, shape and relative stabilities of reaction intermediates (Carbocations, Carbanions, Free radicals and Carbenes).

Organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

Stereochemistry: (6 classes of 60 minutes duration each)

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

Chemistry of Aliphatic Hydrocarbons: (18 classes of 60 minutes duration each)

A. Carbon-Carbon sigma bonds

B. Carbon-Carbon pi-bonds
Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations. Reactions of alkenes: Electrophilic additions their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroboration- oxidation, ozonolysis, reduction (catalytic and chemical), syn and anti-hydroxylation (oxidation). 1, 2- and 1, 4- addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene. Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions.

C. Cycloalkanes and Conformational Analysis
Cycloalkanes and stability, Baeyer strain theory, Conformation analysis, Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms.
Aromatic Hydrocarbons (6 classes of 60 minutes duration each)

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

Recommended Books/References:


2.1. Course course: Organic Chemistry Practical

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1. Checking the calibration of the thermometer.
2. Purification of organic compounds by crystallization using the following solvents:
   a. Water    b. Alcohol    c. Alcohol-Water
3. Determination of the melting points of given organic compounds and unknown organic compounds (using Kjeldahl method and electrically heated melting point apparatus).
4. Effect of impurities on the melting point – mixed melting point of two unknown organic compounds.
5. Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and capillary method)
5. Chromatography
a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography

b. Separation of a mixture of two sugars by ascending paper chromatography

c. Separation of a mixture of o-and p-nitrophenol or o-and p-aminophenol by thin layer chromatography (TLC).

**Recommended Books/Reference:**


3. Core course: Physical Chemistry-I

On completion of this course, the students will be able to understand:

Learning objective:

1. Familiarization with various states of matter.
2. Physical properties of each state of matter and laws related to describe the states.
3. Calculation of lattice parameters.
4. Electrolytes and electrolytic dissociation, salt hydrolysis and acid-base equilibria.
5. Understanding Kinetic model of gas and its properties.
6. Maxwell distribution, mean-free path, kinetic energies.
7. Behavior of real gases, its deviation from ideal behavior, equation of state, isotherm, and law of corresponding states.
8. Liquid state and its physical properties related to temperature and pressure variation.
9. Properties of liquid as solvent for various household and commercial use.
10. Solids, lattice parameters – its calculation, application of symmetry, solid characteristics of simple salts.
11. Ionic equilibria – electrolyte, ionization, dissociation.
12. Salt hydrolysis (acid-base hydrolysis) and its application in chemistry.

Self-study:

1. Determination of lattice parameters of given salt.
3. Numerical related to salt hydrolysis, ionic equilibria.

Gaseous state: (12 classes of 60 minutes duration each)

Behavior of real gases: Deviations from ideal gas behavior, compressibility factor, and its variation with pressure for different gases. Causes of deviation from ideal behavior. van der Waals equation of state, its derivation and application in explaining real gas behaviour; van der Waals equation expressed in virial form, Boyle temperature. Isotherms of real gases and their
comparison with van der Waals isotherms, continuity of states, critical state, critical and van der Waals constants, law of corresponding states.

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

**Liquid state: (5 classes of 60 minutes duration each)**

Structure and physical properties of liquids; vapour pressure, surface tension, viscosity, and their dependence on temperature, Effect of addition of various solutes on surface tension, cleansing action of detergents. Structure of water.

**Ionic equilibria: (13 classes of 60 minutes duration each)**


**Solid state: (10 classes of 60 minutes duration each)**

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

**Recommended Text books/references:**

### 3.1. Physical chemistry Practical

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1. **Surface tension measurements.**
   a. Determine the surface tension by (i) drop number (ii) drop weight method.
   b. Study the variation of surface tension of detergent solutions with concentration.

2. **Viscosity measurements using Ostwald’s viscometer.**
   a. Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.
   b. Viscosity of sucrose solution with the concentration of solute.

3. **pH metry**
   a. Effect on pH of addition of HCl/NaOH to solutions of acetic acid,
sodium acetate and their mixtures.
b. Preparation of buffer solutions of different pH
   i. Sodium acetate-acetic acid
   ii. Ammonium chloride-ammonium hydroxide
c. pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base.
d. Determination of dissociation constant of a weak acid.

**Recommended text books/references:**
After completion of the course, the learner shall be able to understand:

Learning objective:

1. Familiarization about classes of organic compounds and their methods of preparation.
2. Basic uses of reaction mechanisms.
3. Name reactions, uses of various reagents and the mechanism of their action.
4. Preparation and uses of various classes of organic compounds.
5. Organometallic compounds and their uses.
6. Organic chemistry reactions and reaction mechanisms.
7. Use of reagents in various organic transformation reactions.

Self-study:

1. Elucidating reaction mechanisms for organic reactions.
2. Organometallic compounds and their uses.
3. Use of active methylene groups in organic mechanism and preparation of new organic compounds.

Chemistry of Halogenated Hydrocarbons: (8 classes of 60 minutes duration each)

*Alkyl halides:* Methods of preparation, nucleophilic substitution reactions – S_N1, S_N2 and S_N1 mechanisms with stereochemical aspects and effect of solvent etc.; nucleophilic substitution vs. elimination.

*Aryl halides:* Preparation, including preparation from diazonium salts. nucleophilic aromatic substitution; S_NAr, Benzyne mechanism.

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

Organometallic compounds of Mg and Li and their use in synthesis.

Alcohols, Phenols, Ethers and Epoxides: (6 classes of 60 minutes duration each)
Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3° alcohols, Bouvaelt-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement.

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

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

Carbonyl Compounds: (10 classes of 60 minutes duration each)
Structure, reactivity and preparation; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α-substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, LiAlH₄, NaBH₄, MPV, PDC and PGC);
Addition reactions of unsaturated carbonyl compounds: Michael addition.
Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

Carboxylic Acids and their Derivatives: (10 classes of 60 minutes duration each)
Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids; Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic substitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmannbromamide degradation and Curtius rearrangement.

Sulphur containing compounds: (6 classes of 60 minutes duration each)
Preparation and reactions of thiols, thioethers and sulphonic acids.
Recommended Books/references:

4.1. Core course: Organic Chemistry-Practical

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(List of experiments given are suggestive. One experiment from each group to be demonstrated)
1. Identification of elements (N, S, and halogen) and Functional group tests for alcohols, phenols, carbonyl, carboxylic acid and amine group of compounds.
2. Organic preparations:
   i. Acetylation of one of the following compounds: amines (aniline, o-, m-, p-toluidines and o-, m-, p-anisidine) and phenols (β-naphthol, vanillin, salicylic acid) by any one method: (Using conventional method and Using green chemistry approach)
   ii. Benzoylation of one of the amines (aniline, o-, m-, p- toluidines and o-, m-, p-anisidine) and one of the phenols (β-naphthol, resorcinol, p-cresol) by Schotten-Baumann reaction.
   iii. Oxidation of ethanol/isopropanol (Iodoform reaction).
   iv. Bromination (any one)
      a. Acetanilide by conventional methods
      b. Acetanilide using green approach (Bromate-bromide method)
   v. Nitration: (any one)
      a. Acetanilide/nitrobenzene by conventional method
      b. Salicylic acid by green approach (using ceric ammonium nitrate).
   vi. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.
   vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.
   viii. Hydrolysis of amides and esters.
ix. Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.
x. S-Benzyliothiouonium salt of one each of water soluble/insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).
xi. Aldol condensation with either conventional or green method.
Xii. Benzil-Benzilic acid rearrangement.
Collected solid samples may be used for recrystallization, melting point and TLC.

**Recommended Books/References:**
5. Core course: Physical Chemistry-II

After completion of the course, the learner shall be able to understand:

Learning objective:

1. Laws of thermodynamics and concepts.
2. Partial molar quantities and its attributes.
3. Dilute solution and its properties.
4. Understanding the concept of system, variables, heat, work, and laws of thermodynamics.
5. Understanding the concept of heat of reactions and use of equations in calculations of bond energy, enthalpy, etc.
7. Understanding the application of thermodynamics: Joule Thompson effects, partial molar quantities.
8. Understanding theories/thermodynamics of dilute solutions.

Self-study:

1. Use of thermochemical equations for calculation of energy and related terms.
2. Use of thermodynamics in explaining chemical behavior of solute/solvent and reactions.

Introduction to thermodynamics: (6 classes of 60 minute duration each)

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics. First law: Concept of heat, $q$, work, $w$, internal energy, $U$, and statement of first law; enthalpy, $H$, relation between heat capacities, calculations of $q$, $w$, $U$ and $H$ for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions.
Thermochemistry: (6 classes of 60 minutes duration each)
Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff’s equations), pressure on enthalpy of reactions.

Second Law: (6 classes of 60 minutes duration each)
Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

Third law of thermodynamics: (4 classes of 60 minutes duration each)
Third Law of thermodynamics, residual entropy, calculation of absolute entropy of molecules.

Free Energy Functions: (6 classes of 60 minutes duration each)
Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

Partial molar quantities: (6 classes of 60 minutes duration each)
Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs-Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

Dilute solutions: (6 classes of 60 minutes duration each)
Dilute solutions; lowering of vapour pressure, Raoult’s and Henry’s Laws and their applications. Excess thermodynamic functions. Thermodynamic derivation using chemical potential to derive relations between the four colligative properties: [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount
of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.

Recommended Books/References
1 Atkins P. and De Paula, J. Physical Chemistry Tenth Ed., OUP, 2014.
5 Roy, B. N. Fundamentals of Classical and Statistical Thermodynamics Wiley, 2001

5.1. Core course: Physical Chemistry-Practical

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(A list of suggested experiments are given. However, more experiments can be added based on facilities available in the laboratories).

1. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.
2. Study the equilibrium of at least one of the following reactions by the distribution method:
   (i) \( I_2 \) (aq) + \( I^- \) \( \rightarrow \) \( I_3^- \) (aq)
   (ii) \( \text{Cu}^{2+} \) (aq) + \( n \text{NH}_3 \) \( \rightarrow \) \( \text{Cu(NH}_3)_n \)
3. Study the kinetics of the following reactions.
   a. Acid hydrolysis of methyl acetate with hydrochloric acid.
   b. Saponification of ethyl acetate.
Adsorption
Verification of Freundlich and Langmuir isotherms for adsorption of acetic acid and selected organic dye(s) on activated charcoal.
(Use of calorimeter for calculation of heat of reactions may be demonstrated)

Recommended Books/References:
6. Core course: Organic Chemistry-III

After completion of the course, the learner shall be able to understand:

Learning objective:

1. Nitrogen containing functional groups and their reactions.
2. Familiarization with polynuclear hydrocarbons and their reactions.
3. Heterocyclic compounds and their reactions.
4. Alkaloids and Terpenes
5. Understanding reactions and reaction mechanism of nitrogen containing functional groups.
6. Understanding the reactions and mechanisms of diazonium compounds.
7. Understanding the structure and their mechanism of reactions of selected polynuclear hydrocarbons.
8. Understanding the structure, mechanism of reactions of selected heterocyclic compounds.
9. Classification, structure, mechanism of reactions of few selected alkaloids and terpenes.

Self-study:

1. Use of benzene diazonium salt in organic synthesis.
2. Applications of heterocyclic compounds in pharmaceutics/drugs and the mechanism of actions.
3. Pharmaceutics/Biomedical applications of alkaloids and terpenes.
4. Nitrogen containing organic compounds/heterocyclic compounds in synthetic chemistry.

Nitrogen Containing Functional Groups (8 classes of 60 minutes duration each).

Preparation and important reactions of nitro and compounds, nitriles and isonitriles Amines:
Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann’s exhaustive methylation, Hofmann-elimination reaction; Distinction between 1°, 2° and 3° amines with Hinsberg reagent and nitrous acid. Diazonium salts: Preparation and synthetic applications.
Polynuclear Hydrocarbons: (8 classes of 60 minutes duration each)
Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons.

Heterocyclic Compounds: (12 classes of 60 minutes duration each)
Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom; Synthesis, reactions and mechanism of substitution reactions of Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine, Structure elucidation of indole, Fischer indole synthesis and Madelung synthesis), Structure elucidation of quinoline and isoquinoline, Skraup synthesis, Friedlander’s synthesis, Knorr quinoline synthesis, Doebner-Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction Derivatives of furan: Furfural and furoic acid.

Alkaloids (6 classes of 60 minutes duration each)
Natural occurrence, General structural features, Isolation and their physiological action Hoffmann’s exhaustive methylation, Emde’s modification, Structure elucidation and synthesis of Hygrine and Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine.

Terpenes (6 classes of 60 minutes duration each)
Occurrence, classification, isoprene rule; Elucidation of structure and synthesis of Citral, Neral and α-terpineol.

Recommended Text Books/references:
6.1. Core course: Organic Chemistry Practical

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1. Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups, for e.g. salicylic acid, cinnamic acid, nitrophenols, etc.

2. Identification of functional groups of simple organic compounds by IR spectroscopy and NMR spectroscopy (IR and NMR of simple organic compounds may be done wherever facilities are available, otherwise sample spectra may be provided for simple organic compounds like Ethanol, Aniline, Phenol, acetic acid, other simple aldehydes, carboxylic acid, etc., for identification of functional groups. References from standard spectroscopy books may also be taken for such purpose for enhancing students understanding and skill).

3. Preparation of methyl orange.

4. Extraction of caffeine from tea leaves.

5. Analysis of Carbohydrate: aldoses and ketoses, reducing and non-reducing sugars using simple lab procedures.

**Recommended Books/References:**


7. Core course: Molecular Spectroscopy & Photochemistry

Unit-I: (15 classes of 60 minutes duration each)

Unit-II: (10 classes of 60 minutes duration each)
Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.
Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation.

Unit-III: (15 classes of 60 minutes duration each)
Photophysical and photochemical processes: laws of photochemistry, quantum yield. Jablonski diagrams: Franck-Condon principle, Law of photochemical equivalence, quantum efficiency, low and high quantum efficiency, kinetics of photochemical reactions (H\textsubscript{2} + Br\textsubscript{2} = HBr, 2HI = H\textsubscript{2} + I\textsubscript{2}), energy transfer in photochemical reactions (photosensitization and quenching), fluorescence, phosphorescence, chemiluminescence, Discussion of Electronic spectra and photochemistry (Lambert-Beer law and its applications).
**Recommended books/References:**


**7.1. Suggested laboratory experiments:**

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(i). Determination of indicator constant - colorimetry. (instructor may vary indicators available in the lab).

(ii). Verification of Beer’s Law - Determination of concentration of solution by colorimetry. (Instructor may explain the principle of using colorimeter, its handling drawing standard calibration curve, and its application in finding unknown concentration of dyes, concentration of metal solutions (e.g.Ni, Cu using appropriate reagent) from standard calibration curve.

**Suggested books/reference books:**

1. Practicals in physical chemistry – a modern approach, P.S.Sindhu, Macmillan,
8. Core course: Physical Chemistry-III

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After completion the course, the learner shall be able to understand:

Learning objective:

1. Phases, components, Gibbs phase rule, Phase diagrams and applications.
2. Chemical kinetics: type of reactions, determination of rate, theories of reaction rate, steady state approximation.
3. Catalyst – mechanism, acid base catalysis, enzyme catalysis.
4. Adsorption isotherms.
5. Understanding phases, components, Gibb’s phase rule and its applications, construction of phase diagram of different systems, the application of phase diagram.
6. Understanding the basics of chemical kinetics: determination of order, molecularity, and understanding theories of reaction rates, determination of rate of opposing/parallel/chain reactions with suitable examples, application of steady state kinetics, Steady-state approximation.
7. Catalyst – mechanism of catalytic action, enzyme catalysis.

Self-study:

1. Application of phase diagram.
2. Study of reaction kinetics, Fast reactions.
3. Heterogeneous catalysis used in industry and its mechanism of action.
4. Application of adsorption isotherms in metal adsorption, significance.

Phase Equilibria: (10 classes of 60 minutes duration each)

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems,

**Chemical Kinetics: (10 classes of 60 minutes duration each)**

Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated rate laws for first, second and fractional order reactions, pseudounimolecular reactions, determination of the order, kinetics of complex reactions (limited to first order): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (steady-state approximation in reaction mechanisms) (iv) chain reactions. Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates.

**Catalysis: (10 classes of 60 minute duration each)**

Types of catalyst, specificity and selectivity, mechanisms of catalyzed reactions at solid surfaces; effect of particle size and efficiency of nanoparticles as catalysts. Enzyme catalysis, Michaelis-Menten mechanism, acid-base catalysis.

**Surface chemistry: (10 classes of 60 minutes duration each)**

Physical adsorption, chemisorption, adsorption isotherms (Freundlich, Temkin, Derivation of Langmuir adsorption isotherms, surface area determination), BET theory of multilayer adsorption (no derivation), Adsorption in solution.

**Recommended books/References:**

5 Zundhal, S.S. *Chemistry concepts and applications* Cengage India, 2011

**8.1. Core course: Physical Chemistry Practical**

**Conductometry**
1. Determination of cell constant
2. Equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
3. Conductometric titrations of: Strong acid Vs. strong base (ii) Weak acid vs. strong base, (iii) Mixture of strong acid and (iv) weak acid vs. strong base, Strong acid vs. weak base.

**Potentiometry**
Potentiometric titrations of: (i) Strong acid vs. strong base (ii) Weak acid vs. strong base (iii) Dibasic acid vs. strong base (iv) Potassium dichromate vs. Mohr's salt.

**Recommend books/References:**
(List of experiments and references are suggestive. However, more experiments can be added/list of experiments can be revised as per available facilities).
9. Core course: Inorganic Chemistry-II

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After completion of the course, the learner shall be able to understand:

**Learning objective:**

1. Oxidation-Reductions and their use in metallurgy.
2. Chemistry of s and p-block elements.
3. Chemistry of noble gases.
4. Inorganic polymers and their use.
5. Understanding redox reactions in hydrometallurgy processes.
7. Understanding chemistry of boron compounds and their structures.
8. Chemistry of noble gases and their compounds; application of VSEPR theory in explaining structure and bonding.
9. Understanding chemistry of inorganic polymers, their structures and uses.

**Self-study:**

1. Extraction of metals through metallurgical operations and their uses.
2. Bonding of various s and p block elements.
3. Use of boron compounds.
4. Chemistry of inorganic polymers and their uses.

**Oxidation-Reduction and general principle of metallurgy: (8 classes of 60 minutes duration each)**

Chemistry of s and p Block Elements: (16 classes of 60 minutes duration each)


Structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrides, borohydrides (diborane) carboranes and graphitic compounds, silanes, Oxides and oxoacids of nitrogen, Phosphorus and chlorine. Per-oxo acids of Sulphur inter-halogen compounds, polyhalide ions, pseudo-halogens, properties of halogens.

Noble Gases: (8 classes of 60 minutes duration each)

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF₂, XeF₄ and XeF₆; Bonding in noble gas compounds (Valence bond and MO treatment for XeF₂), Shapes of noble gas compounds (VSEPR theory).

Inorganic Polymers: (8 classes of 60 minutes duration each)

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Borazines, silicates and phosphazenes, and polysulphates.

Recommended books/references:


9.1. Course course: Inorganic Chemistry-practical
(A) Iodo / Iodimetric Titrations
(i) Estimation of Cu(II) and K₂Cr₂O₇ using sodium thiosulphate solution (Iodimetrically).
(ii) Estimation of (i) arsenite and (ii) antimony iodimetrically
(iii) Estimation of available chlorine in bleaching powder iodometrically.

(B) Inorganic preparations
(i) Cuprous Chloride, Cu₂Cl₂
(ii) Preparation of Aluminium potassium sulphate (Potash alum) or Chrome alum.

Recommended books/references:
(The above list of experiments are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).
10. Introduction to Quantum Chemistry:

**Unit-I:** Introduction to black-body radiation and distribution of energy, photo-electric effect, concept of quantization, wave particle duality (de-Broglie’s hypothesis), The uncertainty principle, The wave function: wave function and its interpretation, conditions of normalization and Orthogonality and its significance. Basic idea about operators, eigen function and values, Schrödinger equation and application to free-particle and particle in a box, boundary conditions, wave functions and energies, degeneracy, hydrogen atom, Schrödinger equation in polar coordinates, radial and angular parts of the hydrogenic orbitals, degeneracies, spherical harmonics, representations of hydrogenic orbitals. (**15 classes of 60 minutes durations**)  

**Unit-II:** Quantitative treatment of simple harmonic oscillator model, setting up of Schrodinger equation and discussion of solution of wave functions. Rigid rotator model and discussion of application of Schrodinger equation. idea about transformation to spherical polar coordinate, discussion on solution, (**15 classes of 60 minutes durations**)  

**Unit-III:** (**10 classes of 60 minutes durations**)  
Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus. Valence bond and molecular orbital approaches, LCAO-MO treatment of H₂, H₂⁺; bonding and anti-bonding orbitals, Comparison of LCAO-MO and VB treatments of H₂ (only wavefunctions, detailed solution not required) and their limitations.

**Recommended books/References:**  
3. McQuarrie D. A. and Simon J. D. *Physical Chemistry- A Molecular Approach*, University


**10.1. Suggested laboratory experiments:**

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(i) The students may be demonstrated hyperchem lab activities – building a molecular model (leveling of atoms, editing individual atoms, changing bond order, centering, rotation of atoms), Selection of calculation method (e.g. force field calculation, ab-initio set up), displaying calculated properties, (instructor may demonstrate Computer programs that calculate the energy of various conformations of molecules and predict the lowest energy, to learn how to construct or draw representations of molecules using a molecular modeling program called HyperChem (HyperCube, Inc.), to perform geometry optimizations (energy minimizations) to determine the lowest energy conformations of molecules).

(Depending upon the availability of infrastructure facilities, instructor can demonstrate the students use of hyperchem software, Gaussian software – geometry optimization). They can be allowed for academic visit to computational labs to gain knowledge and a report may be considered for viva voce/examination). Open source softwares may be used for lab demonstration and students may prepare a report along with viva-voce shall constitute practical examination. Instructor may encourage the students to gain hand-on experience in using open-source softwares (for performing various calculation as mentioned) in lab computers, periodic evaluation of which can also be accepted as conducting lab practical examination. Basic idea is to encourage the students to get knowledge without keeping any rigid practical syllabus framework).

(Examples of the computational work that can be done: Compare the optimized C-C bond lengths in ethane, ethene, ethyne and benzene. Visualize the molecular orbitals of the ethane σ bonds and ethene, ethyne, benzene and pyridine π bonds.

ii. (a) Perform a conformational analysis of butane. (b) Determine the enthalpy of isomerization of cis and trans 2-butene.
iii. Visualize the electron density and electrostatic potential maps for LiH, HF, N2, NO and CO and comment. Relate to the dipole moments. Animate the vibrations of these molecules. (Software: ChemSketch, ArgusLab (www.planaria-software.com), TINKER 6.2 (dasher.wustl.edu/ffe), WebLab Viewer, Hyperchem, or any similar software.

(ii). Determination of indicator constant - colorimetry.

(iii). Verification of Beer’s Law - Determination of concentration of solution by colorimetry.

**Suggested books/reference books:**

3. Practicals in physical chemistry – a modern approach, P.S. Sindhu, Macmillan,
11. Course course: Inorganic Chemistry-III

After completion of the course, the learner shall be able to understand:

**Learning objective:**

1. Coordination compounds – its nomenclature, theories, d-orbital splitting in complexes, chelate.
2. Transition metals, its stability, color, oxidation states and complexes.
3. Lanthanides, Actinides – separation, color, spectra and magnetic behavior
4. Bioinorganic chemistry – metal ions in biological system, its toxicity; hemoglobin.
5. Understanding the nomenclature of coordination compounds/complexes, Molecular orbital theory, d-orbital splitting in tetrahedral, octahedral, square planar complexes, chelate effects.
6. Understanding the transition metals stability in reactions, origin of colour and magnetic properties.
7. Understanding the separation of Lanthanoids and Actinoids, its color, spectra and magnetic behavior.
8. Understanding the bioinorganic chemistry of metals in biological systems.
9. Hemoglobin and its importance in biological systems.

**Self-study:**

1. IUPAC nomenclature of coordination compounds/complexes.
2. Prediction of structure of complexes using various theories; color and magnetic properties of different complexes.
3. Use of lanthanide/actinide compounds in industries.
4. Toxicity of various metals and mechanism of metal-biological system interactions.

**Coordination Chemistry: (10 classes of 60 minutes duration each)**

Werner’s theory, EAN rule, piano-stool compounds, valence bond theory (inner and outer orbital complexes), Crystal field theory, d-orbital splitting, weak and strong fields, pairing energies, factors affecting the magnitude of (Δ). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar complexes, d orbital
splitting in trigonal bipyramidal, square pyramidal and cubic ligand field environments, CFSE, Variation of lattice energies, enthalpies of hydration and crystal radii variations in halides of first and second row transition metal series, Qualitative aspect of Ligand field theory, MO diagrams of representative coronation complexes, IUPAC nomenclature of coordination compounds, isomerism in coordination compounds. Stereochemistry of complexes with the coordination number 4 and 6, Chelate effect,

**Transition Elements: (10 classes of 60 minutes duration each)**

General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, and ability to form complexes. Stability of various oxidation states and e.m.f. (Latimer & Bsworth diagrams). Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding their metallurgy)

**Lanthanoids and Actinides: (10 classes of 60 minutes duration each)**

Electronic configuration, oxidation states, color, spectra and magnetic behavior, lanthanide contraction, separation of lanthanides (ion-exchange method only).

**Bioinorganic Chemistry: (10 classes of 60 minutes duration each)**

Metal ions present in biological systems, classification of elements according to their action in biological system. Geochemical effect on distribution of metals. Sodium / K-pump, carbonic anhydrase and carboxypeptidase. Excess and deficiency of some trace metals. Toxicity of metal ions (Hg, Pb, Cd and As), toxicity, chelating agents in medicine. Iron and its application in bio-systems, Haemoglobin; Storage and transfer of iron.

**Recommended text books/References:**

11.1. Core course: Inorganic Chemistry Practical

1. Qualitative semimicro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given on understanding of the chemistry of different reactions. Following radicals may be analyzed:
   Carbonate, nitrate, nitrite, sulphide, sulphate, sulphite, acetate, fluoride, chloride, bromide, iodide, borate, oxalate, phosphate, ammonium, potassium, lead, copper, cadmium, bismuth, tin, iron, aluminum, chromium, zinc, manganese, cobalt, nickel, barium, strontium, calcium, magnesium.
   Mixtures containing one interfering anion, or insoluble component (BaSO₄, SrSO₄, PbSO₄, CaF₂ or Al₂O₃) or combination of anions e.g. CO₃²⁻ and SO₃²⁻, NO₂⁻ and NO₃⁻, Cl⁻ and Br⁻, Br⁻ and I⁻, NO₃⁻ and Br⁻, NO₃⁻ and I⁻. Spot analysis/tests should be done whenever possible.

2. Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs thermodynamic factors.

3. Preparation of acetylacetanato complexes of Cu²⁺/Fe³⁺. (Also find the λ_max of the prepared complex using instrument).

4. Synthesis of ammine complexes of Ni(II) and its ligand exchange reactions (e.g. bidentate ligands like acetylacetone, DMG, glycine) by substitution method.

**Recommended text books/references:**

12. Core course: Analytical Chemistry

After completion of the course, the student shall be able to understand:

Learning objective:

1. Familiarization with fundamentals of analytical chemistry.
2. Basics of spectroscopic, thermal, electrochemical techniques
3. Learning basics of separation techniques and its applications.
4. Understanding analytical tools, statistical methods applied to analytical chemistry.
5. Understanding principle of UV-Vis spectroscopy and its applications.
6. Understanding principles of thermo-gravimetric analysis and study of thermal decomposition of materials/characterization of materials.
7. Understanding basics of electro-analytical techniques and its applications.
8. Understanding principles of separation technology and its use in advanced instrumentations.

Self-study:

1. Thermo-gravimetric Analysis of different compounds and application of mathematical models.
2. Study of different kinds of chromatograms; calculation of Rf,
3. Analysis of GC/HPLC data for known materials/compounds.

Qualitative and quantitative aspects of analysis: (4 classes of 60 minutes duration each)

Tools in analytical chemistry and their applications, Sampling, evaluation of analytical data, errors, accuracy and precision, statistical test of data; F, Q and t-test, rejection of data, and confidence intervals.

Spectroscopy: (8 classes of 60 minutes duration each)

**Vibration spectroscopy:** Basic principles of instrumentation, sampling techniques. Application of IR spectroscopy for characterization through interpretation of data, Effect and importance of isotope substitution. Introduction to Raman spectra

**UV-Visible Spectrometry:** Basic principles of instrumentation, principles of quantitative analysis using estimation of metal ions from aqueous solution, Determination of composition of metal complexes using Job’s method of continuous variation and mole ratio method.

**Thermal analysis: (6 classes of 60 minutes duration each)**
Theory of thermogravimetry (TG and DTG), instrumentation, estimation of Ca and Mg from their mixture.

**Electroanalytical methods: (6 classes of 60 minutes duration each)**
Classification of electroanalytical methods, basic principle of pH metric, potentiometric and conductometric titrations. Techniques used for the determination of equivalence points. determination of pKa values.

**Separation techniques: (16 classes of 60 minutes duration each)**
Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and non-aqueous media.


**Recommended Books/Reference Books:**
   California, USA, 1988.
5 Skoog, D.A. Holler F.J. & Nieman, T.A. Principles of Instrumental Analysis, Saunder College
6 Mikes, O. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood
7 Ditts, R.V. Analytical Chemistry; Methods of separation, van Nostrand, 1974.
8 Khopkar, S. M., Basic Concepts of Analytical Chemistry, New Age (Second edition)1998

12.1.Core course: Analytical Chemistry Practical

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(Recommended to carry out at least two experiments from each section)

I. Chromatography:
   (i) Paper chromatographic separation of Fe$^{3+}$, Al$^{3+}$, and Cr$^{3+}$.
   (ii) Separation and identification of the monosaccharides present in the given mixture (glucose &
        fructose) by paper chromatography. Reporting the $R_f$ values.
   iii. Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on
        the basis of their $R_f$ values.
   (iv) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

II. Solvent Extractions:
   (i) To separate a mixture of Ni$^{2+}$ & Fe$^{2+}$ by complexation with DMG and extracting the Ni$^{2+}$-
        DMG complex in chloroform, and determine its concentration by spectrophotometry.
   ii. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.
   iii. Determination of Na, Ca, Li in cola drinks and fruit juices using flame photometric
        techniques.
III. Analysis of soil:
(i) Determination of pH of soil.
(ii) Total soluble salt
(iii) Estimation of calcium, magnesium, phosphate, nitrate

IV. Ion exchange:
(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.
(ii) Separation of metal ions from their binary mixture.
(iii) Separation of amino acids from organic acids by ion exchange chromatography.

V. Spectrophotometry
(i). Determination of pKa values of indicator using spectrophotometry.
(ii) Structural characterization of compounds by infrared spectroscopy.
(iii) Determination of dissolved oxygen in water.
(iv) Determination of chemical oxygen demand (COD).
(v) Determination of Biological oxygen demand (BOD).
(vi) Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by Job’s method.

Recommended text books/references:
13. Core course: Green Chemistry

After completion of the course, the learner shall be able to understand:

**Learning objective:**

1. Green chemistry and its principles.
2. Green synthesis and reactions.
3. Green chemistry for sustainable solutions.
4. Understanding principles of green chemistry.
5. Understanding design of chemical reactions/chemical synthesis using green chemistry principles.
6. Atom economy and design of chemical reactions using the principle.
7. Understanding the use of green chemistry principle and processes in laboratory reactions.

**Self-study:**

1. Use of green chemistry in designing new laboratory experiments.
2. Use of principle of atom economy and design experiments using the principle.
3. Use of green chemistry in combinatorial chemistry and biomimetic catalyst.

**Introduction to Green Chemistry (4 classes of 60 minutes duration each)**

Basic introduction and explaining goals of Green Chemistry. Limitations/Obstacles in the pursuit of the goals of Green Chemistry

**Principles of Green Chemistry and Designing a Chemical synthesis (12 classes of 60 minutes duration each)**

Twelve principles of Green Chemistry with their explanations and examples and special emphasis on Designing a Green Synthesis using these principles (Prevention of Waste/byproducts; maximum incorporation of the materials used in the process into the final products,
Atom Economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions).

**Green Synthesis / Reactions: (16 classes of 60 minutes duration each)**

1. Green Synthesis of adipic acid, catechol, disodium iminodiacetate (alternative to Strecker synthesis).
2. Microwave assisted reactions in water: (Hofmann Elimination, methyl benzoate to benzoic acid, oxidation of toluene and alcohols) and reactions in organic solvents (Diels-Alder reaction and Decarboxylation reaction).
3. Ultrasound assisted reactions: sonochemical Simmons-Smith Reaction (Ultrasonic alternative to Iodine)
5. Designing of Environmentally safe marine antifoulant.
6. An efficient, green synthesis of a compostable and widely applicable plastic (poly lactic acid) made from corn.

**Future Trends in Green Chemistry (8 classes of 60 minutes duration each)**

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

**Recommended Books/References:**


**13.1. Core course: Green Chemistry Practical**

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(Following is the list of suggestive experiments. However, depending upon available resources, experiments may be added/changes may be incorporated): (six experiments may be conducted)

1. Preparation and characterization of nanoparticles of gold using tea leaves.
2. Preparation of biodiesel from vegetable/ waste cooking oil.
3. Use of molecular model kit to stimulate the reaction to investigate how the atom economy illustrates Green Chemistry.
4. Reactions like addition, elimination, substitution and rearrangement may also be studied for the calculation of atom economy.
5. Benzoin condensation using Thiamine Hydrochloride as a catalyst (instead of cyanide).
7. Mechanochemical solvent free synthesis of azomethines
8. Solvent free, microwave assisted one pot synthesis of phthalocyanine Cu(II) complex.
9. Photoreduction of benzophenone to benzopinacol in presence of sunlight.

**Recommended Books/References:**

14. Core course: Chemistry of Materials

After completion of the course, the learner shall be able to understand:

Learning objective:

2. Silica based materials in applications.
5. Composites and its applications
6. Understanding basic parameters of crystalline solids, symmetry and crystal structures.
7. Mesoporous/microporous silica based materials, functionalized hybrid materials and its applications.
8. Preparation of inorganic solids, host-guest chemistry, ionic liquids and its significance.
10. Understanding composites and their industrial applications.

Self-study:

1. Hybrid materials/functionalyzed hybrid materials and their applications in industry.
2. Applications of nano-structured materials in targeted drug delivery/pharmaceutical applications/industrial applications.
3. Use of composites in industry.

Basics of crystalline solids (8 classes of 60 minutes duration each)
Crystalline solids, crystal systems, Bravais lattices, coordination number, packing factors – cubic, hexagonal, diamond structures, lattice planes, Miller indices, interplanar distances, directions, types of bonding, lattice energy, Madelung constants, Born Haber cycle, cohesive energy, Symmetry elements, operations, translational symmetries - point groups, space groups, equivalent positions, close packed structures, voids, crystal structures, Pauling rules, defects in crystals, polymorphism, twinning.
Silica based materials: (8 classes of 60 minutes duration each)

Inorganic solids/ionic liquids of technological importance: (8 classes of 60 minutes duration each)

Nanomaterials: (8 classes of 60 minutes duration each)
Overview of nanostructures and nano-materials: classification. Preparation of gold and silver metallic nanoparticles, self-assembled nanostructures-control of nano-architecture-one dimensional control. Carbon nanotubes and inorganic nanowires.

Composite materials: (8 classes of 60 minutes duration each)
Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

Recommend books/References:

14.1. Materials Chemistry Practical

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(The list of experiments are suggestive. However, faculties/academic bodies may add more experiments/references or incorporate suitable revisions based on infrastructure facilities available).

1. Preparation of urea-formaldehyde resin
2. Preparations of novalac resin/resol resin
3. Synthesis of materials/porous materials (Sol-gel, hydrothermal, microwave). (Similarly other materials synthesis can be designed).
4. Preparation of silver nano material. (Similarly other nano materials of other metals synthesis can be designed).
5. Analysis of XRD pattern of crystals.
6. Interpretation of FTIR, NMR and UV-Vis data of given material.
7. Estimation of particle size from the BET, SEM techniques.
8. Density measurement of ionic liquids
9. Determining dynamic viscosities of given ionic liquids
10. Determination of hydration number IR spectra.
DISCIPLINE SPECIFIC ELECTIVE COURSES

These courses have the following credit pattern.

For Theory based courses:

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For laboratory based courses:

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1. Medicinal Chemistry

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After completion of the course, the learner can be able to understand:

1. The basics of medicinal chemistry, biophysical properties
2. Biological activity parameters
3. Drug metabolism
4. Biophysical and chemical properties of enzymes, hormones, vitamins
5. Concept of rational drug design

Bio-physicochemical properties

Acidity/Basicity, Solubility, Ionization, Hydrophobic properties, Hydrophilic properties, Lipinski Rule, Drug-like properties, Understanding of the biological activity parameters such as Ki, Ka, LD50, EC50, IC50, CC50, ADMET properties

Structural properties

Isosterism, Bioisosterism, Nonclassical isosteres, Understanding of the 3D-structure along with bond length, bond angle and dihydral angle, Concept of Configuration and Conformation with
examples, Concept of stereochemistry in terms of biological response with examples, Stereoselective receptors or enzymes such as muscarinic receptor, Stereochemically pure drug and recemates, Examples such as catecholamines, etc.

**Drug target understanding**
Metabolism, Drug metabolism, Anti-metabolite, Enzyme inhibitor, Agonist, Antagonist, Examples.

**Medicinal Chemistry of Therapeutic Agent**
Structure, Chemistry, Mode of action and adverse effect of the representative therapeutic agents such as Anti-infective agent, Antimalarials, Antibacterial, Antiviral, Anticancer, CNS acting drugs, Adrenergic Agents, Cholinergic Drugs, Diuretics, Cardiovascular, local anesthetic agent, Analgesic Agents, Histamine and Antihistamine agents

**Steroids, Prostaglandins, Enzyme, Hormone and Vitamins**
Biophysico-chemical properties, Steroid Hormone Receptors, Chemical Contraceptive agents, COX-2 inhibitors, Prostaglandins for Ophthalmic use, pharmaceutically important enzyme products such as Pancreatin, Trypsin, Insulin. Classification of vitamins with examples.

**Concept of rational drug design**
Structure activity relationship, Drug-receptor understanding, Molecular modeling, Structure based drug design. QSAR.

**Recommended books/References:**
1. Wilson and Gisvold's Textbook of Organic Medicinal and Pharmaceutical ...by Charles Owens Wilson, John H. Block, Ole Gisvold, John Marlowe Beale
4. Burgers Medicinal Chemistry by Manfred E. Wolff, Alfred Burger

**Practical work suggested:**
1. Purification Techniques of Solvents by Fractional Distillation and Vacuum Distillation
2. Thin Layer Chromatography Technique and Purification of commercially available drugs/Synthesized Compounds by Column Chromatography.
3. Preparation of Acid/Basic Salts of Drugs and Evaluation of their Physicochemical Properties.(Benzilic Acid & Sodium Benzoate)

4. Synthesis & Purification of following Compounds using:
   (i) Precipitation or Recrystallization.
   (ii) Synthesis of Benzimidazole.
   (iii) Synthesis of Anthranilic Acid.
   (iv) Synthesis of Sulphanilamide.
   (v) Synthesis of benzoic acid from benzyl alcohol.
   (vi) Synthesis of 1,4 – dihydropyridine.

5. Computational modeling of drug design/use of softwares may be demonstrated to students.

**Suggested books/references:**

(The list of experiments and books are purly suggestive; University/institute may incorporate further changes in number of experiments and books/references (updated version from time to time) based on course design and available infrastructure facilities).
2. Electrochemistry

After completion of the course, the learner can be able to understand:

1. Basic principle of laws of electrochemistry.
2. Understanding about chemical cells and their function
3. Understanding about electrodes, EMF measurement.
4. Understanding about potentiometric titrations and their applications.

Unit-I


Unit-II

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

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


Recommended books/reference books

List of suggested laboratory experiments

1. Determination of pH of a given solution using glass electrode.
2. Determination of cell constant.
3. Determination of equivalent conductance, degree of dissociation, and dissociation constant of weak acid.
4. Conductometric titration: strong acid vs. strong base, weak acid vs. strong base.
5. Potentiometric titration: strong acid vs. strong base, weak acid vs. strong base, potassium dichromate vs. mohr’s salt.
Recommended books/reference books:


3. Polymer Chemistry

After completion of the course, the learner can be able to understand:

1. The mechanism of polymer material formation.
2. Molecular weight and structure property relationship
3. Polymerization procedure and Zigler-Natta catalysis.
4. Characterization of polymers

Introduction
Polymer, monomer, examples of polymers, biopolymers, classification, polymerization process, degree of polymerization, condensation, addition polymers, kinetics of addition polymerization process.

Polymeric Structure and Property Relationship
Structure of polymers - Linear, branched, cross linked, and network polymers, molecular weight (number average, weight average, viscosity average) and distribution of molecular weight, polydispersity index, crystallinity in polymer, melting temperature and glass transition temperature, Volumetric properties - molar volume, density, Van der Waals volume - Coefficient of linear thermal expansion and volumetric thermal expansion - Pressure volume temperature (PVT) relationship.

Polymerization Chemistry
Industrial methods of polymerization such as a bulk, solution, emulsion, suspension. Stereochemistry of polymers and stereo-specific polymerization, Catalysts-their utility in polymers and stereo-specific polymerizations, Catalysts their utility in polymer manufacture, Ziegler-Natta, Metallocene and others.
Characterization of Polymers
Molecular Weight Determination by Light Scattering, Osmometry, End-Group Analysis, Viscosity, Gel Permeation Chromatography; Application, of FTIR, UV-visible, NMR, and Mass Spectroscopy for Identification of polymers.

Recommended books/References:

List of suggested laboratory practicals
1. Free radical solution polymerization of any one: Styrene, methylmethacrylate, methyl acrylate, methacrylic acid (using free radical initiators). (purification of monomer should be taught)
2. Preparation of phenol-formaldehyde resins
3. Emulsion polymerization of polymethylmethacrylate.
4. Use of viscometer for molecular weight determination – (any known polymer, example: polyvinyl pyrrolidone in water/polyacrylamide in NaNO₂ solution) by viscometry. (students should be explained regarding principles and use of ubblohde/ostwald viscometer).
5. Estimation of amount of HCHO in a given solution by sodium bisulphite method.
6. Use of FTIR/TGA/DSC – for polymer characterization (may be demonstrated to students)
7. Determination of exchange capacity of cation exchange resins and anion exchange resins.
Recommended Books/Reference books


(The list of experiments and books are purely suggestive; University/institute may incorporate further changes in number of experiments and books/references (updated version from time to time) based on course design and available infrastructure facilities).
4. Environmental Chemistry

After completion of the course, the learner can be able to understand:
1. Composition of atmosphere
2. Biogeochemical cycles
3. Hydrological cycle
4. Water quality parameters
5. Atmospheric chemical phenomena and environmental pollution

Environment
Composition of atmosphere, temperature variation of earth atmospheric system (temperature vs. altitude curve), biogeochemical cycles of C, N, P, S and O system.

Hydrosphere: Hydrological cycle, aquatic pollution and water quality parameters – Dissolve oxygen, biochemical oxygen demand, chemical oxygen demand, Analytical methods for the determination of fluoride, chromium and arsenic, residual chlorine and chlorine demand, purification and treatment of municipal water and waste water.

Atmosphere
Chemical composition of atmosphere – particle, ions, and radicals in their formation, chemical and photochemical reactions in atmosphere, smog formation, oxides of N, C, S, and O and their effect, pollution by chemicals, CFC, Green House effect, acid rain, air pollution and control.

Aquatic chemistry
Water and its necessities, various water quality parameters (DO, BOD, COD, conductivity, pH, alkalinity, hardness) and its determination, Industrial, municipal water treatment processes, Waste water treatment procedure (primary, secondary and tertiary), Solid waste treatment. Soil pollution and Noise pollution.
Recommended Books/References:
4. S. E. Manahan, Environmental chemistry, 1993, Boca Raton, Lewis publisher
5. Environmental chemistry, Sharma and Kaur, 2016, Krishna publishers

List of suggested laboratory practicals
Determination of water quality parameters in following aspect:
1. Determination of dissolved oxygen in given water (chemical method/instrumentation method).
2. Determination of Biological Oxygen Demand (BOD₅).
3. Determination of Chemical Oxygen Demand (COD).
4. Finding out percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by titration method (AgNO₃ and potassium chromate).
6. Estimation of total alkalinity of water samples (carbonate, bicarbonate) by titration method.
7. Estimation of SPM in air samples.
List of Recommended books/Reference Books:


(The list of experiments and books are purly suggestive; University/institute may incorporate further changes in number of experiments and books/references (updated version from time to time) based on course design and available infrastructure facilities).
5. Advanced Materials Chemistry

Crystal structure of solids
Fundamental of lattices, unit cell, atomic coordinates, Bravais lattices, crystal direction and planes, types of close packing, packing efficiency, radius ratios; few important crystal structures. Synthesis of Inorganic solids; solid state, solution phase and vapor phase synthesis; precipitation, hydrothermal, sol-gel, surfactant based synthesis. Growth of single crystals. Crystal structure determination by X-ray diffraction, d-spacing formula, symmetrically absent reflections, Multiplicities, Scattering of X-rays by an atom and a crystal. Single crystal and powder diffraction. Electron and neutron diffraction. Concept of reciprocal lattice. Electron microscopy techniques.

Nanomaterial fundamentals

Frontier areas of polymer science and technology
Conducting polymers: basic principles of conducting polymers, delocalized electronic states of conjugated polymers, polyanilines, polyacetylenes, polythiophene, applications of conducting polymers. Biodegradable polymers: Definition classification of natural biodegradable polymers, cellulose, cellulose acetate, cellophane, soy protein, corn, zein protein, wheat gluten protein, synthetic biodegradable polymers, polyhydroxy alkanoates, polycarpolactone, poly(vinyl alcohol), polyacetic acid, application of biodegradable and biomedical polymers, contact lens, dental polymers, artificial heart, kidney, skin, and blood cells.
Fibers: natural fibers, cotton, wool, silk, rayon, artificial fibers, polyamides, acrylic acid, PVC, PVA.
Rubber: Compounding and elastomeric properties, vulcanization, reinforcement.

**Recommended books/References:**

**List of suggested Laboratory Experiment.**
(The list of experiments are suggestive. However, faculties/academic bodies may add more experiments/references or incorporate suitable revisions based on infrastructure facilities available).
1. Preparation of gold and silver nano-particles.
2. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
3. Determination of composition of dolomite (by complexometric titration).
4. Analysis of XRD pattern of few selected crystals like NaNO₃, CaCl₂, etc.; Indexing of a given powder diffraction pattern of a cubic crystalline system.
5. Interpretation of FTIR, NMR and UV-Vis data of given material.
6. Estimation of particle size from the BET, SEM techniques.

**Recommended books/Reference Book:**
6. Advanced Analytical Chemistry

Statistical methods in chemical analysis
Theory of error and treatment of quantitative data, accuracy and precision, ways of expressing accuracy and precision, Normal error curve and its equation. Useful statistical tests with equation, test of significance, the F-test, the students t-test, the Chi-test, the correlation coefficient, confidence limit of the mean, comparison of two standard values, comparison of two standard values, comparison of standard deviation with average deviation, comparison of mean with true values, regression analysis (least square method).

Polarography
Current-voltage relationship, theory of polarographic waves, instrumentation, qualitative and quantitative applications.

Atomic spectroscopy
Atomic absorption spectroscopy, theory and application (with some examples).

Thermal analysis
Theory, methodology, instruments and applications of thermogravimetric analysis (TGA/DTA), and differential scanning calorimetry (DSC).

Chromatography
Principles of chromatography, paper, column and thin layer chromatography, Gas-liquid chromatography, HPLC.

Analysis of fuel and drugs
Fuel analysis: Solid, liquid and gaseous fuels, ultimate and proximate analysis of solid fuel, Determination of calorific value of solid, liquid and gaseous fuels, Flash point and fire point.
Drug analysis: Classification of drugs, Analysis of some standard drug using various chromatographic techniques.

Recommended books/references:
List of suggested laboratory experiments

1. Study the effect on pH of addition of HCl/NaOH to solutions of acetic acid, sodium acetate and their mixtures. Preparation of buffer solutions of different pH (i. Sodium acetate-acetic acid, ii. Ammonium chloride-ammonium hydroxide

2. Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:
   i. Ni (II) and Co (II)
   ii. Fe (III) and Al (III)

3. Chromatographic separation of the active ingredients of plants, flowers and juices by TLC.

4. IR/DSC analysis of known polymer sample (for students demonstration only)

5. Determination of flash point & fire point of given fuel sample.

6. Determination of viscosity index, cloud point, pour point of given fuel sample.


9. Determination of the iodine number of oil.

10. Determination of the saponification number of oil.

Recommended books/Reference books:


Khopkar, S.M. *Basic Concepts of Analytical Chemistry*. New Age International Publisher, 2009

7. Nuclear & Radiation Chemistry

Nucleus and its classification, nuclear forces, nuclear stability, binding energy, nuclear models. Radioactive decay (Radioactive elements, general characteristics of radioactive decay, decay kinetics - decay constant, half life, mean life period), units of radioactivity, Transient and secular equilibria, Carbon dating and its usefulness.

Nuclear reactions: Bethe notation, types of nuclear reactions (n, p, α, d and γ), conservation of quantities (mass-energy and linear momentum) in nuclear reactions, reaction cross-section, compound nucleus theory and nuclear reactions. Nuclear fission: the process, fragments, mass distribution, and fission energy.

Measurement of radioactivity, idea about accelerator and detectors, Van de Graaaf and linear accelerators, synchrotrons, Geiger-Muller detector, Scintillation detectors, Type of nuclear reactions, Nuclear fission, Nuclear fusion, Nuclear reactor: classification of reactors, the natural uranium reactor, breeder reactor. Nuclear fusion and stellar energy.

Radiation chemistry: Elementary ideas of radiation chemistry, radiolysis of water and aqueous solutions, unit of radiation chemical yield (G-value), radiation dosimetry (Fricke’s dosimeter), units of radiation energy (Rad, Gray, Rontgen, RBE, Rcm, Sievert)

Recommended Books/references:
1. Friendlander G, Kennedy G and Miller J. M. Nuclear and Radiochemistry, Wiley Interscience
2. Harvey, B. G. Introduction to Nuclear Physics & Chemistry, Prentice – Hall,

Suggested laboratory practicals:
1. The safe laboratory use of radionuclide and radioisotopes
2. demonstration of activity on Geiger-Muller and scintillation based counter.
3. liquid scintillation counting, alpha spectrometry, gamma spectrometry – to identify and quantify radioisotopes
4. occurrence of radon daughter particles in environmental samples.
5. Liquid-liquid separation/extraction of radio nuclide from environmental samples/water samples.
6. Isotopic application in removal process adsorption / ion exchange.

(The above list is just suggestive. More experiments can be added/incorporated based on facility/expertise available. Since above experiments require certified labs which may not be available at all places, therefore, it is advised that institute/university/teacher may arrange/allow academic visit of students to nuclear chemistry labs in the country following proper procedure and to prepare comprehensive report of the visit/viva voce of students which can also form a lab course until available facilities are available).
8. Organic Spectroscopy

**Basic Principles of UV Spectroscopy:**
Application of Woodward-Fiser rule in interpretation of Organic compounds: Application of visible, ultraviolet and infrared spectroscopy in organic molecules. Electromagnetic radiation, electronic transitions, $\lambda_{\text{max}}$ & $\varepsilon_{\text{max}}$, chromophore, auxochrome, bathochromic and hypsochromic shifts. Application of electronic spectroscopy and Woodward rules for calculating $\lambda_{\text{max}}$ of conjugated dienes and $\alpha,\beta$ – unsaturated compounds.

**Basic principles of IR Spectroscopy:**
Identification of Functional groups of various classes of organic compounds: Infrared radiation and types of molecular vibrations, functional group and fingerprint region. IR spectra of alkanes, alkenes and simple alcohols (inter and intramolecular hydrogen bonding), aldehydes, ketones, carboxylic acids and their derivatives (effect of substitution on $>\text{C}=\text{O}$ stretching absorptions).

**NMR (1H and 13C NMR):**
Application of Chemical Shifts, Splitting of signals, Spin coupling and Over Houser effect in interpretation of NMR spectra, Isotopic exchange

**Basic principles Mass Spectrometry:**
Application of fragmentation rule in characterization of organic compounds. Problems on structure elucidation of organic compounds based on spectral data.

**Recommended Books/References:**
Suggested laboratory experiments

1. Purification method for liquid, solid organic substance (distillation, recrystallization, chromatography)

2. Analysis of spectra of UV-Vis, FTIR, NMR and Mass of simple organic compounds. (students may encourage to prepare simple organic compounds following given protocol (azodyes, acetanilides, benzoic acid, etc.) (or may use commercially available organic compounds) and can be trained to identify/analyze important peaks/functionality, determine mass of the molecules (mass-spectra). They can submit a report regarding their analysis to course teacher.
9. Heterocyclic Chemistry

Heterocyclic Chemistry

Three-membered rings with one heteroatom: Chemistry of oxiranes, aziridines and episulphides - synthetic approaches and reactivities.

Three-membered heterocycles with two heteroatoms: oxaziranes, diaziridines and diazirines - synthetic approaches and reactivities.

Four-membered heterocycles: oxitanes, azatidanes and thietanes - synthetic approaches and reactivities. Natural products: synthesis of Peniciline and cephalosporine.

Five-membered aromatic heterocycles:

1. With one heteroatom: furans, pyrroles and thiophenes - general synthetic approaches, properties and reactivities.
2. With two heteroatoms: oxazoles, isoxazoles, imidazoles, thiazoles, pyrazoles and isothiazoles - general synthetic approaches and reactivities.
3. With three and four heteroatoms: triazoles and tetrazoles - synthetic approaches, properties and reactivity.

Condensed five-membered Heterocycles:

Benzofuran, indoles and benzothiazoles - general synthetic approaches, with greater emphasis on the chemistry of Indoles.

Recommended Books/references:

2. The Essence of heterocyclic Chemistry, A. R. Parikh, H. Parikh, R. Khunt, New Age Int. Publication,

List of suggested laboratory experiments
1. Identification of hetero atoms (S, N, X) in given organic compounds in lab.
2. Identification/separation of simple organic compounds containing hetero atoms using column chromatography/TLC) in lab.
3. Spectroscopic identification of simple organic compounds (spectra may be provided to the students and teachers may help the students to identify the compounds using spectra). Melting point/boiling point of the compounds may be checked for its purity.
4. Teacher may guide the students for preparation of : Indigo (using aldol condensation reaction of 2-nitrobenzaldehyde with acetone in basic condition);
   (Depending upon laboratory facilities, more preparation of heterocyclic group of compounds may be incorporated by teacher).
10. Biochemistry

Carbohydrates: (8 classes of 60 minutes duration each)
Biological importance of carbohydrates, Metabolism, Cellular currency of energy (ATP), Glycolysis, Alcoholic and Lactic acid fermentations, Krebs cycle.

Proteins: (8 classes of 60 minutes duration each)
Classification, biological importance; Primary, secondary and tertiary structures of proteins: α-helix and β-pleated sheets, Denaturation of proteins.

Enzymes: (8 classes of 60 minutes duration each)
Nomenclature, Characteristics (mention of Ribozymes), Classification; Active site, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme inhibitors, Biocatalysis in Green Chemistry” and Chemical Industry

Lipids: (8 classes of 60 minutes duration each)
Biological importance of triglycerides and phosphoglycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications.

Structure of DNA/RNA: (8 classes of 60 minutes duration each)
Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy.

Recommended Books/References:
Suggested Practical in Biochemistry

1. Quantitative estimation of protein using Lowry’s method. Determine the concentration of the unknown sample.

2. Action of salivary amylase at optimum conditions

3. Effect of pH on the action of salivary amylase

4. Effect of temperature on salivary amylase

5. Effect of inhibitor on salivary amylase


7. Effect of temperature, organic solvents, on semi-permeable membrane.

8. Isolation of Genomic DNA from E Coli

(The above course structure/number of classes are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).
11. Organometallic and Bioinorganic Chemistry

Chemistry of 3d metals: Oxidation states displayed by Cr, Fe, Co, Ni and Co. A study of the following compounds (including preparation and important properties); Peroxo compounds of Cr, K₂Cr₂O₇, KMnO₄, K₄[Fe(CN)₆], sodium nitroprusside, [Co(NH₃)₆]Cl₃, Na₃[Co(NO₂)₆].

Organometallic Compounds
Definition and classification of organometallic compounds on the basis of bond type. Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. π-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding.

Zeise’s salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls.

Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.

Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich Condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.
Definition and Classification with appropriate examples based on nature of metal-carbon bond (ionic, s, p and multicentre bonds). Structures of methyl lithium, Zeiss salt and ferrocene. EAN rule as applied to carbonyls. Preparation, structure, bonding and properties of mononuclear and polynuclear carbonyls of 3d metals. p-acceptor behaviour of carbon monoxide. Synergic effects (VB approach)- (MO diagram of CO can be referred to for synergic effect to IR frequencies). Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

Bioinorganic chemistry
A brief introduction to bio-inorganic chemistry. Role of metal ions present in biological systems with special reference to Na⁺, K⁺ and Mg²⁺ ions: Na/K pump; Role of Mg²⁺ ions in energy production and chlorophyll. Role of Ca²⁺ in blood clotting, stabilization of protein structures and structural role (bones).

Recommended books/reference books

List of Laboratory experiments
(necessary infrastructure may be developed and adequate precaution should be maintained to conduct such experiments; instructor may demonstrate the experiment to students)
1. Reaction of metal with halide – preparation of Grignard reagent. (only demonstration purpose)
2. Grignard preparation of dye (malachite green (using methylbenoate)/crystal violet (using diethylcarbonate) (starting material as p-bromo N, N-dimethyl aniline) (only demonstration purpose)
4. Preparation of any two of the following complexes and measurement of their conductivity measurement:
   a. tetraamminecarbonatocobalt (III) nitrate
   b. tetraamminecopper (II) sulphate
   c. potassium trioxalatoferrate (III) trihydrate

**Recommended books/reference books**
2. A.I. Vogel: Qualitative Inorganic Analysis, Prentice Hall, 7th Edn.
12. Introduction to Nanochemistry & Applications

Unit-I: Introduction to nanoscience, nanostructure and nanotechnology (basic idea), Overview of nanostructures and nano-materials, classification, (cluster, colloid, nanoparticles, and nanostructures - Spheroid, Wire, Rod, Tube, and Quantum Dot); Calculation of percentage of surface atom and surface to volume ratio of spherical, wire, rod, and disc shapes nanoparticles.

Unit-II: Size dependent properties of nanomaterials (basic idea with few examples only): Quantum confinement, Electrical, Optical (Surface Plasmon resonance), variation in colors (Blue shift & Red shift), Magnetic, thermal and catalytic properties.


Unit-IV: Material characterization techniques (basic idea of use of following instruments in nanomaterial characterization need to be emphasized): Electron microscopic technique, diffraction technique, photoelectron spectroscopy, zeta-potential measurement; Examples of use of nanomaterials in environmental remediation and biology (few practical examples of use of materials can be discussed).

Recommended Books/References books:

**List of Laboratory Experiments suggested:**

1. Synthesis of ZnO nanoparticles.
2. Preparation of Silver nanoparticles.
   (diverse nanoparticles can be prepared by various routes)
3. Verification of Beer-Lambert law using nano-particles (above prepared nano-particles may be used for the study).
   (Depending upon the availability of infrastructure facilities, instructor may encourage the students to prepare bimetallic nano-particles, etc. and characterized them, study their various properties like magnetism, adsorption, etc.)

**Recommended/Ref. Books:**

GENERIC ELECTIVE COURSES

Generic elective courses are both theory and practical based. Both Honours and Pass students can chose the course as outlined in the pattern of modeled credit distribution. Some of the courses are based largely on practical. These courses shall have the following credit pattern.

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1. Mathematical Methods in Chemistry

Fundamentals of mathematics: (10 classes of 60 minutes duration each)
Mathematical functions, polynomial expressions, logarithms, exponential function, units of a measurement, inter-conversion of units, constants and variables, equation of a straight line, plotting graphs, data representation, pi-charts, histogram.

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


Algebraic operations on real scalar variables, Roots of quadratic equations analytically and iteratively, Numerical methods of finding roots (Newton-Raphson, binary –bisection).
**Mathematical series: (10 classes of 60 minutes duration each)**

Power series, Maclaurin, Taylor series, convergence (e.g. pressure virial equation of state, colligative properties). Pythagoras theorem in three dimensions. Trigonometric functions, identities.

**Differential calculus: (10 classes of 60 minutes duration each)**

The tangent line and the derivative of a function, numerical differentiation, differentials of higher order derivatives, discontinuities, stationary points, maximum-minimum problems, inflexion points, limiting values of functions: L’Hopital’s rule, combining limits.

Calculus of several variables: Functions, change of variables, total differential, chain rule, partial differentiation, Euler’s theorem, exact and inexact differentials (applications in the domains of thermodynamics, surface chemistry), line/surface-integrals.

**Integral calculus: (10 classes of 60 minutes duration each)**

Integration, odd-even functions, indefinite integrals, standard integrals, methods of integration (by parts, substitution, partial fractions and others. Examples from kinetics, thermodynamics, nuclear chemistry and surface chemistry, numerical integration (Trapezoidal and Simpson rules, e.g. entropy/enthalpy change from heat capacity data), probability distributions and mean values. Tri-gonometric functions (applications in chemistry need to be emphasized throughout)

**Recommended Books/References:**


(The above course structure, number of classes and recommended books/references are suggestive. Faculty/academic bodies may incorporate revision as per need).

*(PRACTICALS/COMPUTATIONAL TOOL WORKS NEED TO BE DESIGNED BY FACULTIES BASED ON THE AVAILABLE FACILITIES)*
2. Life Science/Biology-I

Cell and Cellular Processes: (14 classes of 60 minutes)
The Cell Theory; Prokaryotic and eukaryotic cells; Cell size and shape; Eukaryotic Cell components

Cell Organelles

Mitochondria: Structure, marker enzymes, composition; mitochondrial biogenesis; Semiautonomous organelle; Symbiont hypothesis; Proteins synthesized within mitochondria; mitochondrial DNA

Chloroplast: Structure, marker enzymes, composition; semiautonomous nature, chloroplast DNA


Peroxisomes and Glyoxisomes: Structures, composition, functions in animals and plants and biogenesis.

Nucleus (10 classes of 60 minutes duration each)
Nuclear Envelope- structure of nuclear pore complex; chromatin; molecular organization, DNA packaging in eukaryotes, euchromatin and heterochromatin, nucleolus and ribosome
The functions of membranes; Models of membrane structure; The fluidity of membranes;
Membrane proteins and their functions; Carbohydrates in the membrane; Faces of the membranes; Selective permeability of the membranes; Cell wall

Cell Cycle: (6 classes of 60 minutes duration each)
Role of Cell division; Overview of Cell cycle; Molecular controls; Meiosis Interphase, Mitosis and Meiosis.
**Instrumentation techniques: (10 classes 60 minutes duration each)**

Principles of microscopy; Light Microscope; Phase contrast microscopy; Fluorescence microscopy; Confocal microscopy; Sample Preparation for light microscopy; Introduction to Electron microscopy (EM)- Scanning EM and sample analysis with examples.

**Recommended books/References:**

(The above course structure, number of classes and recommended books/references are suggestive. Faculty/academic bodies may incorporate revision as per need).

**Tutorials/practical for Biology (preferably any six from the following list)**
1. Study of prokaryotic cells (bacteria), viruses, eukaryotic cells using microscope.
2. Study of the photomicrographs of cell organelles.
3. To study the structure of plant cell through temporary mounts.
4. To study the structure of animal cells by temporary mounts-squamous epithelial cell and nerve cell.
5. Preparation of temporary mounts of striated muscle fiber.
6. To prepare temporary stained preparation of mitochondria from striated muscle cells/ cheek epithelial cells using vital stain Janus green.
7. To prepare temporary stained squash from root tips of *Allium cepa* and to study the various stages of mitosis.
8. Study the effect of temperature, organic solvent on semi permeable membrane.
9. Demonstration of dialysis of starch and simple sugar.
10. Study of plasmolysis and deplasmolysis on *Rhoeo* leaf.
11. Measure the cell size (either length or breadth/diameter) by micrometry.
12. Study the structure of nuclear pore complex by photograph (from Gerald Karp)
3. Physics-I

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**Mathematical Physics: (8 classes of 60 minutes duration each)**
Scalar and vector products, polar and axial vectors, triple and quadruple products.

**Vector calculus:**
Scalar and vector fields, differentiation of a vector, gradient, divergence, curl and O operations and their meaning, idea of line, surface and volume integrals, Gauss and Stokes’ theorem.

**Classical Mechanics: (18 classes of 60 minutes duration each)**
*Particle dynamics*: Newton’s laws of motion, conservation of linear momentum, center of mass, conservative forces, work energy theorem, particle collision.

*Rotational kinematics and dynamics*: Rotational motion, forces and pseudo forces, torque and angular momentum, kinetic energy of rotation, rigid body rotation dynamics, moment of inertia, conservation of angular momentum, comparison of linear and angular momentum, motion of a top.

*Oscillations*: Linearity and superposition principle, free oscillation with one and two degrees of freedom, simple pendulum, combination of two simple harmonic motions. Lissajous figures, free and damped vibrations, forced vibrations and resonance, Q factor; wave equation, travelling and standing waves, superposition of waves, phase and group velocity.

**Wave optics: (14 classes of 60 minutes duration each)**
Interference, division of amplitudes, Young’s double split, Fresnel’s biprism, interference in thin films and wedged shaped films. Fresnel diffraction: Diffraction at a single slit and a circular aperture, diffraction at a double split, plane transmission grating, resolving power of a telescope and a microscope, resolving and dispersive power of a plane diffraction grating. Polarization: Polarization by reflection and refraction, Brewster’s law, double refraction, nicol prism, quarter and half-wave plates, Production and analysis of circularly and elliptically polarized light.
**Recommended Text books/references:**


(The above course structure, number of classes and recommended books/references are suggestive. Faculty/academic bodies may incorporate revision as per need).

**Physics-I– Practicals**

(Recommended that physics practical to be carried out from mechanics and optics as per availability of facilities with minimum 3 experiments from each group)

**Group-A: Mechanics**

1. Determination of spring constant of a spring by (i) static, and (ii) dynamic methods.
2. Study of damped harmonic oscillator- Q factor.
3. Determination of temperature coefficient of resistance using platinum resistance thermometer.
4. Study of thermal couple calibration and inversion temperature.
5. LCR study of resonance Q-factor.

**Group-B: Optics**

7. Determination of wavelength of light by Fresnel’s biprism.
9. Determination of refractive index of tint glass using a spectrometer.
10. Determination of dispersive power of a glass prism using Cauchy’s constant. Also determine the resolving power of a prism.
11. Determination of wavelength of sodium light using a plane transmission grating and resolving power of a diffraction grating.
12. Determination of specific rotation of cane sugar solution using a polarimeter.
4. Mathematics-II

**Differential equations: (8 classes of 60 minutes duration each)**

**Partial differential equations: separation of variables. (10 classes of 60 minutes duration each)**
Multiple integrals. Change variables. Vector derivative operators. Multiple integrals involving other coordinate systems (spherical polar). Maximum and minimum of functions of several variables. Stationary points, complex numbers, complex plane, Euler’s formula and polar form of complex numbers, complex conjugates, modulus of a complex number.

**Operators: (6 classes of 60 minutes duration each)**
Operator algebra, linear and Hermitian operators, eigenfunctions and eigenvalues, commutators of operators.

**Vectors and coordinate systems: (6 classes of 60 minutes duration each)**
Unit vectors (application in solid state), addition and subtraction of vectors, multiplication of vectors. Vector calculus. Vectors and coordinate systems in three dimensions (Cartesian, spherical polar and their inter-conversion), Jacobian.

**Determinants and Matrices: (10 classes of 60 minutes each)**
**Recommended Books/references:**


(The above course structure/number of classes are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).

(Suitable Laboratory Practicals may be designed by the faculty of Mathematics/Chemistry based on above course modules and available facilities)
5. Physics-II

Electrostatics and magnetism: (15 classes of 60 minutes duration each)
Electric field, potential due to a charge distribution and due to a dipole, electrical potential energy, flux, Gauss’s law, electric field in a dielectric, polarization, energy stored in an electric field. Magnetic field due to a current-carrying conductor, Biot Savart law, magnetic force on a current, Lorentz force, electromagnetic induction, Lenz’s law, magnetic properties of matter, para-dia- and ferromagnetism, spinning of a magnetic dipole in an external magnetic field. Modification of Ampere’s law, equation of continuity and displacement current, Maxwell’s equations, wave equation and its plane wave solution, nature of electromagnetic waves, transversality and polarization, propagation of electromagnetic plane waves in dielectric media.

Electronics: (15 classes of 60 minutes duration each)
Half-wave, full-wave and bridge rectifiers, ripple factor, rectification efficiency, filters (series in inductor, shunt capacitor, LC and π sections), voltage regulations, load regulation, Zener diode as voltage regulator. Characteristic curves of bipolar transistors, static and dynamic load line, biasing (fixed and self) of transistor circuit, thermal instability of bias, the black box idea of CE, CB and CC transistor circuits as two-port network, small signal active output, hybrid model of a CE transistor circuit, analysis of a small signal amplifier: its voltage and current gains, negative and positive feedback. Barkhausen’s criterion for self-sustaining oscillations, LC and phase shift oscillators.

Digital electronics: (10 classes of 60 minutes duration each)
Number systems (binary, BCD, octal and hexadecimal), 1’s and 2’s complements. Logic gates, AND, OR, NAND, NOR, XOR and NXOR. Boolean algebra (Boolean laws and simple expressions), binary adders, half adder, half subtractor, full adder and full subtractor.
**Recommended Text books/References:**


(The above course structure/number of classes are suggestive. Faculty/academic bodies may incorporate revision/may incorporate text and reference books as per need).

**Physics Practical**

2. Determination of high resistance by leakage method.
3. Determination of mutual inductance by Ballistic Galvanometer.
5. Study of transistor characteristics (CB, CE, CC configurations).
7. Study of basic RC coupled amplifier (frequency response and band width).
8. Self-inductance measurement by Owen’s bridge.
9. Measurement of magnetic field by search coil.
10. To verify experimentally OR, NAD, NOT, NOR, NAND gates.

(The above list of experiments are suggestive. Faculty/academic bodies may incorporate revision in the list of experiments depending upon experimental facilities available/may incorporate text and reference books as per need).
ABILITY ENHANCEMENT COURSES

These courses have the following credit pattern. For theory papers:

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1. English for communication

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Communication: Language and communication, differences between speech and writing, distinct features of speech, distinct features of writing.

Writing Skills; Selection of topic, thesis statement, developing the thesis; introductory, developmental, transitional and concluding paragraphs, linguistic unity, coherence and cohesion, descriptive, narrative, expository and argumentative writing.

Technical Writing: Scientific and technical subjects; formal and informal writings; formal writings/reports, handbooks, manuals, letters, memorandum, notices, agenda, minutes; common errors to be avoided.

(The above course is suggestive. However, the course teacher/academic bodies may incorporate changes as per the need with incorporation of appropriate text books, reference materials).
2. Intellectual Property Rights

Learning outcomes
On completion of this course, the students will be able to:

- Understand the concept of IPR
- Differentiate between various agreements of IPR
- Compare copyrights, patents and Geographical Indicators
- Examine various legal issues related to IPR
- Relate to various cyber issues concerning IPR

Keywords:
Copyright act, IPR and WTO, Patents, Bioprospecting, Biopiracy, Database

Unit I: Introduction to Intellectual Property Right (IPR) 7 lectures

Unit II: Patents, Copyrights and Trademarks 7 lectures

Unit III: Protection of Traditional Knowledge, Industrial Designs and Plant Varieties 7 lectures
Unit IV: Information Technology Related I P R 7 lectures


Practical:

There are no experimental lab based Practical. However, the students are expected to prepare some project report based on the Success stories of Traditional Patents secured by India. Likewise, prepare a database for Indian products wherein issue is still under consideration of the competent authorities. Prepare the dos and don’ts on Patents for Botanists

Suggested Readings


3. History of Indian Science

Learning outcomes

On completion of this course, the students will be able to:

- Develop understanding of various branches of science during different eras
- Analyze the role played by different Indian organizations in science
- Appraise the contribution of different Indian Scientists in science

Keywords:
Astronomy, Ancient India, Colonial India, Modern India, Agricultural techniques, Green revolution

Unit I: Science in Ancient and Medieval India 8 lectures
History of development in astronomy, mathematics, engineering and medicine subjects in Ancient India, Use of copper, bronze and iron in Ancient India, The geography in literature of Ancient India. Influence of the Islamic world and Europe on developments in the fields of mathematics, chemistry, astronomy and medicine, innovations in the field of agriculture-new crop introduced new techniques of irrigation.

Unit II: Indian Science in before and after Independence 7 lectures
Introduction of different surveyors, botanists and doctors as early scientist in Colonial India, Indian perception and adoption for new scientific knowledge in Modern India, Establishment of premier research organizations like CSIR, DRDO and ICAR and ICMR, Establishment of Atomic Energy Commission, Launching of the space satellites, Botanical survey of India.

Unit III: Prominent Indian scientists 8 lectures
Unit IV: Prominent research in Plant Sciences in Republic of India

7 lectures

History of plant tissue culture from India, Green revolution in India: causes, details, and outcomes. First gene cloning in plants, First genome sequencing from India. Premier Plant Research institutes and scientists in India, GM Mustard. Allelopathy Plant research in India

Practical:
There are no experimental lab based Practical. However, the students are expected to prepare some term paper reports on the Life and works of some noted Indian Scientists especially the Botanists. Likewise, students need to prepare and organize some discussion on the ancient and medieval science in India and trace the reasons of inadequate visibility in the world. Prepare term papers on GM Crops, the controversies and procedure for approval. Prepare term papers on the significance of Allelopathic research from India

Suggested Readings

4. Good Laboratory Practices (largely Practical based)

Learning outcomes
After completing this course, the learner will be able to:

- Apply practical skills in science courses with the understanding of general laboratory practices
- Use various micro techniques used in chemistry
- Apply various techniques to study chemical compounds, salts
- Explore various research issues and their solutions

Keywords:
Laboratory calculations, calibration procedures, use of glasswares, safety aspects in preparation

Unit I: General Laboratory Practices

Unit II: Instrument-Techniques and laboratory preparation procedure.
Use of micropipette, analytical balances, pH meter, conductivity meter, rotary evaporator, potentiometer. Use of purified water in lab experiments, Cleaning and drying of glasswares, Perpartion of crystals from given salt. Preparation of Dyes, Demonstraton of preparation of material using Sol-gel procedure.

Suggested Readings
5. Introduction to Forensic Science and technology

Scope of forensic science, Evidences in criminal law (act, case studies), Physical evidences (identification, collection and preservation of sample, physical properties of sample material, use of physical evidences in criminal proceedings), biological evidences (drugs, effects, identification, serology of blood, semen, saliva, DNA evidence, use of biological evidence in criminal proceedings), trace evidences (finger print, blood stream, hair, firearms, fibers, paints, etc), basic techniques of chemical analysis (FTIR, Mass spectrosopy, HPLC and GC with example of analysis). Admissible and non-admissible scientific evidence in legal system, Principle and limitation of DNA finger printing.

Recommended Books/references:
6. Renewable Energies (solar and biogas)

Introduction to renewable energy sources – solar, wind, small hydro, biomass, geothermal and ocean energy, energy flow in ecosystem

Solar Energy Resources

Solar radiation: Spectrum of EM radiation, sun structure and characteristics, extraterrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution

Measurement of solar radiation
Instruments: sunshine recorder, Pyranometer, Pyrheliometer, Albedometer. Radiation measurement stations in India (NIWE, IMD etc.), solar radiation data, graphs, Meteonorm and NASA-SSE databases
Hands-on measurement of beam, diffuse and total radiation

Solar mapping using satellite data, Typical Meteorological Year
Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components

Basics Biomass resources: plant derived, residues, aquatic and marine biomass, various wastes, photosynthesis. Biomass resource assessment
Estimation of woody biomass, non woody biomass and wastes, ASTM standards

Bulk chemical properties Moisture content, proximate and ultimate analyses, calorific value, waste water analysis for solids
Chemical composition of biomass Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass, extractable, COD.

Structural properties Physical structure, particle size and size distribution, permeability. Physical properties: Bulk density, angle of repose, thermal analysis (thermogravimetric, differential thermal and differential scanning calorimetry).
Properties of microbial biomass: Protein estimation, flocculating ability, relative hydrophobicity of sludge, sludge volume index.
7. Chemoinformatics

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

Representation of molecules and chemical reactions: Nomenclature, Different types of notations, SMILES coding, Matrix representations, Structure of Molfiles and Sdfiles, Libraries and toolkits, Different electronic effects, Reaction classification.

Searching chemical structures: Full structure search, sub-structure search, basic ideas, similarity search, three dimensional search methods, basics of computation of physical and chemical data and structure descriptors, data visualization.

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

Recommended Books/references:

8. Water remediation and conservation studies

Sources of water pollutants, pollutants, Industrial and human contribution, WHO recommendation about potable water, current scenario of drinking water quality, chemistry of toxicants like arsenic, fluoride, chromium, lead and mercury, cause and effects of water pollution, remediation, techniques involved such as adsorption, coagulation-filtration, Nalgonada techniques, reverse osmosis, activated charcoal detoxification, applications of non-toxic oxides and mixed oxides, regeneration and recycling, mechanisms of detoxification, bio-remediation, need of green chemistry, future scope.

Introduction to water conservation and erosion of soil, forms of water erosion, factors affecting water erosion, types of water erosion, mechanics of water erosion control, agronomical measures of water erosion control, Terraces for water erosion control:
Modeling of watershed processes, Case study of water-shed modeling for water conservation and water quality.

Recommended Books/references:

2. De A. K. Environmental Chemistry, Wiley Eastern
3. Clarison D., Dara S. S. A text book of Environmental chemistry and pollution control, S Chand Co. Soil and water analytical method
9. Research Methodology

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**Learning outcomes:**
At the end of the course the students will be able to,

- Understand the concept of research and different types of research in the context of biology
- Develop laboratory experiment related skills.
- Develop competence on data collection and process of scientific documentation
- Analyze the ethical aspects of research
- Evaluate the different methods of scientific writing and reporting

**Keywords:**
Qualitative, Quantitative, Reproducibility, Scientific methodology, Plagiarism, Scientific misconduct, Ethics in Science

**Unit I: Basic Concepts of Research**
12 lectures
Research-definition and types of research (Descriptive vs analytical; applied vs fundamental; quantitative vs. qualitative; conceptual vs empirical). Research methods vs methodology. Literature-review and its consolidation; Library research; field research; laboratory research.

**Unit II: Data Collection and Documentation of Observations**
12 lectures
Maintaining a laboratory record; Tabulation and generation of graphs. Imaging of tissue specimens and application of scale bars. The art of field photography.

**Unit III: Overview of Application to Chemistry related problems**
10 lectures
Key chemistry research areas, chemoinfomatics.
Unit IV: Ethics and Good Practical’s and Art of Scientific Writing

Authors, acknowledgements, reproducibility, plagiarism, Numbers, units, abbreviations and nomenclature used in scientific writing. Writing references. Power-point presentation. Poster presentation. Scientific writing and ethics, Introduction to copyright-academic misconduct/plagiarism.

Practical

1. Experiments based on chemical calculations.
2. Lab computational experiments.
3. Poster presentation on defined topics.
4. Technical writing on topics assigned.
5. Identification of different type of research in day by day life
6. Curation of relevant scientific literature from Google Scholar
7. Demonstration for checking of plagiarism using recommended software
8. Technical writing on topics assigned.

(More Practical may be added depending on the available facilities)

Suggested Readings

10. Chemistry in Everyday life

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**Respiration and energy production in human body**

Respiration, Respiratory enzymes, brief outline of hemoglobin and myoglobin, oxygen transport mechanism in body, co-operativity, Respiration in lower animals, hemocyanine, hemerythrine. Energy production in body, ATP; enzyme responsible for food digestion, mechanism of food digestion, active site of cytochrome c-oxidase.

**Chemical aspects of some common health hazards**

Anemia, sickle cell anemia, leukemia, blood pressure irregularity, blood sugar, arthritis, carbon monoxide poisoning in mines, cyanide poisoning, fluorosis etc.

**Vitamins and minerals:**

Need for vitamin in body, types of vitamins, water soluble and fat soluble vitamins, Vitamin B-12, vitamin C (Cyanocobalamine), D, Vitamin K. Role of minerals in body, iodine deficiency and remedy.

**Significance of Radical chemistry in living system**

Radical production in environment, superoxide and peroxide, health impact, action of radicals, cell mutation, diseases caused by free radical, cancer, radical quencher, anti-oxidants, natural anti-oxidants like vegetables, beverages like tea and coffee, fruits.

Radical destroying enzymes: superoxide dismutase, catalase, peroxidase, mechanism of action.

**Chemistry of Materials**

Soaps and Detergents – their action, Biofuels – production of biofuels and its utility as alternative fuel source, Fibers: natural fibers, cotton, wool, silk, rayon, artificial fibers, polyamides, acrylic acid, PVC, PVA; Examples of natural biodegradable polymers, cellulose, cellulose acetate, cellophane, soy protein, corn, zein protein, wheat gluten protein, synthetic biodegradable polymers. Use of polymeric materials in daily life.
**Recommended Books/references:**


**Suggested Laboratory experiments:**

1. Analysis of soaps and detergents.
2. Analysis of Biofuels - flash point, pour point, cloud point
3. Preparation of Nylon 6/6,6
4. Testing of adulterant in food, oil and vegetable
5. Vitamin-C preparation.
11. Chemistry of food, nutrition and preservation

Learning objective:

1. To know about the basic of human physiological system and food science
2. To learn about the nutrition and its importance
3. To learn about the food preservation and its utility.

Key words: Food, nutrition, preservation.

Unit-I: (10 lecture class)
Basic of human physiological system and food science:

Unit-II (10 lecture class)
Nutrition: Dietary fibers (composition, properties and Minerals and trace elements (biochemical and physiological role, bioavailability and requirement with examples), Vitamines (examples, biochemical and physiological requisments, deficiency and excesses), Water (requirement, water balance), basic idea about community nutrition (objective, importance of various programmes).

Unit-III (10 lecture class)
Food preservation:
Food preservation: definition, objectives and principles of food preservation. Different methods of food preservation. Preserved Products: Jam, Jelly, Marmalade, Sauces, Pickles, Squashes, Syrups-types, composition and manufacture, selection, cost, storage, uses and nutritional aspects, Food Standards : ISI, Agmark, FPO, MPO, PFA, FSSAI.
Practical:

Identification of Mono, Di and polysaccharides, Identification of Proteins, Identification of glycerol., Determination of moisture content in food, ash content and determination of calcium, iron, vitamin-C.
Comparison with norms and interpretation of the nutritional assessment data and its significance.
Quantitative estimation of Sugars (Glucose, lactose, starch), Estimation of acid value, iodine value, Saponification value of fats, Estimation of blood Glucose, Estimation of serum cholesterol

Reference/suggested books

9..SrilakshmiB(2018): Food Science, 7th Colour Ed. New Age International (P) Lt
SKILL ENHANCEMENT COURSES

A number of courses has been enlisted. These courses have the following credit pattern. For theory based papers:

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For practical based papers:

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1. Skill Enhancement Course: Personality Development

Learning outcomes:
After the completion of this course, the learner will be able to:

- Develop understanding of the concepts and principles of basic psychological skills
- Apply techniques and methods to enhance productivity and time management
- Develop critical thinking skills
- Organize human resources with improved leadership qualities

Keywords:
Mental heuristics, Mental priming, Checklists, Stress management, Cognitive biases, Leadership qualities

Unit I: Basic Psychology Skills 8 lectures
Mental Heuristics and Priming, Cialdini’s six psychological principles, Charisma and charisma enhancements, facing interviews
Unit II: Productivity and Time Management 7 lectures
Eisenhower Matrix, Pomodoro Technique, Dealing with Procrastination, Journaling methods, Checklists, to-do lists and scheduling the events

Unit III: Dealing Negativity 7 lectures Work-life balance, stress management, coping with failures and depression

Unit IV: Critical Thinking and Human resources 8 lectures
Logical fallacies, Cognitive biases, Mental Models, Critical Thinking. Evaluation and improvement; Leadership qualities.

Suggested Readings
2. Bast, F. (2016). Crux of time management for students. Available at: https://www.ias.ac.in/article/fulltext/reso/021/01/0071-0088
2. Computer Applications in Chemistry

Learning outcomes:

After the completion of this course the learner will be able to:

- Apply the basic operations of spreadsheet applications
- Recognize advanced resources for accessing scholarly literature from internet
- Utilize bibliography management software while typing and downloading citations
- Operate various software resources with advanced functions and its open office substitutes

Keywords:

Spreadsheet, Google search, Subscription, Bibliography, MS office, Image processing

Unit I: Spreadsheet Applications                      8 lectures

Introduction of spreadsheet (MS Excel), application, formulas and functions, performing basic statistics using spreadsheet applications, creating basic graphs using spreadsheet applications, logical (Boolean) operators.

Unit II: Internet Resources                       7 lectures

Advanced Google search operators and Boolean functions, Introduction to Google Scholar and accessing scholarly literature from Internet, Fake News and spotting the fake news, multimedia resources and podcasts, RSS/XML Feeds and feed subscription using a feed reader.

Unit III: Bibliography management                 8 lectures

Introducing a bibliography management software (for e.g. Endnote), Styles and Templates, Changing the bibliography style as per journal format, Citing while typing in the office application, downloading citations from Google Scholar.
Unit IV: Other software resources  

7 lectures

Introduction to advanced functions of MS Word and its Open Office substitutes including tracking changes, inserting page numbers and automatic table of contents, Google Docs and Forms, MS Power point, Microphotography and scale calibration with ImageJ, digital image processing (Paint.net or GIMP).

Suggested Readings

1. User manual and online user manual of respective softwares for the most updated content
2. Published books are not recommended as versions keep on updating very frequently; therefore, it is not easy to follow.
3. Science Communication and Popularization

Learning outcomes:
After the completion of this course, the learner will be able to:

- Identify the need and role of science communication in human development
- Utilize visual media science communication for creating scripts and documentaries
- Contribute in science popularization through internet communication and public sensitization

Keywords:
Print science, Visual media, Internet communication, Blogs, Outreach talks, Public sensitization

Unit I: Print Science Communication
9 lectures
Need for Science Journalism: Science has potential for breaking news, impact on Human life, impact on technology. Role of science and technology in human development. Framing policies at national and international levels. Writing and communicating popular articles effectively, case studies of celebrated works of science communicators including Cosmos by Carl Sagan, works of Bill Bryson, Richard Dawkins, Richard Feynman, Isaac Asimov, Carl Zimmer and Matt Riddley, importance for communication through regional languages.

Unit II: Visual Media Science Communication
7 lectures
Science outreach through visual media: Creating science documentaries, creating the outline and expanding, scripts, citing authentic sources, case study: Famous documentaries of Carl Sagan, David Attenborough and Prof. Yashpal
Unit III: Internet Science Communication  
Science outreach through internet: Social media, Websites, Blogs, Youtube, Podcast etc.

Unit IV: Science Outreach Talks and Public Sensitization  
Tactics for providing a charismatic and effective public talk, use of metaphors, speaking in context, Science outreach for biodiversity conservation sensitization of public

Suggested Readings

4. Biofertilizers (Practical based course)

Learning outcomes:
On the completion of this course, the students will be able to;

- Develop their understanding on the concept of bio-fertilizer
- Identify the different forms of biofertilizers and their uses
- Compose the Green manuring and organic fertilizers
- Develop the integrated management for better crop production by using both nitrogenous and phosphate bio fertilizers

Keywords:
Useful microbes, Cyanobacteria, Mycorrhiza, Organic farming, Recycling, Vermicompost

Unit I 9 lectures

Unit II 7 lectures
Cyanobacteria (blue green algae), *Azolla* and *Anabaena azollae* association, nitrogen fixation, factors affecting growth, blue green algae and *Azolla* in rice cultivation.

Unit III 7 lectures
Unit IV

7 lectures


Suggested Readings

5. Herbal Technology (Practical based)

Learning outcomes:
On completion of this course the students will be able to;

- Develop their understanding on Herbal Technology
- Define and describe the principle of cultivation of herbal products.
- List the major herbs, their botanical name and chemical constituents.
- Evaluate the drug adulteration through the biological testing
- Formulate the value added processing / storage / quality control for the better use of herbal medicine
- Develop the skills for cultivation of plants and their value added processing / storage / quality control

Keywords:
Herbal medicines, Plant products, Biopesticides, Pharmacognosy, Adulteration, Secondary metabolites

Unit I 7 lectures
Herbal Technology: Definition and scope; Herbal medicines: history and scope; Traditional systems of medicine, and overview of AYUSH (Traditional Indian Systems of Medicine); Cultivation - harvesting - processing - storage of herbs and herbal products.

Unit II 7 lectures
Value added plant products: Herbs and herbal products recognized in India; Major herbs used as herbal medicines, nutraceuticals, cosmeticals and biopesticides, their Botanical names, plant parts used, major chemical constituents.
Unit III  
8 lectures
Pharmacognosy - Systematic position, botany of the plant part used and active principles of the following herbs: Tulsi, Ginger, Curcuma, Fenugreek, Indian Gooseberry, *Catharanthus roseus*, *Withania somnifera*, *Centella asiatica*, *Achyranthes aspera*, Kalmegh, Giloe (Tinospora), Saravar. Herbal foods, future of pharmacognosy.

Unit IV  
8 lectures
Analytical pharmacognosy: Morphological and microscopic examination of herbs, Evaluation of drug adulteration - types, methods of drug evaluation - Biological testing of herbal drugs - Phytochemical screening tests for secondary metabolites (alkaloids, flavonoids, steroids, triterpenoids, phenolic compounds). Plant gene banks, Cultivation of Plants and their value added processing / storage / quality control for use in herbal formulations, Introductory knowledge of Tissue culture and Micro propagation. of some medicinal plants (*Withania somnifera*, neem and tulsi),

Suggested Readings


6. Fermentation Science and Technology

Learning outcomes:
After completing this course the learner will be able to;

- Employ the process for maintenance and preservation of microorganisms
- Analyze the various aspects of the fermentation technology and apply for Fermentative production
- Demonstrate proficiency in the experimental techniques for microbial production of enzymes: amylase and protease, bio product recover

Keywords:
Microbial culture, Fermentation, Metabolites, Fermented products, Enzyme production, Bioproduct recovery

Unit I 8 lectures
Preparation of microbial culture, Preparation and sterilization of fermentation media. Isolation and improvement of industrially important microorganisms.

Unit II 8 lectures

Unit III 8 lectures
Scope and opportunities of fermentation technology. Principles of fermentation: Submerged, solid state, batch, fed-batch and continuous culture. Fermentative production of vinegar, alcohol (ethanol, wine, beer), acids (citric acid and gluconic acid), amino acids (lysine and glutamic acid) and antibiotics (penicillin and streptomycin).
Unit IV                           6 lectures

Microbial production of enzymes: Amylase and Protease. Bioproduct recovery.

Suggested readings

7. Environmental impact analysis (Practical based)

Learning outcomes:
After completing this course the learner will be able to;

- Have critical understanding of environmental impact
- Learn important steps of EIA process
- Interpret the environmental appraisal and procedures in India.

Keywords:
Environmental management, Environmental impact assessment, Project proponent, Consultant, Environmental audit, Risk assessment, Legislation

Unit I: Origin and Development  
8 lectures
Purpose and aim, core values and principles, History of EIA development, Environmental Management Plan, Environmental Impact Statement, Scope of EIA in Project planning and Implementation.

Unit II: EIA Process  
8 lectures

Unit III: Main participants in EIA Process  
7 lectures
Role of Project proponent, environmental consultant, PCBs, PCCs, public and IAA. Public participation.
Unit IV: Environmental Appraisal and Procedures in India and EIA

7 lectures

Methodology, indicators and mitigation, Environmental Audit of different environmental resources, Risk Analysis, Strategic environmental assessment, ecological impact assessment: legislation.

Practical

1. Prepare a Matrix of every environmental existing resource of your college or your hostel/mohalla or any defined area and evaluate each component using established methods and make audit analysis
2. Prepare a case report of Environmental impact of any area under development

Suggested readings:

8. **Skill Enhancement Course: IT skills for chemists**

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1. **IT Skills for Chemists**

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

Uncertainty in experimental techniques: Displaying uncertainties, measurements in chemistry, decimal places, significant figures, combining quantities. Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares (regression). Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms). Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).

Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations). Numerical integration (Trapezoidal and Simpson’s rule, e.g. entropy/enthalpy change from heat capacity data).

**Computer programming:**

Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.
BASIC/FORTRAN programs for curve fitting, numerical differentiation and integration (Trapezoidal rule, Simpson’s rule), finding roots (quadratic formula, iterative, Newton-Raphson method).

**Recommended books/References:**

9. Intellectual property right (IPR) and business skills for chemists

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**Introduction to Intellectual Property:**

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

**Copyrights**

Introduction, How to obtain, Differences from Patents.

**Trade Marks**

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

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

**Geographical Indications**

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

**Industrial Designs**

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

**Layout design of integrated circuits**

Circuit Boards, Integrated Chips, Importance for electronic industry.

**Trade Secrets**

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

**Different International agreements**

(a) **Word Trade Organization (WTO):**

(i) General Agreement on Tariffs & Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement (ii) General Agreement on Trade related Services (GATS) (iii) Madrid Protocol (iv) Berne Convention (v) Budapest Treaty
(b) Paris Convention

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


Business Basics

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

Chemistry in Industry

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

Financial aspects

Financial aspects of business with case studies.

Recommended Books/References:

10. Analytical Clinical Biochemistry

Structure, properties and functions of carbohydrates, lipids and proteins:

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

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

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

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

Biochemistry of peptide hormones.

Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy. Enzymes: Nomenclature, classification, effect of pH, temperature on enzyme activity, enzyme inhibition.

A diagnostic approach to biochemistry:


Recommended books/references:
Analytical Clinical Biochemistry Practical

Identification and estimation of the following:
1. Carbohydrates – qualitative and quantitative.
2. Lipids – qualitative.
5. Determination of cholesterol using Liebermann-Burchard reaction.
7. Isolation of protein.
8. Determination of protein by the Biuret reaction.
(visit to clinical laboratory/medical centre(s))

Recommended Books/References:
11. Mushroom Culture Technology

Learning outcomes:
On completion of this course, the students will be able to:

- Recall various types and categories of mushrooms.
- Demonstrate various types of mushroom cultivating technologies.
- Examine various types of food technologies associated with mushroom industry.
- Value the economic factors associated with mushroom cultivation
- Device new methods and strategies to contribute to mushroom production.

Keywords:
Edible mushrooms, Poisonous mushrooms, Cultivation technology, Mushroom bed, Mushroom unit, Storage and Nutrition

Unit I
7 lectures
Introduction, History. Nutritional and medicinal value of edible mushrooms; Poisonous mushrooms. Types of edible mushrooms available in India - *Volvariella volvacea, Pleurotus citrinopileatus, Agaricus bisporus*.

Unit II
9 lectures
Cultivation Technology : Infrastructure: substrates (locally available) Polythene bag, vessels, Inoculation hook, inoculation loop, low cost stove, sieves, culture rack, mushroom unit (Thatched house) water sprayer, tray, small polythene bag. Pure culture: Medium, sterilization, preparations of spawn, multiplication. Mushroom bed preparation - paddy straw, sugarcane trash, maize straw, banana leaves. Factors affecting the mushroom bed preparation- Low cost technology, Composting technology in mushroom production.
**Unit III**  
7 lectures


**Unit IV**  
7 lectures

Food Preparation: Types of foods prepared from mushroom. Research Centres - National level and Regional level. Cost benefit ratio - Marketing in India and abroad, Export Value.

**Suggested Readings**


(The above mentioned courses are indicative. Based on the facilities/expertise available, more similar courses can be introduced. The list of courses offered/recommended by UGC may also be considered/referred to while designing new courses/incorporating revision in the courses. References/Text books may be incorporated as per requirements/necessities of the subject concerned).