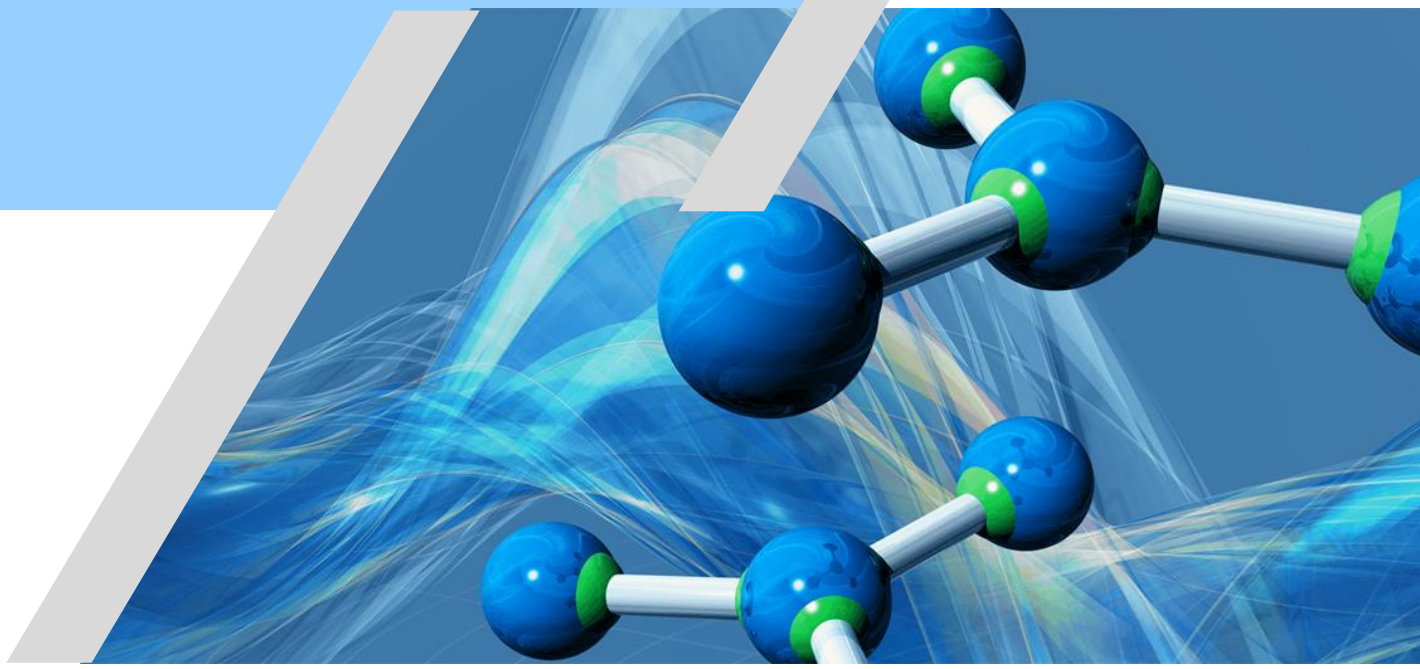
Rajiv Gandhi University

(NAAC 'A' Grade University)

Curriculum and Syllabus of

Four-Year Undergraduate Programme (FYUP) in Chemistry



Effective from Academic Session 2023-24

Department of Chemistry

Faculty of Basic Sciences

Rajiv Gandhi University, Arunachal Pradesh

CURRICULUM AND SYLLABUS OF FOUR-YEAR UNDERGRADUATE PROGRAMME (FYUP)
in
CHEMISTRY

(*as per NEP 2020*)

Department of Chemistry

Faculty of Basic Sciences
Rajiv Gandhi University
Rono Hills, Doimukh, Arunachal Pradesh

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PART 1: OVERVIEW

1.1 Introduction

The National Education Policy 2020 (hereafter referred to as NEP 2020) is a transformative education policy of India and aims to address our country's developmental goals as envisioned in its Constitution - a democratic, just, socially conscious, cultured and humane nation upholding liberty, equality, fraternity, and justice for all. This Policy proposes to revise and revamp all aspects of the education structure, including its regulation and governance, to create a new system aligned with the aspirational goals of 21st-century higher education, including Sustainable Development Goal 4 (SDG 4), while building upon India's traditions and value systems. The NEP 2020 emphasises the development of good, thoughtful, well-rounded, and creative individuals. This policy envisions a complete overhaul and re-energising of the higher education system to overcome the current challenges and deliver quality education with equity and inclusion.

The NEP 2020 states, *"Assessments of educational approaches in undergraduate education that integrate the humanities and arts with Science, Technology, Engineering and Mathematics (STEM) have consistently shown positive learning outcomes, including increased creativity and innovation, critical thinking and higher-order thinking capacities, problem-solving abilities, teamwork, communication skills, more in-depth learning and mastery of curricula across fields, increases in social and moral awareness, etc., besides general engagement and enjoyment of learning."*

The 4-year multidisciplinary Bachelor's programme allows the opportunity to experience the full range of holistic and interdisciplinary education, in addition to focusing on the chosen major and minors, per the student's choices. The undergraduate degree will be of either 3 or 4-year duration, with multiple exit options within this period, with appropriate certifications, e.g., a UG certificate after completing 1 year in a discipline or field including vocational and professional areas or a UG diploma after 2 years of study, or a Bachelor's degree after a 3-year programme.

Following the UGC "*Curriculum and Credit Framework for Undergraduate Programmes (2022)*," a new student-centric ***Curriculum and Credit Framework for Four-Year Undergraduate Programmes in Chemistry*** has been formulated. This framework incorporates a flexible choice-based credit system, a multidisciplinary approach, and multiple entry and exit options. It will facilitate students' pursuit of their career path by allowing them to choose the subject/field of their interest.

The curriculum has been prepared to support a uniform, advanced and effective Chemistry curriculum for undergraduate studies in Chemistry. The concerns, needs and interests of students and teachers, as well as societal expectations, have been considered while developing the syllabus. Each course aims to present learning targets and objectives and thus provide learning and teaching strategies, assessments and resources. The programme also states the attributes that it offers to inculcate at the graduation level. The graduate attributes encompass values related to well-being, emotional stability, critical thinking, social justice and also skills for employability.

1.2 Bearings of NEP 2020 on the Curricula

The NEP 2020 envisions an education system rooted in Indian ethos that contributes directly to transforming the country sustainably into an equitable and vibrant knowledge society by providing high-quality education to all, thereby making India a global knowledge superpower. The Policy envisages that the curriculum and pedagogy of our institutions must develop among the students a deep sense of respect towards the Fundamental Duties and Constitutional values, bonding with one's country, and a

conscious awareness of one's roles and responsibilities in a changing world. The vision of the Policy is to inculcate among the learners a deep-rooted pride in being Indian, not only in thought but also in spirit, intellect, and deeds, as well as to develop knowledge, skills, values, and dispositions that support responsible commitment to human rights, sustainable development and living, and global well-being, thereby reflecting a truly global citizen.

The NEP 2020 highlights certain fundamental principles that would guide the education system at large and individual educational institutions. The principles that have a direct bearing on the curricula for different levels of higher education include:

- Recognizing, identifying, and fostering the unique capabilities of each student to promote her/his holistic development;
- Flexible learning so that learners can select their learning trajectories and programmes and thereby choose their paths in life according to their talents and interests;
- Multidisciplinary and holistic education across the sciences, social sciences, arts, humanities, and sports for a multidisciplinary world;
- Emphasis on conceptual understanding rather than rote learning, critical thinking to encourage logical decision-making and innovation; ethics and human & constitutional values, and life skills such as communication, teamwork, leadership, and resilience;
- Extensive use of technology in teaching and learning, removing language barriers, increasing access for *Divyang* students, and educational planning and management;
- Respect for diversity and respect for the local context in all curricula, pedagogy, and policy;
- Equity and inclusion are the cornerstone of all educational decisions to ensure that all students can thrive in the education system and the institutional environment is responsive to differences to ensure that high-quality education is available.
- Rootedness and pride in India and its rich, diverse, ancient, and modern culture, languages, knowledge systems, and traditions.

1.3 Initiatives that Have a Bearing on Undergraduate Education

The NEP 2020 envisages several transformative initiatives in higher education. These include:

- Introducing holistic and multidisciplinary undergraduate education that would help develop all capacities of human beings - intellectual, aesthetic, social, physical, emotional, ethical, and moral - in an integrated manner; soft skills such as complex problem solving, critical thinking, creative thinking, communication skills; and rigorous specialisation in a chosen field(s) of learning.
- Adoption of flexible curricular structures to enable creative combinations of disciplinary areas for study in multidisciplinary contexts that would also allow flexibility in course options that would be on offer to students, in addition to rigorous specialisation in a subject or subjects.

- Undergraduate degree programmes of either 3 or 4-year duration, with multiple entry and exit points and re-entry options, with appropriate certifications such as:
    - a UG certificate after completing 1 year (2 semesters) of study in the chosen fields of study,
    - a UG diploma after 2 years (4 semesters) of study,
    - a bachelor's degree after a 3-year (6 semesters) programme of study,
    - a 4-year bachelor's degree (honours) after an eight-semester programme of study. If the student completes a research project in their major area(s) of study in the 4th year of a bachelor's degree (honours with research).

- The 4-year bachelor's degree programme is considered a preferred option since it would provide the opportunity to experience the full range of holistic and multidisciplinary education in addition to a focus on the chosen major and minors as per the student's choices.

- Credit-based courses and projects in community engagement and service and environmental and value-based education.

- Environmental education should include climate change, pollution, waste management, sanitation, conservation of biological resources and biodiversity management, forest and wildlife conservation, and sustainable development and living.

- Value-based education includes the development of humanistic, ethical, constitutional, and universal human values of truth, righteous conduct, peace, love, nonviolence, scientific temper, citizenship values, and life skills.

- Lessons in service and participation in community service programmes to be an integral part of holistic education.

- Global Citizenship Education and education for sustainable development to form an integral part of the curriculum to empower learners to become aware of and understand global and sustainable development issues and to become active promoters of more peaceful, tolerant, inclusive, secure, and sustainable societies.

- Students to be provided with opportunities for internships with local industry, businesses, artists, crafts persons, etc., as well as research internships with faculty and researchers at their own or other HEIs/research institutions so that students may actively engage with the practical side of their learning and further improve their employability.

- Reorienting teaching programmes to ensure the development of capabilities across various disciplines, including sciences, social sciences, arts, humanities, languages, and vocational subjects. This would involve offering programmes/courses of study relating to Languages, Literature, Music, Philosophy, Art, Dance, Theatre, Statistics, Pure and Applied Sciences, Sports, etc., and other such subjects needed for a multidisciplinary and stimulating learning environment.

- Preparing professionals in cutting-edge areas that are fast gaining prominence, such as Artificial Intelligence (AI), 3-D machining, big data analysis, and machine learning, in addition to genomic studies, biotechnology, nanotechnology, neuroscience, with important applications to health,

environment, and sustainable living that will be woven into undergraduate education for enhancing the employability of the youth.

PART 2: CURRICULUM & CREDIT FRAMEWORK

2.1 Eligibility

Senior Secondary School Leaving Certificate or Higher Secondary (12th Grade) Certificate obtained after completing Grade 12 or equivalent stage of education corresponding to National Credit Framework (NCrF) credit level 4.0 with chemistry and mathematics as one of the regular subjects.

2.2 Duration

The duration of the UG programme is 4 years or 8 semesters with multiple entry and exit points and re-entry options, with appropriate certifications provided they secure the requisite number of credits.

Students may be permitted to take a break from studying during the study period, but the total duration of completing the programme shall not exceed 7 years.

2.3 UG Certificate, UG Diploma, and Degrees

2.3.1 UG Certificate

If a student wants to leave after completing the first year (2 semesters), the student will be given a UG Certificate in Chemistry. Students who exit with a UG certificate can re-enter within three years and complete the degree programme.

2.3.2 UG Diploma

If a student desires to leave after completing the second year (4 semesters), the student will be given a UG Diploma in Chemistry. Students who exit with a UG diploma can re-enter within three years and complete the degree programme.

2.3.3 3-Year Bachelor's Degree (Major)

If a student leaves after completing the third year (6 semesters), the student will be awarded a 3-Year Bachelor's Degree (Major) in Chemistry.

2.3.4 4-Year Bachelor's Degree (Honours)

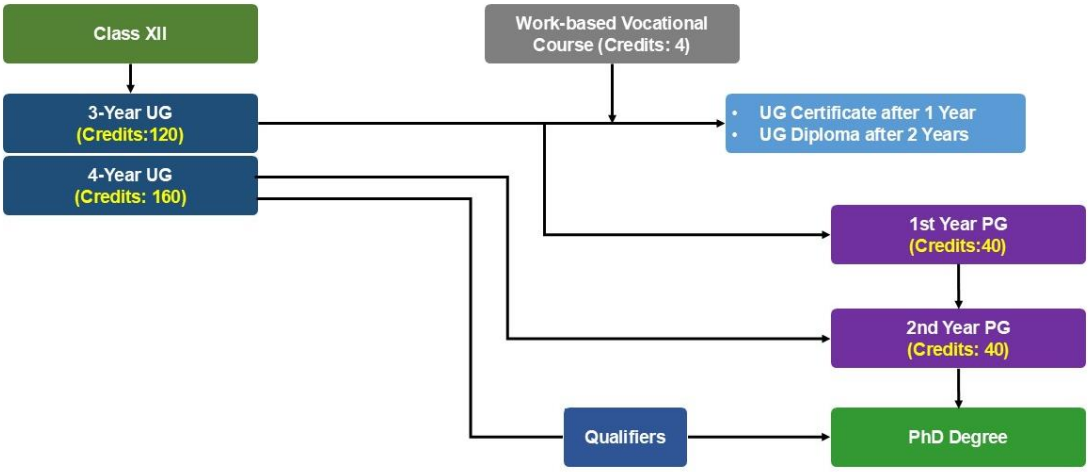
If the student completes 4th year of a bachelor's degree (8 semesters), the student will be awarded a 4-year Bachelor's Degree (Honours) in Chemistry.

2.3.5 4-Year Bachelor's Degree (Honours with Research)

A student who completes a research project in their major area(s) of study in the 4th year of a bachelor's degree (8 semesters). In that case, the student will be awarded a 4-year Bachelor's Degree (Honours with Research) in Chemistry.

NOTE: Affiliating colleges offering a 4-year UG Degree (Honours with Research) must have the required infrastructure, such as a library, access to journals, a computer lab and software, laboratory facilities to conduct experimental research work, and at least two permanent faculty members recognised as Ph.D. supervisors.

2.4 Progression of Four-Year Undergraduate Programme



2.5 The Nature and Extent of the Four-Year Undergraduate Programme in Chemistry

The new curriculum of the Four-Year Undergraduate Programme (FYUP) in Chemistry offers inorganic, organic, physical, materials and analytical chemistry courses. All the courses have defined objectives and Learning Outcomes, which will help prospective students choose the elective courses to broaden their skills in chemistry and interdisciplinary areas. New interdisciplinary subjects like nanomaterials, biomaterials, etc. and their applications from a chemistry point of view provide a new dimension to materials chemistry. Thus, the programme bridges the overlapping areas of chemistry with physics, biology, and 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 and teachers to broaden their theoretical and experimental knowledge that suits the needs of academics and industry.

The curriculum will also equip students for national-level competitive exams. To ensure the implementation of a holistic pedagogical model, students can choose several allied disciplines in this framework, including Physics, Mathematics, Biology and ability enhancement electives. In addition, the employability of graduates is given due importance so that their core competency in the subject matter, both theoretical and practical, is ensured. Several skill development courses are also introduced in this framework to increase employability.

2.6 The Programme Educational Objectives (PEOs)

The Four-Year Undergraduate Programme (FYUP) in chemistry has the following Programme Educational Objectives (PEOs):

PEO 1: Broad and balanced knowledge of chemistry and understanding of key chemical concepts, principles and theories.

PEO 2: To develop the ability and skill of the students to acquire expertise in solving theoretical and applied chemistry problems.

PEO 3: To provide knowledge and skills 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.

PEO 4: To provide an environment that ensures the cognitive development of students in a holistic manner. A complete dialogue about chemistry, chemical equations and their significance is fostered in this framework rather than mere theoretical aspects.

PEO 5: To provide the latest subject matter, both theoretical and practical, in such a way as to foster their core competency and discovery learning. As envisioned in this framework, a chemistry graduate would be sufficiently competent to undertake further discipline-specific studies and begin domain-related employment.

PEO 6: To make a responsible citizen aware of basic domain-independent knowledge, including critical thinking and communication.

2.7 The Programme Outcomes (POs)

	Type of Programme Outcome (PO)	*Programme Outcome (PO) Descriptor*
PO 1	**Problem-Solving**	A graduate student should be able to demonstrate the capability to: • solve problems of familiar and non-familiar contexts that are best approached with critical thinking and apply the learning to real-life situations.
PO 2	**Analytical Reasoning & Critical Thinking**	The graduates should be able to demonstrate the capability to: • apply analytical thought to a body of knowledge, including the analysis, evaluation and practices, as well as evidence, arguments, claims, beliefs, and the reliability and relevance of evidence, • identify relevant assumptions or implications; and formulate coherent arguments, • identify logical flaws in the arguments, • analyse and synthesise data from various sources, draw valid conclusions and support them with evidence and examples.
PO 3	**Creativity**	The graduates should be able to demonstrate the ability to: • create, perform, or think in different and diverse ways about the same objects or scenarios, • deal with problems and situations that do not have simple solutions, • innovate and perform tasks in a better manner, • view a problem or a situation from multiple perspectives, • think 'out of the box' and generate solutions to complex problems in unfamiliar contexts, • adopt innovative, imaginative, lateral thinking, interpersonal skills and emotional intelligence.

PO 4	**Communication Skills**	The graduates should be able to demonstrate the skills that enable them to: • listen carefully, read texts and research articles analytically, and present complex information clearly and concisely to peers and the public at large, • express thoughts and ideas effectively in writing and orally and communicate with others using appropriate media, • confidently share views and express herself/himself, • construct logical arguments using correct technical language related to a field of learning, work/vocation, or an area of professional practice, • convey ideas, thoughts, and arguments using respectful and sensitive language to gender and other minority groups.
PO 5	**Research-related Skills**	The graduates should be able to demonstrate: • a keen sense of observation, inquiry, and capability for asking relevant/ appropriate questions, • the ability to solve problems, synthesise and articulate issues and design research proposals, • the ability to define problems, formulate appropriate and relevant research questions, formulate hypotheses, test hypotheses using quantitative and qualitative data, establish hypotheses, make inferences based on the analysis and interpretation of data, and predict cause-and-effect relationships, • the capacity to develop appropriate methodology and tools for data collection, • the appropriate use of statistical and other analytical tools and techniques, • the ability to plan, execute and report the results of an experiment or investigation, • the ability to understand basic research ethics and skills in practising/doing ethics in the field/personal research work, regardless of the funding authority or field of study.
PO 6	**Coordinating / Collaborating with others**	The graduates should be able to demonstrate the ability to: • work effectively and respectfully with diverse teams, • facilitate cooperative or coordinated effort on the part of a group, • act together as a group or a team in the interests of a common cause and work efficiently as a team member.
PO 7	**Leadership Development**	The graduates should be able to demonstrate the capability for: • mapping out a team's or an organisation's tasks and setting direction. • formulating an inspiring vision and building a team that can help achieve the vision, motivating and inspiring team members to engage with that vision. • using management skills to guide people to the right destination.

PO 8	**Digital and technological skills**	The graduates should be able to demonstrate the capability to: • use ICT in a variety of learning and work situations, • access, evaluate, and use a variety of relevant information sources, • use appropriate software for analysis of data.
PO 9	**Multicultural competence and inclusive spirit**	The graduates should be able to demonstrate: • the acquisition of knowledge of the values and beliefs of multiple cultures and a global perspective to honour diversity, • capability to effectively engage in a multicultural group/society and interact respectfully with diverse groups, • capability to lead a diverse team to accomplish common group tasks and goals. • gender sensitivity and adopt gender-neutral approach, as also empathy to the less advantaged and the differently-abled including those with learning disabilities.
PO 10	**Value inculcation**	The graduates should be able to demonstrate the acquisition of knowledge and attitude that are required to: • embrace and practice constitutional, humanistic, ethical, and moral values in life, including universal human values of truth, righteous conduct, peace, love, nonviolence, scientific temper, citizenship values, • formulate a position/argument about an ethical issue from multiple perspectives • practice responsible global citizenship required for responding to contemporary global challenges, enabling learners to become aware of and understand global issues and to become active promoters of more peaceful, tolerant, inclusive, secure, and sustainable societies, • identify ethical issues related to work and follow ethical practices, including avoiding unethical behaviour such as fabrication, falsification or misrepresentation of data, or committing plagiarism, and adhering to intellectual property rights, • adopt objective, unbiased, and truthful actions in all aspects of work, • instil integrity, identify ethical issues related to work, and follow ethical practices.
PO 11	**Environmental awareness and action**	The graduates should be able to demonstrate the acquisition of and ability to apply the knowledge, skills, attitudes, and values required to take appropriate actions for: • recognize environmental and sustainability issues, and participate in actions to promote sustainable development. • mitigating the effects of environmental degradation, climate change, and pollution, • effective waste management, conservation of biological diversity, management of biological resources and biodiversity,
PO 12	**Community engagement and service**	The graduates should be able to demonstrate the capability to • participate in community-engaged services/ activities for promoting the well-being of society.

2.8 The Programme Specific Outcomes (PSOs)

	Type of Programme Specific Outcome (PSO)	*Programme Specific Outcome (PSO) Descriptor*
PSO 1	**Knowledge & understanding**	Graduates should be able to demonstrate the acquisition of: • comprehensive knowledge and understanding of theoretical and experimental chemistry knowledge in various fields of interest like Analytical Chemistry, Physical Chemistry, Inorganic Chemistry, Organic Chemistry, Material Chemistry, etc. • application of knowledge and understanding in a broad multidisciplinary context, their different learning areas, their linkages with related fields of study, and current and emerging developments.
PSO 2	**Skills Related to One's Specialization**	• skills involving the constructive use of knowledge in the subfields of chemistry (analytical, inorganic, organic and physical), and other related fields of study in a range of settings, including for pursuing higher studies related to the chosen area of specialization within chemical sciences.
PSO 3	**Application of Knowledge and Skills**	Graduates should be able to apply: • standard chemistry-related methodologies to conduct chemical syntheses, analyses or other chemical investigations to seek solutions to problems that emerge from the subfields of chemistry as well as from broader interdisciplinary subfields relating to chemistry.
PSO 4	**Quantitative, Analytical and Instrument-based Skills**	Graduates should be able to acquire: • hands-on training on various analytical instruments and classical quantitative techniques that will enable them to cross branches to join analytical, pharmaceutical, material testing and biochemical labs besides standard chemical laboratories.

2.9 The Structure of the UG Programmes

The curriculum is drafted according to the '*UGC Curriculum and Credit Framework for Undergraduate Programmes (2022)*' to equip students with knowledge, skills, values, and attitudes.

The curriculum consists of major stream courses, minor stream courses and courses from other disciplines, language courses, skill courses, and a set of courses on environmental education, understanding India, digital and technological solutions, health & wellness, yoga education, and sports and fitness. At the end of the second semester, students can decide to continue with their chosen 'major' or request a change in the 'major'. The minor stream courses will help the students to be equipped with job-oriented skills.

Overall, a three-year Degree course consists of three sections: Major (Core) Courses, Minor Courses, and Common Courses. While the Core Courses consist of Major and Departmental Electives, the Common Courses are divided into four sub-groups.

2.9.1 Major Courses

The Major Courses are divided into **Core Courses** and **Departmental Electives**.

Core Courses: A core course is a course that all students must study to complete the requirements for the undergraduate degree. These courses are designed to provide students with an in-depth knowledge of various areas of chemistry. These courses include foundation or introductory, intermediate-level, and higher-level courses and will enable students to thoroughly understand fundamental principles, theories, and applications in chemistry. Through laboratory experiments, the use and application of software, research projects, and hands-on training on analytical instruments, the students will enhance their academic prowess and develop a passion for advancing their understanding of chemistry.

Departmental Elective Courses: A departmental elective course can be chosen from a pool of courses. These specialised courses support the discipline of study, provide an extended scope, enable exposure to other domains, and nurture the candidate's proficiency/skill. Departmental Electives allow students to tailor their academic journey to their interests and career aspirations. These courses complement their major and provide insights into specialised knowledge and analytical skills for solving complex scientific challenges by exploring diverse topics.

The minimum number of credits to be earned from Major Courses for a 3-year UG Degree (Major) is 62 credits. For a 4-year Bachelor's Degree (Honours) it is 94 credits, while for a 4-year Bachelor's Degree (Honours with Research) it is 82 credits with 12 credits earned through a research project.

2.9.2 Minor Courses

Students will have the option to choose minor courses from other disciplines. After exploring courses from different disciplines, students may declare their minor and vocational stream choice at the end of the second semester. The students must opt for at least four credits per semester throughout the 3-year /4-year undergraduate programmes. Students must choose minor courses from other disciplines until their third year of undergraduate study, preferably from cognate disciplines. In the fourth year of UG, students can opt for online courses (MOOCs) from the SWAYAM platform. Students enrolling in a 4-year Bachelor's Degree (Honours with Research) must enrol in research methodology and ethics courses from the SWAYAM platform.

The minimum number of credits to be earned from Minor Courses for a 3-year UG Degree (Major) is 24 credits. For both 4-year Bachelor's Degree (Honours) and 4-year Bachelor's Degree (Honours with Research) is 32 credits.

2.9.3 Multi-Disciplinary Courses (MDC)

All undergraduate students must take three introductory-level courses relating to any of the broad disciplines given below. These courses are intended to broaden the intellectual experience and form part of liberal arts and science education. Students cannot choose MDC from courses already taken at the higher secondary level (12th class) in the proposed Major and Minor stream. These courses have a total of 9 credits.

These courses span over five different groups of subjects:

1. Natural and Physics Science,
2. Mathematics, Statistics, and Computer Applications,
3. Library, Information, and Media Sciences,
4. Commerce and Management, and
5. Humanities and Social Sciences.

2.9.4 Ability Enhancement Courses (AEC)

Students must achieve competency in the Modern Indian Language (MIL) and English, with special emphasis on language and communication skills. These courses aim to enable the students to acquire and demonstrate the core linguistic skills, including critical reading and expository and academic writing skills, that help them articulate their arguments, present their thinking clearly and coherently, and recognise the importance of language as a mediator of knowledge and identity. These courses are compulsory and will have a total of 8 credits.

2.9.5 Skill Enhancement Courses (SEC)

These courses aim to impart practical skills, hands-on training, soft skills, etc. They are compulsory and will have a total of 9 credits. These courses will enhance the employability/entrepreneurship of students who wish to exit after the first or second year of the UG programmes and will have a total of 9 credits.

2.9.6 Value Added Courses (VAC)

These courses span over the following broad areas. These courses will have a total of 6 credits.

1. Understanding India,
2. Environmental Science,
3. Digital and Technological Solutions, and
4. Health & Wellness, Yoga Education, Sports and Fitness

The environmental science courses are based on the UGC '*Guidelines and Curriculum Framework for Environment Education at Undergraduate Level (2023)*'. A course on Indian Knowledge System (IKS) relating to ancient Indian chemistry is introduced as part of the broad area 'Understanding India'.

2.9.7 Summer Internship/Apprenticeship

A key aspect of the new UG programme is the introduction of internships/apprenticeships for the students. All undergraduate students must undertake internships/apprenticeships of 2 credits in a firm, industry, or organisation or undergo laboratory training with faculty and researchers in their own or other HEIs/research institutions during the summer term to actively engage with the practical side of their learning and, as a by-product improve their employability.

Field-based minor project: The field-based learning/minor project will provide opportunities for students to understand the different socio-economic contexts. It will expose students to development-related issues in rural and urban settings. It will provide opportunities for students to observe situations in rural and urban contexts and to observe and study actual field situations regarding issues related to socioeconomic development. Students will be given opportunities to gain a first-hand understanding of the policies, regulations, organisational structures, processes, and programmes that guide development. They would have the chance to understand the complex socio-economic problems in the community and innovative practices required to generate solutions to the issues identified. This may be a summer term project on the subject of study.

2.9.8 Research Project/Dissertation

Students choosing a 4-Year Bachelor's degree (Honours with Research) must take up research projects under the guidance of a faculty member. The students are expected to complete the Research Project in the eighth semester. The research outcomes of their project work may be published in peer-reviewed journals or may be presented in conferences /seminars or may be patented.

2.9.9 Other Activities

Students enrolled in FYUP programmes in Chemistry may participate in activities related to the National Service Scheme (NCC), National Cadet Corps (NCC), adult education/literacy initiatives, mentoring

school students, and other similar activities to expose themselves to socio-economic issues in society, gain actual life experiences, and generate solutions to real-life problems, thereby contributing to nation-building.

Community engagement and service: The curricular component of 'community engagement and service' seeks to expose students to the socio-economic issues in society so that the theoretical learnings can be supplemented by actual life experiences to generate solutions to real-life problems. This can be part of summer term activity.

2.9.10 Course Structure for Four-Year Undergraduate Programme (FYUP) in Chemistry (Honours)

NCrF Credit Level	Sem	Major (CC)		Minor (MC)		Multidisciplinary Course (MDC)		Ability Enhancement Course (AEC)		Skill Enhancement Course (SEC)		Value-Added Course (VAC)		Internship/ Dissertation/ Seminar		Total Credit
		Course	Credit	Course	Credit	Course	Credit	Course	Credit	Course	Credit	Course	Credit	Course	Credit	
4.5	1st	Major 1	4	Minor 1	4	MDC 1	3	AEC 1	4	SEC 1	3	VAC 1	2			**20**
	2nd	Major 2	4	Minor 2	4	MDC 2	3	AEC 2	4	SEC 2	3	VAC 2	2			**20**
Students exiting the programme after the second Semester with 40 credits will be awarded a **UG Certificate in Chemistry**, provided they secure an additional 4 credits in work-based vocational courses offered during the summer term or internship / Apprenticeship																
5.0	3rd	Major 3	4	Minor 3 / VOC 1	4	MDC 3	3			SEC 3	3	VAC 3	2			**20**
		Major 4	4													
	4th	Major 5	4	Minor 4 / VOC 2	4											**20**
		Major 6	4													
		Major 7	4													
		Major 8	4													
Students exiting the programme after the fourth Semester with 80 credits will be awarded the **UG Diploma in Chemistry** provided they secure an additional 4 credits in skill-based vocational courses offered during the first or second-year summer term																
5.5	5th	Major 9	4	Minor 5 / VOC 3	4									Internship	2	**20**
		Major 10	4													
		Major 11	4													
		Major 12	2													
	6th	Major 13	4	Minor 6 / VOC 4	4											**20**
		Major 14	4													
		Major 15	4													
		Major 16	4													
Students exiting the programme after the 6th Semester with 120 credits will be awarded a **3-Year Bachelor's Degree (Major) in Chemistry**																
6.0	7th	Major 17	4	Minor 7 (Research Methodology)	4											**20**
		Major 18	4													
		Major 19	4													
		Major 20	4													
	8th	Major 21	4	Minor 8 (Research Publication Ethics)	4											**20**
		Major 22 (Departmental Elective 1)	4													
		Major 23 (Departmental Elective 2)	4													
		Major 24 (Departmental Elective 3)	4													
			94		**32**		**9**		**8**		**9**		**6**		**2**	**160**

2.9.11 Course Structure for Four-Year Undergraduate Programme (FYUP) in Chemistry (Honours with Research)

NCrF Credit Level	Sem	Major (CC)		Minor (MC)		Multidisciplinary Course (MDC)		Ability Enhancement Course (AEC)		Skill Enhancement Course (SEC)		Value-Added Course (VAC)		Internship/ Dissertation/ Seminar		Total Credit
		Course	Credit	Course	Credit	Course	Credit	Course	Credit	Course	Credit	Course	Credit	Course	Credit	
4.5	1st	Major 1	4	Minor 1	4	MDC 1	3	AEC 1	4	SEC 1	3	VAC 1	2			**20**
	2nd	Major 2	4	Minor 2	4	MDC 2	3	AEC 2	4	SEC 2	3	VAC 2	2			**20**
Students exiting the programme after the second Semester with 40 credits will be awarded a **UG Certificate in Chemistry**, provided they secure an additional 4 credits in work-based vocational courses offered during the summer term or internship / Apprenticeship																
5.0	3rd	Major 3	4	Minor 3 / VOC 1	4	MDC 3	3			SEC 3	3	VAC 3	2			**20**
		Major 4	4													
	4th	Major 5	4	Minor 4 / VOC 2	4											**20**
		Major 6	4													
		Major 7	4													
		Major 8	4													
Students exiting the programme after the fourth Semester with 80 credits will be awarded the **UG Diploma in Chemistry** provided they secure an additional 4 credits in skill-based vocational courses offered during the first or second-year summer term																
5.5	5th	Major 9	4	Minor 5 / VOC 3	4									Internship	2	**20**
		Major 10	4													
		Major 11	4													
		Major 12	2													
	6th	Major 13	4	Minor 6 / VOC 4	4											**20**
		Major 14	4													
		Major 15	4													
		Major 16	4													
Students exiting the programme after the 6th Semester with 120 credits will be awarded a **3-Year Bachelor's Degree (Major) in Chemistry**																
6.0	7th	Major 17	4	Minor 7 (Research Methodology)	4											**20**
		Major 18	4													
		Major 19	4													
		Major 20	4													
	8th	Major 21	4	Minor 8 (Research Publication Ethics)	4									Research Project	12	**20**
			82		**32**		**9**		**8**		**9**		**6**		**14**	**160**

2.9.12 Semester-Wise Credit Structure

SEMESTER I										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-1110	General Chemistry I	Major	Theory	45	80	20	100	3:0:1	4	**20**
			Practical	30	80	20	100			
XXX-001-MC-xxxx	Minor 1	Minor							4	
XXX-001-MD-xxxx	MDC 1	MDC							3	
ENG-001-AE-1110	English Language & Communication Skills	AEC		60	80	20	100	3:1:0	4	
CHE-001-SE-0010	Water Treatment and Analysis	SEC	Theory	30	80	20	100	1:0:2	3	
			Practical	30	80	20	100			
EVS-001-VA-1110	Environmental Science I	VAC		30	80	20	100	2:0:0	2	

SEMESTER II										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-1210	General Chemistry II	Major	Theory	45	80	20	100	3:0:1	4	**20**
			Practical	30	80	20	100			
XXX-001-MC-xxxx	Minor 2	Minor							4	
XXX-001-MD-xxxx	MDC 2	MDC							3	
ENG-001-AE-1210	Academic Writing & Professional Communication	AEC		60	80	20	100	3:1:0	4	
CHE-001-SE-0020	Soil Chemistry and Analysis	SEC	Theory	30	80	20	100	1:0:2	3	
			Practical	30	80	20	100			
EVS-001-VA-1210	Environmental Science II	VAC		30	80	20	100	2:0:0	2	

SEMESTER III										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-2110	General Chemistry III	Major	Theory	45	80	20	100	3:0:1	4	**20**
			Practical	30	80	20	100			
CHE-001-CC-2120	General Chemistry IV	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
XXX-001-MC-xxxx	Minor 3 / VOC 1	Minor							4	
XXX-001-MD-xxxx	MDC 3	MDC							3	
CHE-001-SE-0030	Air Pollution	SEC	Theory	30	80	20	100	1:0:2	3	
			Practical	30	80	20	100			
CHE-001-VA-2110	VAC 3 / MOOCs	VAC		30	80	20	100	2:0:0	2	

SEMESTER IV										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-2210	Inorganic Chemistry I	Major	Theory	45	80	20	100	3:0:1	4	**20**
			Practical	30	80	20	100			
CHE-001-CC-2220	Organic Chemistry I	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
CHE-001-CC-2230	Physical Chemistry I	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
CHE-001-CC-2240	Fundamentals of Molecular Spectroscopy	Major	Theory	45	80	20	100	2:1:1	4	
			Practical	30	80	20	100			
XXX-001-MC-xxxx	Minor 4 / VOC 2	Minor							4	

SEMESTER V										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-3110	Inorganic Chemistry II	Major	Theory	45	80	20	100	3:0:1	4	**20**
			Practical	30	80	20	100			
CHE-001-CC-3120	Organic Chemistry II	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
CHE-001-CC-3130	Physical Chemistry II	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
CHE-001-CC-3140	Green Chemistry	Major		30	80	20	100	1:1:0	2	
XXX-001-MC-xxxx	Minor 5 / VOC 3	Minor			80	20	100		4	
CHE-001-IN-3110	Internship	Internship		60	80	20	100	0:0:2	2	

SEMESTER VI										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-3210	Inorganic Chemistry III	Major	Theory	45	80	20	100	3:0:1	4	**20**
			Practical	30	80	20	100			
CHE-001-CC-3220	Organic Chemistry III	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
CHE-001-CC-3230	Physical Chemistry III	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
CHE-001-CC-3240	Quantum Chemistry	Major	Theory	45	80	20	100	2:1:1	4	
			Practical	30	80	20	100			
XXX-001-MC-xxxx	Minor 6 / VOC 4	Minor			80	20	100		4	

SEMESTER VII										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-4110	Inorganic Chemistry IV	Major	Theory	45	80	20	100	3:0:1	4	**20**
			Practical	30	80	20	100			
CHE-001-CC-4120	Organic Chemistry IV	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
CHE-001-CC-4130	Physical Chemistry IV	Major	Theory	45	80	20	100	3:0:1	4	
			Practical	30	80	20	100			
CHE-001-CC-4140	Advanced Molecular Spectroscopy	Major	Theory	60	80	20	100	3:1:0	4	
CHE-001-RC-4110	Research Methodology / MOOCs	Minor		60	80	20	100	3:1:0	4	

Semester-Wise Credit Structure for Four-Year Undergraduate Programme (FYUP) in Chemistry (Honours)

SEMESTER VIII										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-4210	Advanced Organometallic Chemistry	Major	Theory	45	80	20	100	2:1:1	4	**20**
			Practical	30	80	20	100			
CHE-001-DE-42XX0	Departmental Elective I	Major	Theory	45	80	20	100	2:1:1	4	
			Practical	30	80	20	100			
CHE-001-DE-42XX0	Departmental Elective II	Major	Theory	45	80	20	100	2:1:1	4	
			Practical	30	80	20	100			
CHE-001-DE-42XX0	Departmental Elective III	Major	Theory	45	80	20	100	2:1:1	4	
			Practical	30	80	20	100			
CHE-001-RC-4210	Research and Publication Ethics / MOOCs	Minor		60	80	20	100	3:1:0	4	

Semester-Wise Credit Structure for Four-Year Undergraduate Programme (FYUP) in Chemistry (Honours with Research)

SEMESTER VIII										
Course Code	**Course Title**	**Type of Course**	**Course Component**	**Contact Hour**	**Maximum Marks**			**Credit Distribution (L:T:P)**	**Credit**	**Total Credit**
					End Semester Examination	**Internal Assessment**	**Total**			
CHE-001-CC-4210	Advanced Organometallic Chemistry	Major	Theory	45	80	20	100	2:1:1	4	**20**
			Practical	30	80	20	100			
CHE-001-RC-4210	Research and Publication Ethics / MOOCs	Minor		60	80	20	100	3:1:0	4	
CHE-001-RP-4210	Research Project			360	240	60	300	0:0:12	12	

2.9.13 Semester-Wise Distribution of Courses

(A) MAJOR (CORE) COURSES

Semester	Course Code	Course Title	Credit Distribution (L:T:P)	Credit
I	CHE-001-CC-1110	General Chemistry I	3:0:1	4
II	CHE-001-CC-1210	General Chemistry II	3:0:1	4
III	CHE-001-CC-2110	General Chemistry III	3:0:1	4
	CHE-001-CC-2120	General Chemistry IV	3:0:1	4
IV	CHE-001-CC-2210	Inorganic Chemistry I	3:0:1	4
	CHE-001-CC-2220	Organic Chemistry I	3:0:1	4
	CHE-001-CC-2230	Physical Chemistry I	3:0:1	4
	CHE-001-CC-2240	Fundamentals of Molecular Spectroscopy	2:1:1	4
V	CHE-001-CC-3110	Inorganic Chemistry II	3:0:1	4
	CHE-001-CC-3120	Organic Chemistry II	3:0:1	4
	CHE-001-CC-3130	Physical Chemistry II	3:0:1	4
	CHE-001-CC-3140	Green Chemistry	1:1:0	2
VI	CHE-001-CC-3210	Inorganic Chemistry III	3:0:1	4
	CHE-001-CC-3220	Organic Chemistry III	3:0:1	4
	CHE-001-CC-3230	Physical Chemistry III	3:0:1	4
	CHE-001-CC-3240	Quantum Chemistry	2:1:1	4
VII	CHE-001-CC-4110	Inorganic Chemistry IV	3:0:1	4
	CHE-001-CC-4120	Organic Chemistry IV	3:0:1	4
	CHE-001-CC-4130	Physical Chemistry IV	3:0:1	4
	CHE-001-CC-4140	Advanced Molecular Spectroscopy	3:1:0	4
VIII	CHE-001-CC-4210	Advanced Organometallic Chemistry	2:1:1	4
	CHE-001-DE-42XX0	Departmental Elective I	2:1:1	4
	CHE-001-DE-42XX0	Departmental Elective II	2:1:1	4
	CHE-001-DE-42XX0	Departmental Elective III	2:1:1	4

Departmental Electives (DE)

Semester	Course Code	Course Title	Credit Distribution (L:T:P)	Credit
VIII	CHE-001-DE-42010	Bioinorganic Chemistry	2:1:1	4
	CHE-001-DE-42020	Inorganic Reaction Mechanisms	2:1:1	4
	CHE-001-DE-42030	Organic Synthesis	2:1:1	4
	CHE-001-DE-42040	Chemistry of Natural Products	2:1:1	4
	CHE-001-DE-42050	Polymer Chemistry	2:1:1	4
	CHE-001-DE-42060	Advanced Chemical Kinetics	2:1:1	4

(B) MINOR COURSES

For Four-Year Undergraduate Programme (FYUP) in Chemistry

- Please refer to the syllabus of other departments/disciplines for opting for Minor Courses.

- Some Universities in India require mathematics and/or physics courses to be studied by the student for admission into M.Sc. (Chemistry). Thus, students are advised to choose accordingly.

For other Departments/Disciplines

Semester	Course Code	Course Title	Credit Distribution (L:T:P)	Credit
I	CHE-001-MC-1110	Fundamentals of Chemistry I	3:0:1	4
II	CHE-001-MC-1210	Fundamentals of Chemistry II	3:0:1	4
III	CHE-001-MC-2110	Fundamentals of Chemistry III	3:0:1	4
IV	CHE-001-MC-2210	Fundamentals of Chemistry IV	3:0:1	4
V	CHE-001-MC-3110	Fundamentals of Chemistry V	3:0:1	4
VI	CHE-001-MC-3210	Fundamentals of Chemistry VI	3:0:1	4

For FYUP BSc (Chemistry)

Semester	Course Code	Course Title	Credit Distribution (L:T:P)	Credit
VII	CHE-001-RC-4110	Research Methodology	3:1:0	4
VIII	CHE-001-RC-4210	Research and Publication Ethics	3:1:0	4

(C) MULTIDISCIPLINARY COURSES (MDC)

Semester	Course Code	Course Title	Credit Distribution (L:T:P)	Credit
I	CHE-001-MD-1110	Chemistry of Food, Cosmetics and Perfumes	3:0:0	3
II	CHE-001-MD-1120	Chemistry in Daily Life	3:0:0	3
III	CHE-001-MD-2110	Introduction to Medicinal Chemistry	3:0:0	3

- Students cannot choose MDC from courses already taken at the higher secondary level (12th class) in the proposed major and minor stream.

(D) ABILITY ENHANCEMENT COURSES (AEC)

Semester	Course Code	Course Title	Credit Distribution (L:T:P)	Credit
I	ENG-001-AE-1110	English Language & Communication Skills	3:1:0	4
II	ENG-001-AE-1210	Academic Writing & Professional Communication	3:1:0	4

(E) SKILL ENHANCEMENT COURSES (SEC)

Semester	Course Code	Course Title	Credit Distribution (L:T:P)	Credit
I	CHE-001-SE-0010	Water Treatment and Analysis	1:0:2	3
II	CHE-001-SE-0020	Soil Chemistry and Analysis	1:0:2	3
III	CHE-001-SE-0030	Air Pollution	1:0:2	3

(F) VALUE-ADDED COURSES (VAC)

Semester	Course Code	Course Title	Credit Distribution (L:T:P)	Credit
I	EVS-001-VA-1110	Environmental Science I	2:0:0	2
II	EVS-001-VA-1210	Environmental Science II	2:0:0	2
III	CHE-001-VA-2110	Indian Knowledge System: Chemistry in Ancient India	2:0:0	2

- Students must choose **VAC 3** (Semester III) from one of the courses related to the following three domains.
    1. Understanding India,
    2. Digital and Technological Solutions, and
    3. Health & Wellness, Yoga Education, Sports and Fitness

2.9.14 Conversion of Percentage into Credit(s) and Grade(s)

- Under the absolute grading system adopted by the University, the marks shall be converted to grades based on pre-determined class intervals. The grading system with the following letter grades shall be adopted to award the grades and CGPA under the credit-based semester system.

% of Marks	Grade Point	Letter Grade
90-100 %	10	O (Outstanding)
80-less than 90 %	9	A+ (Excellent)
70-less than 80 %	8	A (Very Good)
60-less than 70 %	7	B+ (Good)
50-less than 60 %	6	B (Above Average)
40-less than 50 %	5	C (Average)
35-less than 40 %	4	P (Pass)
Less than 35	0	F (Fail)
Absent	0	AB (Absent)

- Conversion to grade point to percentage = Grade Point $\times$ 10.0.
- A student obtaining a Grade D shall be considered failed and shall be required to reappear in the examination.

- Computation of SGPA and CGPA:
    (i) **Semester Grade Point Average (SGPA)** is the sum of the products of the course credit and grade points scored by a student divided by the sum of all course credits offered by the student. It can be calculated in the following manner:

$$SGPA\ (S_i) = \frac{\sum(C_i \times G_i)}{\sum C_i}$$

    Where, C_i is the number of credits of the i^{th} course and G_i is the grade point scored by the student in the i^{th} course.

    (i) **Cumulative Grade Point Average (CGPA)** is the sum of the products of the total number of credits of all courses taken by a student in a semester with the SGPA in that

semester divided by the total number of credits of all courses taken. It can be calculated in the following manner:

$$CGPA = \frac{\sum(C_i \times S_i)}{\sum C_i}$$

Where, S_i is the SGPA of the i^{th} semester and C_i is the number of credits in that semester.

2.9.15 Teaching-Learning Processes

B.Sc. (Hons) Chemistry programme is a three-year degree programme designed to provide students with a sound theoretical background and practical training in all aspects of chemistry and helps them develop an appreciation of the importance of chemistry in different contexts. The programme includes foundational and in-depth courses that span the traditional sub-disciplines of chemistry. Along with the above Core Courses, there are Discipline Specific Elective Courses, Generic Elective Courses and Ability Enhancement Courses, which will address the need of the hour.

These courses shall be delivered through classroom, laboratory work, projects, case studies and fieldwork in a challenging, engaging, and inclusive manner that accommodates a variety of learning styles and tools (PowerPoint presentations, audiovisual resources, e-resources, seminars, workshops, models, software).

The laboratory training complements the theoretical principles learned in the classroom and includes molecule synthesis, measurement of chemical properties and phenomena, hands-on experience with modern instruments, computational data analysis, modelling, and laboratory safety procedures.

2.9.16 Assessment Methods

The primary objective of the assessment of the academic performance of a student in various courses is to assess the learning outcomes of the course in tune with the broad outcomes of strengthening core theoretical knowledge and practical laboratory skills. The assessment methodologies that should be adopted for this curriculum include (but are not limited to) the following.

- The oral and written examinations (Scheduled and surprise tests),
- Problem-solving exercises,
- Practical assignments and laboratory reports,
- Individual and group assignments,
- seminar presentations,
- *Viva voce* interviews.

2.9.17 Conduct of Examinations

(a) All students shall be subjected to continuous evaluation and assessment. Accordingly, a student must attend and duly pass at least two Internal Assessment tests out of three and the End Semester Examination.

(b) The structure of these Internal Assessment Tests and End Semester Examinations shall be 20:80.

(c) To calculate the SGPA, the two best internal assessment tests taken shall be considered. Attending two Internal Assessment tests out of three shall be compulsory.

(d) The following shall be applicable:
   (i) At least two Internal Assessment tests will be written.
   (ii) At least one Internal Assessment test shall be an assignment such as a term course, book review, group discussion, PowerPoint presentation, or even another written test. The format to apply shall be at the discretion of the course teacher.
   (iii) Internal Assessment tests for all practical courses shall always be a practical test.

(e) In terms of marks, a theoretical component of each course is 100 marks: 20 marks for internal assessment and 80 marks for end-semester examination. The practical component will be 100 marks: 20 for the internal assessment and 80 for the end-semester practical examination.

(f) The minimum pass mark for each course at the end-semester examination shall be 35 %. The minimum pass mark for the internal assessment tests shall be 35 % for each course. The minimum pass mark for a practical course shall be the same as that of the theory course. The questions for the end-term theory examination will be distributed as follows:

For courses (L:T:P) **:** 1:1:0 / 2:0:0 / 3:0:0 / 1:0:2 / 2:1:1 / 3:0:1

Section	Total Questions	Marks for Each Question	To Attempt	TOTAL
A	4	5	4	20
B	4	10	3	30
C	3	15	2	30
				80

For courses (L:T:P)**:** 3:1:0

Section	Total Questions	Marks for Each Question	To Attempt	TOTAL
A	5	5	4	20
B	4	10	3	30
C	4	15	2	30
				80

(g) Students choosing a 4-Year Bachelor's degree (Honours with Research) must take up research projects under the guidance of a faculty member. Upon completion of the research project, students must submit the work as a dissertation followed by an oral presentation in the presence of faculty members and external expert(s). The research outcomes of their project work may be published in peer-reviewed journals or may be presented in conferences /seminars or may be patented.

PART 3: COURSE CONTENTS

3.1 MAJOR (CORE) COURSES

SEMESTER I

NCrF Level	4.5	
Course Code	CHE-001-CC-1110	
Title of the Course	General Chemistry I	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course reviews the structure of the atom, which is a necessary prerequisite to understanding the nature of chemical bonding in compounds. It is designed to teach the concept of aromaticity and its applications in detail so that the students can acquire the foundation for a better understanding of other organic chemistry topics in subsequent semesters. The course further covers the basic and advanced concepts regarding gaseous states of matter. It deals with various mathematical equations that express different physical properties of gases. The course also provides insight into laboratory courses involving acid-base and redox titrations.

Course Outcomes

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

CO1: Understand the quantum mechanical model of atoms, quantum numbers, electronic configuration, radial and angular distribution curves, and shapes of *s*, *p*, and *d* orbitals.

CO2: Apply the concept of aromaticity to explain the various physical and chemical properties of different organic compounds.

CO3: Acquire knowledge on methods of determination of organic reaction mechanism, kinetically and thermodynamically controlled products and reactions.

CO4: Understand the differences between ideal and real gases, derive the kinetic gas equation, and determine the deviation from ideal behaviour and its reason.

CO5: Estimate metal contents in different samples using acid-base and redox titration techniques.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Atomic Structure Bohr's theory, limitations, and the atomic spectrum of hydrogen. Wave mechanics: de Broglie equation, Heisenberg's uncertainty principle and its significance, Schrödinger's wave equation, the significance of ψ and ψ^2. Quantum numbers and their significance. Normalised and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atoms. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals. Pauli's exclusion principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.	15	CO1

Conceptual Organic Chemistry Aromaticity: Hückel's rule, aromatic, non-aromatic, antiaromatic, homoaromatic compounds, *n*-annulenes. Applications of concept of aromaticity: acidity & basicity, stability, reaction kinetics. Effect of magnetism on aromaticity. Reaction mechanisms: thermodynamic and kinetic requirements of reactions, Hammond postulate, intermediate and transition states, kinetically and thermodynamically controlled products and reactions, methods of determining mechanism, and primary and secondary kinetic isotope effect. Linear free energy relationship and their applications (Hammet equation & modification).	15	CO2, CO3
States of Matter I *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, the relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. *Behaviour of Real Gases*: Deviations from ideal gas behaviour, compressibility factor, *Z*, and its variation with pressure for different gases. Causes of deviation from ideal behaviour. van der Waals equation of state, its derivation and application in explaining real gas behaviour, introduction of equations of state; virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, and law of corresponding states.	15	CO4
Practical: General Chemistry I 1. Acid-Base Titrations (a) Determination of alkali content of antacid tablets using HCl. (b) Estimation of calcium content in chalk as calcium oxalate. (c) Estimation of carbonate and hydroxide present together in mixture. (d) Estimation of carbonate and bicarbonate present together in a mixture. (e) Estimation of free alkali present in different soaps/detergents 2. Redox Titrations (a) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution. (b) Estimation of oxalic acid and sodium oxalate in a given mixture. (c) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicators.	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins's Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015). (ISBN: 978-0198757177).
4. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2020). (ISBN: 978-8192143330).
5. Sykes, P., *A Guidebook to Mechanism in Organic Chemistry*, 6th Ed., Pearson Education India (2003). (ISBN: 978-8177584332).
6. Kalsi, P. S., *Organic Reactions and Their Mechanisms*, 5th Ed., New Age Science (2022). (ISBN: 978-9389802085).
7. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015). (ISBN: 978-8126556588).
8. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press, New Delhi (2014). (ISBN: 978-0198728719).
9. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
10. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
11. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019). (ISBN: 978-9353165185).
12. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093).

Practical

1. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).
2. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Pearson Education India (2009). (ISBN: 978-8131723258).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO2	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO3	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO4	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	M	H	M

H = High; M = Medium; L = Low

SEMESTER II

NCrF Level	4.5	
Course Code	CHE-001-CC-1210	
Title of the Course	General Chemistry II	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course introduces students to *s*- and *p*-block elements and compounds. Stereochemistry is introduced to visualise organic molecules in a three-dimensional space. The course also aims to provide perceptions of various mathematical equations that express different physical properties of gases, liquids and solids.

Course Outcomes

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

CO1: Understand the relative stability of different oxidation states, structure, bonding, preparation, properties and uses of *s*- & *p*-block elements.

CO2: Understand the stereochemical and conformational aspects of acyclic and cyclic organic molecules.

CO3: Evaluate molecular velocities (average, root mean square and most probable) and average kinetic energy of gases.

CO4: Derive mathematical expressions for different properties of gas, liquid, and solids to understand their physical significance.

CO5: Have practical experience in the measurement of surface tension and viscosity.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemistry of *s*- and *p*-Block Elements Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of the first member of each group. Allotropy and catenation. Complex formation tendency of *s*- and *p*-block elements. Study the following compounds with emphasis on structure, bonding, preparation, properties and uses. (a) Boron: Boric acid and borates, boron nitrides, borohydrides (diborane). (b) Carbon: Types of carbide, CaC_2, SiC, Al_4C_3- preparation, properties and uses (c) Silicon: Silanes, silicon halides. (d) Nitrogen & Phosphorus: ammonia-manufacture (Haber's process), Oxides and oxoacids of nitrogen and phosphorus.	15	CO1

(e) Sulphur: Sulphuric acid and its properties as dehydrating agent, oxidising property and action on metals and non-metals. Peroxo acids of sulphur. (f) Halogen: Basic properties of halogens, interhalogen compounds, polyhalide ions, pseudohalogens.		
Stereochemistry I Stereoisomerism in organic compounds. Constitutional, conformational and configurational isomers. Nomenclature for conformers: American and British systems of nomenclature, Klyne-Prelog conformational terminology. Optical activity & isomerism. Homomers, enantiomers, diastereomers. Chiral centres. Projection formulae and interconversion. Chiral axis and chiral planes, helical chirality. Conformational analysis of simple cyclic & acyclic systems. Optical purity. Atropisomerism.	15	CO2
States of Matter II *Gaseous State*: Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, the law of equipartition of energy, degrees of freedom and molecular basis of heat capacities. *Liquid State*: Physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Temperature variation of viscosity of liquids and comparison with that of gases. Qualitative discussion of the structure of water. *Solid State:* Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law. Defects in crystals.	15	CO3, CO4
Practical: General Chemistry II 1. Surface tension measurements. (a) Determine the surface tension by the drop number method. (b) Study the variation of surface tension of detergent solutions with concentration. 2. Viscosity measurement using Ostwald's viscometer. (a) Determination of viscosity of aqueous solutions of (i) polymer, (ii) ethanol, and (iii) sugar at room temperature. (b) Study the variation of viscosity of sucrose solution with the concentration of solute. 3. Determination of water of crystallisation.	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).

3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins' Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015). (ISBN: 978-0198757177).
4. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
5. Sykes, P., *A Guidebook to Mechanism in Organic Chemistry*, 6th Ed., Pearson Education India (2003). (ISBN: 978-8177584332).
6. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015). (ISBN: 978-8126556588).
7. Sengupta, S., *Basic Stereochemistry of Organic Molecules*, 2nd Ed., Oxford University Press India (2018). (ISBN: 978-0199492213).
8. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
9. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
10. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019). (ISBN: 978-9353165185).
11. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	M	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	M	H	H

H = High; M = Medium; L = Low

SEMESTER III

NCrF Level	5.0	
Course Code	CHE-001-CC-2110	
Title of the Course	General Chemistry III	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course provides general and advanced knowledge about chemical bonding *viz*. ionic and covalent bonding. It deals with the chemistry of organic molecules such as alcohols, phenols, thiols, esters, thioesters and epoxides. The course also encompasses various named reactions associated with these functional groups and their mechanisms. It further discusses the important topics in physical chemistry like thermodynamic concepts, laws of thermodynamics, thermochemistry, and dependence of thermodynamic parameters on composition. This course will also provide a basic understanding of chromatography, crystallization techniques and detection of elements.

Course Outcomes

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

CO1: Acquire knowledge on chemical bonding viz. ionic and covalent bonding.
CO2: Deduce the shape (geometry) of molecules using radius ratio rules & VSEPR theory.
CO3: Understand the preparation, properties and reactions of alcohols, phenols, thiols, ethers, thioethers and epoxides.
CO4: Understand the laws of thermodynamics, thermochemistry and free energy functions.
CO5: Purify organic compounds using crystallization techniques and to detect different elements present in unknown organic compounds.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemical Bonding I *Ionic Bond*: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, solvation energy. Covalent character in ionic bonds (Fajan's Rule) and its application. *Covalent Bond*: Ionic and covalent bonding (characteristics and properties), Valence bond theory. Application of hybridisation (*sp*, sp^2, sp^3, dsp^3 and d^2sp^3) to explain the structure of simple molecules. Bent's rule, resonance and resonance energy. Polarity in covalent molecules, dipole moment, percentage ionic character and electro-negativity difference. Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs	15	CO1, CO2

and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths.		
Alcohols, Phenols, Thiols, Ethers, Thioethers and Epoxides 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. Preparation and reactions of thiols and thioethers. Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$.	15	CO3
Chemical Thermodynamics I A brief overview of the laws of thermodynamics. Thermodynamic criteria for the processes in terms of entropy change, internal energy change, enthalpy and free energy (Gibbs and Helmholtz) change. *Thermochemistry*: 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) and pressure on enthalpy of reactions. Adiabatic flame temperature, explosion temperature. *Free Energy Functions*: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. The relation between Joule-Thomson coefficient and other 22 thermodynamic parameters; inversion temperature; Gibbs – Helmholtz equation and its utility in reaction thermodynamics; Maxwell relations; thermodynamic equation of state.	15	CO4
Practical: General Chemistry III 1. Purification of organic compounds by crystallisation using Water /Alcohol/Alcohol-Water and determination of their melting points. 2. Detection of elements (nitrogen, sulphur and halogens) in unknown organic compounds.	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).

4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2020). (ISBN: 978-8192143330)
6. Morrison, R. T.; Boyd, R. N.; Bhattacharjee, S. K., *Organic Chemistry*, 7th Ed., Pearson Education India, New Delhi (2010). (ISBN: 978-8131704813).
7. Finar, I. L., *Organic Chemistry*, Volume 1, 6th Ed., Pearson Education (2002). (ISBN: 978-8177585421).
8. Finar, I. L., *Organic Chemistry*, Volume 2, 5th Ed., Pearson Education (2002). (ISBN: 978-8177585414).
9. Graham Solomons, T.W.; Fryhle, C. B.; Snyder, S. A., *Solomons Organic Chemistry*, Global Edition., Wiley (2024). (ISBN: 978-8126568116).
10. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
11. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
12. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India, New Delhi (2003). (ISBN: 978-8177589573).
2. Mann, F. G.; Saunders, B. C., *Practical Organic Chemistry*, 4th Ed., Pearson Education India, New Delhi (2009). (ISBN: 978-8131727102).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers, New Delhi (2007). (ISBN: 978-8123915012).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan, Meerut (2014). (ISBN: 978-8182835054)
5. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2004). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	M	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO2	H	-	-	-	-	-	-	-	-	-	-	-	H	M	H	-
CO3	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	M	M	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER III

NCrF Level	5.0	
Course Code	CHE-001-CC-2120	
Title of the Course	General Chemistry IV	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course aims to provide students with knowledge of bonding theories used to explain the various types of bonds. The students are also introduced to semiconductors and insulators. This course covers details of nitrogen-containing functional groups—their preparation, properties, reactivity, and distinction. Students will study the use of steady-state approximation in deriving rate expressions for simple and complex reaction systems. Students will be introduced to basic experiments on chemical kinetics.

Course Outcomes

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

CO1: Acquire knowledge of the bonding theories and weak chemical forces used to explain various types of bonds (ionic, covalent and metallic).
CO2: Have an understanding of band theory, semiconductors and insulators.
CO3: Acquire a better understanding of the chemistry of compounds having nitrogen-containing functional groups.
CO4: Derive rate expressions for simple and complex reactions using steady-state approximations.
CO5: Acquire practical knowledge on rate determination of simple first and second-order reactions.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemical Bonding II Molecular orbital theory. Molecular orbital diagrams of diatomic (N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions) and simple polyatomic (HCl, BeH_2, CO_2, XeF_2) molecules. *s-p* mixing and orbital interaction. *Metallic Bond*: Qualitative idea of band theory. Semiconductors and insulators. *Weak Chemical Forces*: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment). Effects of chemical force, melting and boiling points, solubility energetics of dissolution process.	15	CO1, CO2

Nitrogen-Containing Functional Groups Preparation and important reactions of nitro 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 their synthetic applications.	15	CO3
Chemical Kinetics I Brief overview of reaction rate, rate equation, order and molecularity Steady-state approximation and kinetics of simple reactions (e.g., decomposition of ozone, reaction between NO and O_2, iodination of acetone, decomposition of gaseous N_2O_5). Kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions, (iii) consecutive reactions. Chain reactions: general treatment and explanation of explosions; reaction mechanism and kinetics of H_2-Br_2 reaction and pyrolysis of alkane. Enzyme catalysis: mechanism and kinetics of enzyme catalysis reaction Oscillatory reactions: mechanism and kinetics. Reactions in flow systems; kinetics of fast reaction.	15	CO4
Practical: General Chemistry IV 1. To determine the rate constant of acid-catalysed hydrolysis of esters. 2. To determine the rate constant of base-catalysed hydrolysis of esters. 3. To investigate the reaction between acetone and iodine in the presence of an acid and to determine the order with respect to each reactant. 4. Determination of relative strengths of HCl and H_2SO_4 by studying the kinetics of hydrolysis of methyl acetate. 5. To determine the rate constant of reaction between KI and $K_2S_2O_8$.	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).

3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).
4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Morrison, R. T.; Boyd, R. N.; Bhattacharjee, S. K., *Organic Chemistry*, 7th Ed., Pearson Education India, New Delhi (2010). (ISBN: 978-8131704813).
6. Finar, I. L., *Organic Chemistry*, Volume 1, 6th Ed., Pearson Education (2002). (ISBN: 978-8177585421).
7. Finar, I. L., *Organic Chemistry*, Volume 2, 5th Ed., Pearson Education (2002). (ISBN: 978-8177585414).
8. Graham Solomons, T.W.; Fryhle, C. B.; Snyder, S. A., *Solomons Organic Chemistry*, Global Edition., Wiley (2024). (ISBN: 978-8126568116).
9. Laidler, K. J., *Chemical Kinetics*, 3rd Ed., Pearson Education, New Delhi (2003). (ISBN: 978-8131709726).
10. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
11. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).
3. Khosla, B. D.; Garg, V. C.; Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2008). (ISBN: 978-8180450792).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO2	H	M	-	-	-	-	-	-	-	-	-	-	H	M	M	-
CO3	H	H	M	-	-	-	-	-	-	-	-	-	H	M	H	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	M	M	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER IV

NCrF Level	5.0	
Course Code	CHE-001-CC-2210	
Title of the Course	Inorganic Chemistry I	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces students to theories that explain acid and base chemistry, including the Pearson acid-base concept. It deals with the basic and advanced topics of synthesis, structure, and bonding in inorganic cages and clusters. Further, it discusses coordination compounds, which find manifold applications in diverse areas. Students will be introduced to the iodometric titration and preparation of inorganic compounds.

Course Outcomes

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

CO1: Understand various theories of acids and bases, Pearson's HSAB principle and its applications.
CO2: Know the synthesis, structure and bonding in inorganic cages and clusters.
CO3: Have good knowledge of various basic concepts associated with coordination chemistry.
CO4: Gain an understanding of chemical bonding in metal complexes and application of Valence Bond Theory to predict the structure and magnetic behaviour of complexes.
CO5: Acquire knowledge of iodometric titration and preparation of inorganic compounds.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Acids and Bases Arrhenius, Brönsted-Lowry, and Lewis concepts of acids and bases, Proton transfer equilibria in water, solvent levelling, classification of acids and bases as hard and soft. Pearson's HSAB concept, acid-base strength and hardness and softness. Theoretical basis of hardness and softness, electronegativity and hardness and softness. Applications of acid-base chemistry in qualitative analysis and catalysis, superacids and superbases.	15	CO1
Inorganic Cages & Clusters Structure and bonding in polyhedral boranes, carboranes, metalloboranes and metallocarboranes, *styx* notation; Wade's rule; electron count in polyhedral boranes; synthesis of polyhedral boranes. Synthesis, structure and bonding in borazines, phosphazenes, sulphur-nitrogen compounds, siloxanes, iso- and hetero-poly anions. Structure and chemistry of silicates, aluminosilicates, zeolites and clays.	15	CO2

Coordination Chemistry Isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Chelate effect, polynuclear complexes, Labile and inert complexes. Werner's theory, valence bond theory, electroneutrality principle and back bonding. Crystal field theory, measurement of 10 D*q* (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 D*q* (Δ_o, Δ_t). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry (Jahn-Teller theorem), square planar geometry. Molecular orbital (MO) theory of selected octahedral and tetrahedral complexes; thermodynamic aspects of CFSE.	15	CO3, CO4
Practical: Inorganic Chemistry I 1. Iodometric titrations (a) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution. (b) Estimation of (i) arsenite and (ii) antimony in antimony potassium tartrate. (c) Estimation of available chlorine in bleaching powder. 2. Inorganic preparations (a) Cuprous Chloride (Cu_2Cl_2) from copper sulphate. (b) Preparation of Manganese phosphate ($MnPO_4 \cdot xH_2O$) from manganese nitrate [$Mn(NO_3)_2$]. (c) Preparation of chrome alum [$K_2SO_4 \cdot Cr_2(SO_4)_3 \cdot 24H_2O$] and potash alum [$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$].	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).
4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins's Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015). (ISBN: 978-0198757177).
6. Miessler, G.; Tarr, D. A., Inorganic Chemistry, 3rd Ed., Pearson Education India, New Delhi (2008). (ISBN: 978-8131718858).

Practical

1. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).
2. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 7th Ed., Pearson Education India (2012). (ISBN: 978-8131773710).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO5	H	H	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER IV

NCrF Level	5.0	
Course Code	CHE-001-CC-2220	
Title of the Course	Organic Chemistry I	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course covers the chemistry of organic molecules bearing a few common functional groups, including polynuclear hydrocarbons, carbonyl, carboxylic acid, and their derivatives. It also deals with the synthesis, reactivity, and chemistry of 5- and 6-membered heterocycles. Synthetic avenues, physical and chemical properties, and characteristic reactions of such compounds will be discussed in detail. The course also encompasses various named reactions associated with these functional groups and their mechanisms. Students will also learn about the identification of functional groups and the preparation of organic compounds.

Course Outcomes

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

CO1: Acquire a better understanding of the chemistry of polynuclear hydrocarbons, carbonyl compounds carboxylic acids and their derivatives.

CO2: Acquire knowledge on name reactions (including mechanisms) associated with carbonyl compounds, carboxylic acids, their derivatives and a few important heterocycles.

CO3: Learn about the chemistry of a few 5- and 6-membered heterocycles.

CO4: Practical experiences identifying alcohol, phenol, carbonyl and carboxylic acid functionalities.

CO5: Learn a few organic reactions for functional group transformation.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Polynuclear Hydrocarbons and Carbonyl Compounds *Polynuclear Hydrocarbons*: Structures, preparations and reactions of naphthalene, phenanthrene and anthracene. *Carbonyl Compounds*: Structure, preparation and reactivity; nucleophilic addition-elimination reactions with ammonia derivatives and their mechanisms. *Active Methylene Compounds*: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate. *Named Reactions:* Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin and Cannizzaro	15	CO1, CO2

reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Michael addition.		
Carboxylic Acids and their Derivatives 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 sulphonic acids. Preparation and reactions of acid chlorides, anhydrides, esters and amides; Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.	15	CO1, CO2
Heterocyclic Compounds Classification and nomenclature, Structure, aromaticity in 5- and 6-membered rings containing one heteroatom (pyrrole, furan, thiophene and pyridine); synthesis, reactions and mechanism of substitution reactions of: furan, pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzsch synthesis), thiophene, pyridine (Hantzsch synthesis); 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. Concept of π-excessive and π-deficient heterocyclics.	15	CO3
Practical: Organic Chemistry I 1. Functional group tests for alcohols, phenols, carbonyl and carboxylic acid group. 2. Organic preparations: (a) Benzolyation of phenols (β-naphthol/resorcinol/p-cresol) by Schotten-Baumann reaction. (b) Oxidation of ethanol/ acetone (Iodoform reaction). (c) Reduction of *p*-nitrobenzaldehyde/ *m*-nitrobenzaldehyde by sodium borohydride. (d) Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.	30	CO4, CO5

Recommended Books

Theory

1. Morrison, R. T.; Boyd, R. N.; Bhattacharjee, S. K., *Organic Chemistry*, 7th Ed., Pearson Education India, New Delhi (2010). (ISBN: 978-8131704813).
2. Finar, I. L., *Organic Chemistry*, Volume 1, 6th Ed., Pearson Education (2002). (ISBN: 978-8177585421).
3. Finar, I. L., *Organic Chemistry*, Volume 2, 5th Ed., Pearson Education (2002). (ISBN: 978-8177585414).
4. Graham Solomons, T. W.; Fryhle, C. B.; Snyder, S. A., *Solomon's Organic Chemistry*, Global Edition., Wiley (2024). (ISBN: 978-8126568116).
5. Ghosh, S. K., *Advanced General Organic Chemistry*, Part-I & Part-II, 3rd Ed., New Central Book Agency (2010). (ISBN: 978-8173814419).

6. Bhal, B. S.; Bhal, A., *A Textbook of Organic Chemistry*, 22nd Ed., S. Chand and Company (2019). (ISBN: 978-9352531967).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India, New Delhi (2003). (ISBN: 978-8177589573).
2. Mann, F. G.; Saunders, B. C., *Practical Organic Chemistry*, 4th Ed., Pearson Education India, New Delhi (2009). (ISBN: 978-8131727102).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers, New Delhi (2007). (ISBN: 978-8123915012).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan, Meerut (2014). (ISBN: 978-8182835054).
5. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2004). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	-	M	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	-	M	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	M	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	L	-	-	-	H	-	-	-	-	-	-	H	H	H	H
CO5	H	L	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER IV

NCrF Level	5.0	
Course Code	CHE-001-CC-2230	
Title of the Course	Physical Chemistry I	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course discusses chemical equilibrium, equilibrium constants, and the relationship between three different types of equilibrium constants in detail. It also aims to help the students understand conductance, conductivity, chemical cells, the Nernst equation, and the applications of EMF measurements in determining various physical chemistry parameters. Further, the course introduces the students to conductometry and potentiometric titrations.

Course Outcomes

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

CO1: Apply the concepts of gas equations, Le Chatelier's principle, Gibbs free energy of reaction, etc., while studying other chemistry courses and everyday life.

CO2: Understand conductance and conductivity and the application of conductance measurement in determining various physical chemistry parameters.

CO3: Understand the standard electrode potential of half cells and calculate the EMF of a cell using the Nernst equation.

CO4: Apply EMF measurements to determine various parameters like free energy, enthalpy, entropy, equilibrium constants, etc.

CO5: Gain experimental knowledge on conductometry and potentiometric titrations.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemical Equilibrium Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases, concept of fugacity. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Coupling of exoergic and endoergic reactions. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between the various equilibrium constants K_p, K_c and K_x. Le Chatelier's principle (quantitative treatment); equilibrium between ideal gases and a pure condensed phase.	15	CO1
Conductance The Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye-	15	CO2

Hückel-Onsager equation. Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.		
Electrochemistry 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/Sb_2O_3 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).	15	CO3, CO4
Practical: Physical Chemistry I 1. Conductometry (a) Determination of cell constant of a given conductivity cell. (b) Determination of equivalent conductance of a weak electrolyte at different concentrations and the dissociation constant of the electrolyte. (c) Study the kinetics of saponification of ethyl acetate by NaOH at two temperatures by conductance measurements and hence determine the energy of activation of the reaction. (d) Perform the following conductometric titrations: (i) Strong acid vs. strong base. (ii) Weak acid vs. strong base. (iii) A mixture of strong acid and weak acid vs. strong base. (iv) Strong acid vs. weak base. 2. Perform the following potentiometric titrations: (a) Strong acid vs. strong base. (b) Weak acid vs. strong base. (c) Dibasic acid vs. strong base.	30	CO5

Recommended Books

Theory

1. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
2. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
3. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019). (ISBN: 978-9353165185).
4. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093).

5. Negi, A. S.; Anand, S. C., *Physical Chemistry*, 3rd Ed., New Age International Publishers (2023). (ISBN: 978-9393159793).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER IV

NCrF Level	5.0	
Course Code	CHE-001-CC-2240	
Title of the Course	Fundamentals of Molecular Spectroscopy	
Nature of the Course	Major	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course aims to make the students understand the basics of Rotational and Raman spectroscopy. It also deals with vibrational, electronic and photoelectron spectroscopy. The course offers a platform to the students to know the use of Beer-Lambert's law in various analyses.

Course Outcomes

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

CO1: Understand the basics of microwave spectroscopy and the effect of isotopic substitution.
CO2: Learn about the theories of Raman spectroscopy and Raman spectra.
CO3: Acquire knowledge about vibrational spectroscopy, transitions and spectra.
CO4: Understand the basic principle of electronic and photoelectron spectroscopy.
CO5: Record the UV-visible spectra of a few inorganic and organic compounds, determine λ_{max} and calculate the energies of transitions.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Rotational and Raman Spectroscopy Rotational spectra of diatomic and polyatomic molecules. Intensities of rotational spectral lines, effect of isotopic substitution. Non-rigid rotators. Classical theory of the Raman effect, polarizability as a tensor, polarizability ellipsoids, quantum theory of the Raman effect, Pure rotational Raman spectra of linear and asymmetric top molecules, Stokes and anti-Stokes lines. Vibrational Raman spectra, Raman activity of vibrations, rule of mutual exclusion, rotational fine structure-O and S branches, Polarization of Raman scattered photons.	15	CO1, CO2
Vibrational Spectroscopy Vibrations of molecules, harmonic and anharmonic oscillators-vibrational energy expression, energy level diagram, vibrational wave functions and their symmetry, selection rules, expression for the energies of spectral lines, computation of intensities, hot bands, effect of isotopic substitution.	15	CO3

Diatomic vibrating rotor, vibrational-rotational spectra of diatomic molecules, P, R branches, breakdown of the Born-Oppenheimer approximation. Vibrations of polyatomic molecules – symmetry properties, overtone and combination frequencies. Influence of rotation on vibrational spectra of polyatomic molecule, P, Q, R branches, parallel and perpendicular vibrations of linear and symmetric top molecules.		
Electronic Spectroscopy Electronic Spectroscopy: Electronic spectroscopy of diatomic molecules, Frank-Condon principle, dissociation and predissociation spectra. $\pi \rightarrow \pi^*$, $n \rightarrow \pi^*$ transitions and their selection rules. Beer-Lambert's law, effect of solvent on UV spectra (λ_{max} and ε), Factors effecting λ_{max} and ε. Photoelectron Spectroscopy: Basic principles, photoelectron spectra of simple molecules (H_2, N_2, O_2), X-ray photoelectron spectroscopy (XPS). Lasers: Laser action, population inversion, properties of laser radiation, examples of simple laser systems.	15	CO4
Practical: Fundamentals of Molecular Spectroscopy 1. Verify Beer-Lambert's law and determine the concentration of $CuSO_4$/$KMnO_4$/$K_2Cr_2O_7$ in a solution of unknown concentration using a spectrophotometer. 2. Study the absorbance spectra of $KMnO_4$ and $K_2Cr_2O_7$ (in 0.1 M H_2SO_4) and determine the λ_{max} values. Calculate the energies of the two transitions in different units (J molecule^{-1}, kJ mol^{-1}, cm^{-1}, eV). 3. Study the pH dependence of the UV-vis spectrum of $K_2Cr_2O_7$. 4. Record the UV spectra (200-350 nm) of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.	30	CO5

Recommended Books

Theory

1. Banwell C. N.; McCash, E. M., Fundamentals of Molecular Spectroscopy, 4th Ed., McGraw Hill Education (2017). (ISBN: 978-9352601738).
2. Pavia, D. L.; Lampman, G. M.; Kriz, G. S.; Vyvyan, J. A., Introduction to Spectroscopy, 5th Ed., Cengage Learning India (2015). (ISBN: 978-9381466476).
3. McQuarrie, D. A.; Simon, J. D., *Physical Chemistry: A Molecular Approach,* 1st Ed., Viva Books. (ISBN: 978-8184959888).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).

3. Khosla, B. D.; Garg, V. C.; Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2008). (ISBN: 978-8180450792).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	M	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	M	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	M	-	-	-	-	-	-	-	H	H	H	-
CO4	H	H	-	-	M	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	H	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER V

NCrF Level	5.5	
Course Code	CHE-001-CC-3110	
Title of the Course	Inorganic Chemistry II	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course includes topics in bioinorganic chemistry which plays a vital role in living bodies. Students will also be familiarized with the *d*- and *f*-block elements and their properties. They will acquire knowledge on horizontal similarity in a period in addition to vertical similarity in a group. Further, the course introduces the students to gravimetric analysis, inorganic complex synthesis and chromatographic separation of transition metal ions.

Course Outcomes

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

CO1: Understand the important properties of transition metals such as variable oxidation states, colour, magnetic and catalytic properties.
CO2: Use Latimer diagrams in identifying reducing, oxidizing and undergoing disproportionation nature of species.
CO3: Learn about the chemistry of lanthanides and actinides.
CO4: Know the preparation, properties and shapes of compounds of noble gases.
CO5: Estimate metal ions by gravimetric analyses and to carry out laboratory preparation of metal complexes.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Transition Elements General group trends with special reference to electronic configuration, colour, variable valency, magnetic and catalytic properties, ability to form complexes. Stability of various oxidation states and EMF (Latimer & Ebsworth diagrams). Difference between the first, second and third transition series. Chemistry of Ti, V, Cr Mn, Fe and Co in various oxidation states (excluding metallurgy).	15	CO1, CO2
Chemistry of Lanthanides, Actinides and Noble Gases Electronic configuration, oxidation states, colour, spectral and magnetic properties, lanthanide contraction, separation of lanthanides and actinides (ion-exchange method only). Rationalization of inertness of noble gases, preparation and properties of XeF_2, XeF_4 and XeF_6, Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2), shapes of noble gas compounds using VSEPR theory.	15	CO3

Structure and Energetics in Metallic and Ionic Solids A brief introduction to crystal systems: Lattices, unit cells, space groups. Packing of spheres: Hexagonal and cubic closed packing, Tetrahedral and octahedral holes in close-packed structure; radius ratios in determining structure type among ionic solids. Characteristic structure types of ionic solids: CsCl, NaCl, Spalerite and Wurtzite types of ZnS, fluorite and anti-fluorite, nickel arsenide, $CdCl_2$, CdI_2, rutile, perovskite and spinels. Lattice enthalpy, consequences of lattice enthalpy.	15	CO4
Practical: Inorganic Chemistry II 1. Gravimetric Analysis (a) Estimation of nickel(II) using dimethylglyoxime (DMG). (b) Estimation of copper as cuprous thiocyanate (CuSCN). (c) Estimation of iron as Fe_2O_3. (d) Estimation of calcium as calcium oxalate monohydrate. (e) Al(III) by precipitating with oxine and weighing as $Al(oxine)_3$. 2. Inorganic Preparations (a) Tetraamminecopper(II) sulphate ($[Cu(NH_3)_4]SO_4 \cdot H_2O$) (b) *cis*- and *trans*-Potassium dioxalatodiaquachromate(III) ($K[Cr(C_2O_4)_2 \cdot (H_2O)_2] \cdot 2H_2O$) (c) Tetraamminecarbonato cobalt(III) nitrate ($[Co(CO_3)(NH_3)_4]NO_3$) (d) Potassium trisoxalato ferrate(III) trihydrate ($K_3[Fe(C_2O_4)_3] \cdot 3H_2O$)	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).
4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins's Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015). (ISBN: 978-0198757177).
6. Miessler, G.; Tarr, D. A., Inorganic Chemistry, 3rd Ed., Pearson Education India, New Delhi (2008). (ISBN: 978-8131718858).

Practical

1. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).
2. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 7th Ed., Pearson Education India (2012). (ISBN: 978-8131773710).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	M	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	M	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	-	-	-	L	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER V

NCrF Level	5.5	
Course Code	CHE-001-CC-3120	
Title of the Course	Organic Chemistry II	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course covers important basic topics of organic stereochemistry. It deals with various ionic and non-ionic reaction intermediates: their generation, stability and stereoselectivity. The course also introduces the students to the laboratory techniques for identification of various *N*-containing functional groups and organic preparations.

Course Outcomes

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

CO1: Learn about different systems of stereochemical nomenclature.
CO2: Learn the concept of stereogenic, chirotopic and achirotopic centre as well as diastereoisomerism in acyclic and cyclic systems.
CO3: Have good understanding on various ionic and non-ionic intermediates.
CO4: Know about the intermediates involved in different name reactions by learning their mechanisms.
CO5: Learn identification of *N*-containing functional groups and organic preparations.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Stereochemistry II Stereochemical nomenclature of compounds containing chiral centres: *D,L*-system of designation and its shortcomings. Absolute configurations*: R,S*-system of nomenclature of containing chiral centres, chiral axis and chiral planes. Asymmetry and dissymmetry: Concept of stereogenic, chirotopic and achirotopic centres; prochirality (*Re*- & *Si* face), prosterioisomerism; homotopic and heterotopic faces and groups/ligands. Diastereomerism in acyclic and cyclic systems. *E,Z*-system of nomenclature of compounds with C=C. Stereochemical nomenclature of compounds containing unsaturation and chiral centre (Combined *R,S* and *E,Z*-nomenclature).	15	CO1, CO2
Ionic Reaction Intermediates *Carbocations*: Generation, structure and reactivity, classical and non-classical carbocations, neighbouring group participation and rearrangements in acyclic, monocyclic and bicyclic systems.	15	CO3, CO4

Carbanions: Generation, structure and reactivity. Organolithium, organomagnesium, organozinc, organocopper reagents. *Enolates*: Themodynamic versus kinetic enolates, enolate equivalent and enamines: Application in carbon-carbon bond formation and other reactions. *Ylides*: Chemistry of phosphorous and sulfur ylides – Wittig reaction: stabilized and non-stabilised ylides, related reactions, Petersen olefination.		
Non-ionic Reaction Intermediates *Free radicals*: Generation, structure, stability and reactions, radical initiator, cage effects, radical cations and radical anions, application of tributyltinhydride/AIBN, Hoffmann-Loeffler-Freytag reaction and Barton nitrite-ester reaction, Barton decarboxylation. *Carbenes*: Formation, structure and stability, singlet and triplet states, reactions involving carbene intermediates- Reimer-Tiemann reaction, Arndt-Eistert reaction, Simmons-Smith reaction. *Nitrenes*: Generation & structure, reactions of nitrenes and related electron-deficient nitrogen intermediates including Curtius rearrangement, Hoffman rearrangement, Schmidt reaction (of carboxylic acid, aldehyde and ketone), Lossen rearrangement, Beckmann rearrangement *Arynes*: Generation, structure and stability, rearrangement reactions, S_NAr mechanism.	15	CO3, CO4
Practical: Organic Chemistry II 1. Functional group tests for nitro, amine and amide groups. 2. Organic preparations: (a) *m*-dintrobenzene from nitro-benzene (b) Benzil from benzoin (c) Phthalic anhydride from phthalic acid (d) *p*-nitroacetanilide from acetanilide (e) *p*-bromoaniline from *p*-bromoacetanilide	30	CO5

Recommended Books

Theory

1. Sengupta, S., *Basic Stereochemistry of Organic Molecules*, 2nd Ed., Oxford University Press India (2018). (ISBN: 978-0199492213).
2. Nasipuri, D. *Stereochemistry of Organic Compounds: Principles and Applications*, 4th Ed., New Age International Publishers, New Delhi (2020). (ISBN: 978-9389802474).
3. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015). (ISBN: 978-8126556588).
4. Sykes, P., *A Guidebook to Mechanism in Organic Chemistry*, 6th Ed., Pearson Education India (2003). (ISBN: 978-8177584332).
5. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press, New Delhi (2014). (ISBN: 978-0198728719).

6. Smith, M. B., *Organic Synthesis*, 4th Ed., Academic Press, Cambridge, Massachusetts (2016). (ISBN: 978-0128007204).
7. Carruthers, W., *Modern Methods of Organic Synthesis*, 4th Ed., Cambridge University Press, New Delhi (2015). (ISBN: 978-1107567450).
8. Zweifel, G. S.; Nantz, M. H.; Somfai, P., *Modern Organic Synthesis: An Introduction*, 2nd Ed., Wiley-Blackwell, New York (2017). (ISBN: 978-1119086536).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India, New Delhi (2003). (ISBN: 978-8177589573).
2. Mann, F. G.; Saunders, B. C., *Practical Organic Chemistry*, 4th Ed., Pearson Education India, New Delhi (2009). (ISBN: 978-8131727102).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers, New Delhi (2007). (ISBN: 978-8123915012).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan, Meerut (2014). (ISBN: 978-8182835054).
5. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2004). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	L	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER V

NCrF Level	5.5	
Course Code	CHE-001-CC-3130	
Title of the Course	Physical Chemistry II	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course aims to make the students understand some of the most important topics in physical chemistry like thermodynamic concepts, dependence of thermodynamic parameters on composition, ionic equilibrium, solutions and colligative properties. Discussion on topics like dissociation of strong and weak electrolytes, hydrolysis of salts, solubility and solubility product of sparingly soluble salts, pH, buffers and different colligative properties will enable the learners to understand the chemistry of everyday life.

Course Outcomes

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

CO1: Acquire knowledge of fugacity and its importance.
CO2: Understand the concept of partial molar properties and the influence of composition on thermodynamic properties.
CO3: Derive expressions for pH for aqueous solutions of various salts and Henderson equation for different buffer solutions.
CO4: Have fair knowledge of the four colligative properties and their application.
CO5: Determine solubility product practically and to perform pH metric titrations.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemical Thermodynamics II Fugacity and activity and their variation with temperature and pressure. Graphical method for the determination of fugacity; fugacity of van der Waals gases. Partial molar quantities and its physical significance; Partial molar free energy (chemical potential) and its variation with temperature and pressure; Gibbs-Duhem equation. Gibbs free energy and entropy of mixing of ideal gases; partial molar volumes; method of determination of partial molar volumes. Thermodynamic description of phase transitions and Clapeyron-Clausius equation.	15	CO1, CO2
Ionic Equilibria Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion	15	CO3

effect; dissociation constants of mono-, di-and triprotic acids (exact treatment). Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity, buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. Qualitative treatment of acid-base titration curves (calculation of pH at various stages). Theory of acid-base indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolyte systems; hydrolysis and hydrolysis constants.		
Solutions and Colligative Properties Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.	15	CO4
Practical: Physical Chemistry II 1. Solubility Product (a) Determine the solubility product of $Ba(IO_3)_2$ at room temperature. (b) Study the variation of solubility of $Ca(OH)_2$ in NaOH solution and hence determine its solubility product. 2. pH metry (a) pH metric titration of (i) strong acid vs. strong base, (ii) weak acid vs. strong base, (iii) mixture of strong and weak acid vs. strong base. **(b)** Determination of dissociation constant of a weak acid using Handerson's equation.	30	CO5

Recommended Books

Theory

1. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
2. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
3. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019). (ISBN: 978-9353165185).
4. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093)
5. Negi, A. S.; Anand, S. C., *Physical Chemistry*, 3rd Ed., New Age International Publishers (2023). (ISBN: 978-9393159793).

6. Kapoor, K. L., *A Textbook of Physical Chemistry: Thermodynamics and Chemical Equilibrium*, Vol. II, 6th Ed., McGraw Hill Education India (2019). (ISBN: 978-9353165208).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).
3. Khosla, B. D.; Garg, V. C.; Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2008). (ISBN: 978-8180450792).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	M	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO2	H	M	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO5	H	H	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER V

NCrF Level	5.5
Course Code	CHE-001-CC-3140
Title of the Course	Green Chemistry
Nature of the Course	Major
Total Credits	2 (L 1 – T 1 – P 0)
Total Contact Hours (CH)	30 (Theory – 30; Practical –0)
Distribution of Marks	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course is designed to introduce students to green chemistry. They will learn about the emerging discipline, its applications in sustainable development, and some real-world cases.

Course Outcomes

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

CO1: Learn the needs, goals and the basic principles of green chemistry.
CO2: Know the concept of atom economy, calculation of atom economy and various green solvents.
CO3: Learn the use of alternative energy sources (microwave & ultrasonic irradiation) in chemical reactions.
CO4: Learn about a few environmental disasters that originated from chemical industries.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Introduction and Principles of Green Chemistry Introduction to green chemistry: What is green chemistry? Need for green chemistry. Goals of green chemistry. Limitations/ obstacles in the pursuit of the goals of green chemistry. Principles of green chemistry and designing a chemical synthesis: Twelve principles of green chemistry with their explanations and examples. Designing a green synthesis using these principles. Prevention of waste/ byproducts; maximum incorporation of the materials used in the process into the final products, Atom economy, calculation of atom economy of the rearrangement, addition, substitution and elimination reactions. Prevention/ minimization of hazardous/ toxic products; designing safer chemicals and different basic approaches to do so. Green solvents: Supercritical fluids, water as a solvent for organic reactions, ionic liquids, fluorous biphasic solvent, PEG, solventless processes, immobilized solvents and how to compare greenness of solvents.	15	CO1, CO2
Green Synthesis Energy requirements for reactions–alternative sources of energy: use of microwaves and ultrasonic energy. Selection of starting materials; avoidance of unnecessary derivatization–careful use of	15	CO3, CO4

blocking/protecting groups. Use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis. Prevention of chemical accidents by designing greener processes, inherent safer design, principle of ISD "What you don't have cannot harm you", greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation. Strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.		

Recommended Books

1. Anastas, P. T.; Warner, J. C., *Green Chemistry: Theory and Practice*, Oxford University Press, Oxford (2005). (ISBN: 978-0195695861).
2. Ahluwalia, V. K.; Kidwai, M. R., *New Trends in Green Chemistry*, Springer India, New Delhi (2012). (ISBN: 978-9401571029).
3. Matlack, A., *Introduction to Green Chemistry*, 3rd Ed., CRC Press (2022). (ISBN: 978-0367470487).
4. Cann, M. C.; Connely, M. E., *Real-World cases in Green Chemistry*, American Chemical Society, Washington (2000). (ISBN: 978-0841237339).
5. Lancaster, M. *Green Chemistry: An Introductory Text*, 3rd Ed., RSC Publishing (2016). (ISBN: 978-1782622949).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	M	H	-	H	-	-	-	-	-	H	-	H	M	H	-
CO2	H	M	H	-	H	-	-	-	-	-	H	-	H	M	H	-
CO3	H	M	H	-	H	-	-	-	-	-	H	-	H	M	H	-
CO4	H	M	H	-	H	-	-	-	-	-	H	-	H	M	H	-

H = High; M = Medium; L = Low

SEMESTER VI

NCrF Level	5.5	
Course Code	CHE-001-CC-3210	
Title of the Course	Inorganic Chemistry III	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course is designed to provide knowledge to the students to comprehend the various aspects of reaction kinetics and mechanisms in inorganic chemistry. The course also emphasizes an elaborate discussion of organometallic compounds of varied types. Learners will study the chemistry of a few important industrial processes involving organometallic species as catalytic systems.

Course Outcomes

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

CO1: Have glimpses of inorganic reaction mechanisms, trans effect and substitution reactions on square planar and octahedral complexes.

CO2: Apply the 18-electron rule to rationalize the stability of metal carbonyls and related species.

CO3: Understand important structural features of the metal alkyls and acquire the concept of multicentre boding in such compounds.

CO4: Have an introduction to metallocene (ferrocene), its structure and an understanding on its aromatic properties and its reactions.

CO5: Have practical knowledge of qualitative analyses of mixtures containing multiple cations and anions.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Reaction Kinetics and Mechanism Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans-effect, theories of trans-effect, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedral complexes.	15	CO1
Organometallic Compounds I Definition and classification of organometallic compounds based on bond types. Concept of hapticity of organic ligands. Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3*d* series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3*d* series. Structures of mononuclear and binuclear carbonyls of	15	CO2

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 the extent of back bonding.		
Organometallic Compounds II Preparation and structure of Zeise's Salt, 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.	15	CO3, CO4
Practical: Inorganic Chemistry III Qualitative semi-micro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested: CO_3^{2-}, NO^-, S^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, CH_3COO^-, F^-, Cl^-, Br^-, I^-, NO_3^-, BO_3^{3-}, $C_2O_4^{2-}$, PO_4^{3-}, NH_4^+, K^+, Pb^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}, Sb^{3+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}. (Mixtures should preferably contain one interfering anion, or insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) or a combination of anions e.g., CO_3^{2-} and SO_3^{2-}, NO_2^- and NO_3^-, Cl^- and Br^-, Cl^- and I^-, Br^- and I^-, NO_3^- and Br^-, NO_3^- and I^-. Spot tests should be done whenever possible.)	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).
4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins' Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015). (ISBN: 978-0198757177).
6. Miessler, G.; Tarr, D. A., Inorganic Chemistry, 3rd Ed., Pearson Education India, New Delhi (2008). (ISBN: 978-8131718858).

Practical

1. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).

2. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 7th Ed., Pearson Education India (2012). (ISBN: 978-8131773710).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	-	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VI

NCrF Level	5.5	
Course Code	CHE-001-CC-3220	
Title of the Course	Organic Chemistry III	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course will enable the students to comprehend various types of organic reactions, their mechanisms and applications. It deals with oxidation reactions with a variety of metal and non-metal-based reagents and name reactions. The course also covers the catalytic reduction of organic compounds, their mechanism and application in organic chemistry.

Course Outcomes

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

CO1: Acquire an understanding of various types of organic reactions, their mechanisms and their application in chemistry.
CO2: Know about various oxidizing reagents, their applications and mechanisms.
CO3: Learn named oxidation processes and their mechanisms.
CO4: Understand reduction reactions, reducing reagents and their stereo selection with mechanism.
CO5: Learn qualitative analysis of unknown organic compounds containing mono and bifunctional groups.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Substitution, Elimination and Addition Reactions *Substitution Reactions*: Mechanism and reactivity of aromatic, aliphatic, nucleophilic substitution reaction, orientation and reactivity in aromatic electrophilic substitution reactions. *Elimination Reactions*: Mechanism, orientation and reactivity, dehydration of alcohols, Shapiro reaction, conversion of epoxide to olefins, dehalogenation of vicinal halide. Substitution vs. elimination, nucleophile vs. base. *Addition Reactions*: Mechanism and stereochemical aspects of addition reactions in carbon-carbon multiple bonds.	15	CO1
Oxidation Reactions Metal and non-metal-based oxidations of alcohols to carbonyls (Chromium-Jone's reagent, Collin's reagent, PCC, PDC; manganese-MnO_2; aluminium-Oppenauer oxidation, silver-Ag_2CO_3; Swern oxidation). Oxidation of phenols: Fremy's salt, alkenes to epoxides: via halohydrin, peroxides/per acids based,	15	CO2, CO3

nucleophilic epoxidation, Sharpless asymmetric epoxidation; alkenes to diols (OsO_4, $KMnO_4$), Prevost reaction and Woodward modification; oxidation of alkyl or alkenyl fragments: selenium dioxide, ketones to ester/lactones: Baeyer-Villiger oxidation.		
Reduction Reactions Catalytic hydrogenation (Heterogeneous: Palladium/ Platinum/ Rhodium/ Nickel (including Raney Nickel Desulfurization) etc.; Homogeneous: Rhodium/ Ir etc.) with special emphasis on chemoselectivity; Reduction by dissolving metals: metal-liquid ammonia processes (Birch reduction, Pinacol formation etc.), Clemmensen reduction etc.; stereo selection and mechanism of the following reagents: Lithium aluminium hydride, DIBAL-H, Sodium borohydride, sodium cyanoborohydride, L-selectride, K-selectride, Zinc borohydride; Meerwein-Pondorff-Verley reduction; non-metallic reducing agents: Wolff-Kishner reduction diimide.	15	CO4
Practical: Organic Chemistry III Qualitative analysis of unknown organic compounds containing monofunctional groups (carbohydrates, aryl halides, aromatic hydrocarbons, nitro compounds, amines and amides) and simple bifunctional groups (salicylic acid, cinnamic acid, nitrophenols, etc.).	30	CO5

Recommended Books

Theory

1. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015). (ISBN: 978-8126556588).
2. Sykes, P., *A Guidebook to Mechanism in Organic Chemistry*, 6th Ed., Pearson Education India (2003). (ISBN: 978-8177584332).
3. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press, New Delhi (2014). (ISBN: 978-0198728719).
4. Smith, M. B., *Organic Synthesis*, 4th Ed., Academic Press, Cambridge, Massachusetts (2016). (ISBN: 978-0128007204).
5. Carruthers, W., *Modern Methods of Organic Synthesis*, 4th Ed., Cambridge University Press, New Delhi (2015). (ISBN: 978-1107567450).
6. Zweifel, G. S.; Nantz, M. H.; Somfai, P., *Modern Organic Synthesis: An Introduction*, 2nd Ed., Wiley-Blackwell, New York (2017). (ISBN: 978-1119086536).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India, New Delhi (2003). (ISBN: 978-8177589573).
2. Mann, F. G.; Saunders, B. C., *Practical Organic Chemistry*, 4th Ed., Pearson Education India, New Delhi (2009). (ISBN: 978-8131727102).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers, New Delhi (2007). (ISBN: 978-8123915012).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan, Meerut (2014). (ISBN: 978-8182835054).
5. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2004). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	-	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VI

NCrF Level	5.5	
Course Code	CHE-001-CC-3230	
Title of the Course	Physical Chemistry III	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces the learners to various theories of reaction rates and kinetics of reactions in solution. It also aims to expand students' understanding and knowledge of phases, the co-existence of phases, phase diagrams as well as the concept of photochemistry and various photophysical processes. Further, the course will help the students acquire knowledge on the practical application of phase and distribution law to various systems.

Course Outcomes

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

CO1: Understand different theories of chemical kinetics, unimolecular reactions and kinetics of reaction in solution.

CO2: Have a fair idea of phase equilibrium, phase rule and phase diagram of systems with one to three components.

CO3: Construct a phase diagram and determine critical solution temperature for simple systems practically.

CO4: Understand Nernst distribution law, its applications in extraction processes and limitations.

CO5: Acquire knowledge of various photo-physical processes, terminologies, laws of photochemistry, Jablonski diagrams etc.

CO6: Acquire knowledge on practical applications of phase and distribution law to various systems.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemical Kinetics II Kinetic control and thermodynamic control of reaction. Theories of reaction rate: Arrhenius theory; simple collision theory (SCT); steric factor, activated complex theory (ACT); thermodynamics of reaction rate and entropy of activation. Theories of unimolecular reactions: Lindemann mechanism and Hinshelwood treatment. Reaction in solution: diffusion-controlled and chemically controlled reaction; factors affecting reaction rate in solution; effect of solvent and ionic strength on the rate constant: primary and secondary salt effect; effect of the dielectric constant of the medium on the rate of reaction in solution.	15	CO1

Phase Equilibria Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, Phase diagram of one component systems (water and sulphur) and two-component systems (silver-lead and KI-H_2O). Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions. Three-component systems, water-chloroform-acetic acid system, triangular plots. Nernst distribution law and its limitations, thermodynamic derivation. Modification of distribution law to cases of association and dissociation of solute and complex formation. Application of the law in the process of extraction.	15	CO2, CO3, CO4
Fundamentals of Photochemistry Characteristics of electromagnetic radiation, Lambert-Beer's law and its limitations, and the physical significance of absorption coefficients. Laws of photochemistry, quantum yield, actinometry, examples of low and high quantum yields, photochemical equilibrium and the differential rate of photochemical reactions, photosensitised reactions, and quenching. Role of photochemical reactions in biochemical processes, photostationary states, Jablonski diagram, simple ideas of fluorescence, phosphorescence, and chemiluminescence.	15	CO5
Practical: Physical Chemistry III 1. Study the effect of temperature on the rate constant of acid-catalysed hydrolysis of ester. 2. Determine the critical solution temperature and composition of the phenol-water system. 3. Study the ternary system (acetic acid-water-chloroform) at room temperature and obtain the binodal curve. 4. Study the distribution of acetic/ benzoic acid between water and cyclohexane. 5. Study the distribution of benzoic acid between benzene and water and hence show that benzoic acid dimerizes in benzene. 6. To verify Lambert-Beer law and hence to determine the concentration of solutions like $KMnO_4$/ organic dye spectrophotometrically.	30	CO6

Recommended Books

Theory

1. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
2. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
3. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093).

4. Negi, A. S.; Anand, S. C., *Physical Chemistry*, 3rd Ed., New Age International Publishers (2023). (ISBN: 978-9393159793).
5. Silbey, R. J.; Alberty, R. A.; Bawendi, M. G., *Physical Chemistry*, 4th Ed., Wiley India (2006). (ISBN: 978-8126508778).
6. Rakshit, P. C., *Physical Chemistry*, 7th Ed., Sarat Book House (2014). (ISBN: 978-8187169079).
7. Kapoor, K. L., *A Textbook of Physical Chemistry: Dynamics of Chemical Reactions, Statistical Thermodynamics, Macromolecules and Irreversible Processes*, Vol. V, 4th Ed., McGraw Hill Education India (2020). (ISBN: 978-9389811322).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).
3. Khosla, B. D.; Garg, V. C.; Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2008). (ISBN: 978-8180450792).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO3	H	M	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO5	H	L	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO6	H	H	-	-	M	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER VI

NCrF Level	5.5	
Course Code	CHE-001-CC-3240	
Title of the Course	Quantum Chemistry	
Nature of the Course	Major	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	90 (Theory – 60; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces the learners to mathematical concepts in deriving various quantum mechanical equations. It aims to expand students' knowledge of solving Schrodinger equations for various simple systems. This course also introduces the learners to different approximation methods for the estimation of the ground state energy of a system. Further, the students will learn the use of GAUSSIAN software in computational calculations of different systems.

Course Outcomes

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

CO1: Learn mathematical concepts in deriving various quantum mechanical equations.
CO2: Learn the postulates of quantum mechanics, operators and their properties.
CO3: Understand how to set up Schrodinger equation for different systems and their solution.
CO4: Acquire knowledge of different approximation methods to solve for estimation of ground state energy of a system.
CO5: Have ideas on the use of *GAUSSIAN* software in computational calculations of different systems.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Origin of Quantum Mechanics Mathematical concepts: differential equation, integration, vectors, matrix and determinants. A brief review of the failure of classical mechanics (Planck's quantum theory, photoelectric effect, wave-particle duality, uncertainty principle). Time-independent Schrödinger equation and properties of wave functions. Postulates of quantum mechanics; normalization and orthogonality; quantum mechanical operators; properties of operators; eigenvalues and eigenfunctions; setting up of operators for different observables; orbital angular momentum operators; Hermitian operators; Schmidt-orthogonalization technique.	15	CO1, CO2, CO3
Wave Mechanics of Simple Systems Particle in a one-dimensional box; characteristics of wave functions; quantization of energy levels; zero-point energy and Heisenberg	15	CO1, CO3

uncertainty principle; probability distribution functions and nodal properties. Three-dimensional box; separation of variables; degree of degeneracy; concept of tunnelling. Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wave functions; normalization of wave functions. Vibrational energy of diatomic molecules and zero-point energy. Rigid rotator model of rotation of diatomic molecule: Schrödinger equation; transformation to spherical polar coordinates. Separation of variables; spherical harmonics and discussion of solution. 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, root mean square and most probable distances of electron from nucleus.		
Application of Quantum Mechanics Variation theorem and linear variation functions; first-order time-independent perturbation theory for non-degenerate states; application of variation treatment and perturbation treatment to the helium atom. Born-Oppenheimer approximation, Hartree and Hartree-Fock Self-Consistent Field method. Slater determinant. Hückel electron theory and extended Hückel MO theory and their application to ethylene, butadiene, allyl system and benzene.	15	CO4
Practical: Quantum Chemistry 1. Perform theoretical calculations using a computer on (a) Least square fitting and plotting linear and exponential graphs. (b) Potential energy diagram of hydrogen molecule ion. (c) Charge density distribution and shapes of *s* and *p* orbitals. 2. Plot Maxwell's speed distribution formula in speed and translational energy terms and calculate the fraction of molecules in a given speed range by numerical integration. 3. *Ab-initio* calculations of organic and inorganic molecules using *GAUSSIAN* software.	30	CO5

Recommended Books

Theory

1. Chandra, A. K., *Introductory Quantum Chemistry*, 4th Ed., McGraw Hill Education India, New Delhi (2017). (ISBN: 978-0074620540).
2. Levine, I. N., *Quantum Chemistry*, 7th Ed., Pearson Education India, New Delhi (2016). (ISBN: 978-9332558533).
3. McQuarrie, D. A., *Quantum Chemistry*, Viva Books, New Delhi (2016). (ISBN: 978-8130918945).

4. Sen, B. K., *Quantum Chemistry Including Spectroscopy*, 2nd Ed., Kalyani Publishers, New Delhi (2004). (ISBN: 978-9327279290).
5. Atkins, P. W., Friedman R. S., *Molecular Quantum Mechanics*, 5th Ed., Oxford University Press, New Delhi (2012). (ISBN: 978-0199541423).
6. Prasad, R. K., *Quantum Chemistry*, 4th Ed., New Age International Publishers, New Delhi (2020). (ISBN: 978-8122424089).

Practical

1. Lewers, E. G., *Computational Chemistry: Introduction to the Theory and Applications of Molecular and Quantum Mechanics*, 3rd Ed., Springer, New York (2016). (ISBN: 978-3319809151).
2. Jensen, F., *Introduction to Computational Chemistry*, 3rd Ed., Wiley-Blackwell, New Jersey (2017). (ISBN: 978-1118825990).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	M	H	-	H	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER VII

NCrF Level	6.0	
Course Code	CHE-001-CC-4110	
Title of the Course	Inorganic Chemistry IV	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	60 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces students to the importance of symmetry and group theory. It deals with the application of group theory in the determination of spectroscopic properties and the construction of hybrid orbitals for molecular bonding. It also deals with the magnetic and electronic properties of *d*- and *f*-block elements. The course will enable the students to learn how to prepare and characterise coordination complexes using various analytical techniques.

Course Outcomes

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

CO1: Understand the basics and importance of symmetry and learn about the matrix representation of symmetry elements and the construction of character tables.

CO2: Understand the application of group theory in IR, Raman and electronic spectroscopy.

CO3: Acquire basic knowledge in constructing hybrid orbitals for σ- & π-bonding.

CO4: Apply concepts in interpreting the electronic spectral properties of *d*- and *f*-block metal complexes.

CO5: Learn the preparation of coordination complexes and their characterisation employing different analytical techniques (including quantitative estimation).

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Molecular Symmetry and Group Theory Symmetry elements and operations. Group and its characteristics, subgroup, classes, similarity transformations. Product of symmetry operations, equivalent atoms and equivalent symmetry elements. Relation between symmetry elements and operations, classes of symmetry operations. Matrix representation of groups, reducible and irreducible representations. Orthogonality theorem, properties of irreducible representations, character tables and their construction. Mulliken notations.	15 (L) 5 (T)	CO1
Applications of Group Theory Direct product representation, projection operator and symmetry-adapted linear combination (SALC), symmetry selection rules for IR, Raman and electronic spectra. Hybrid orbital and hybridisation in polyatomic molecules, construction of hybrid orbitals for sigma & π-bonding (e.g. D_{3h}, D_{4h}, T_d, O_h).	15 (L) 5 (T)	CO2, CO3

Molecular Orbital Theory: LCAO-MO approach; Construction of MO diagrams of polyatomic molecules (e.g. BeH_2, H_2O, BH_3, NH_3, CH_4) including coordination complexes (O_h and T_d).		
Electronic Spectra of *d*- and *f*-block Metal Complexes Microstates and term symbols, term symbols of d_n system, Racah parameters, splitting of terms into weak and strong octahedral and tetrahedral fields. Selection rules for electronic transition-effect of spin-orbit coupling and vibronic coupling, *d-d* transition. Orgel diagrams, Tanabe-Sugano diagrams, D_q, B and β (Nephelauxetic ratio) values calculation, charge transfer spectra. Spectral properties of lanthanide and actinide metal complexes.	15 (L) 5 (T)	CO4
Practical: Inorganic Chemistry IV 1. Preparation and characterisation of coordination complexes by various analytical techniques, wherever appropriate and possible: (a) Metal acetylacetonate complexes (e.g., $Mn(acac)_2$, $Fe(acac)_3$, $Cu(acac)_2$). (b) Optical isomers of tris(ethylenediamine)cobalt(III)chloride. (c) Preparation of Werner complex, $[Co(NH_3)_5Cl]Cl_2$ and subsequent preparation of linkage isomers – $[Co(NH_3)_5NO_2]Cl_2$ and $[Co(NH_3)_5ONO]Cl_2$. (d) Polyoxometallates: tetrabutylammoniumhexamolybdate (VI)) ion. (e) Magnetochemistry: Mercury cobalt(II)tetrathiocyanate, $Hg[Co(SCN)_4]$, Prussian blue *Other new novel syntheses reported in the literature from time to time may be included during the semester.*	30	CO5

Recommended Books

Theory

1. Reddy, K. V., *Symmetry and Spectroscopy of Molecules*, 2nd Ed., New Age International Publishers, New Delhi (2020). (ISBN: 978-8122424515).
2. Cotton, F. A., *Chemical Applications of Group Theory*, 3rd Ed., Wiley India, New Delhi (2020). (ISBN: 978-8194726364).
3. Carter, R. L., *Symmetry and Group Theory*, 1st Ed., Wiley India, New Delhi (2009). (ISBN: 978-0471149552).
4. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
5. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins' Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015). (ISBN: 978-0198757177).
6. Miessler, G.; Tarr, D. A., Inorganic Chemistry, 3rd Ed., Pearson Education India, New Delhi (2008). (ISBN: 978-8131718858).
7. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 978-9356064485).

Practical

1. Woolins, J. D. (Ed.), *Inorganic Experiments*, 3rd Ed., Wiley-VCH (2010). (ISBN: 978-3527324729).
2. Girolami, G. S.; Rauchfuss, T. B.; Angelici, R. J., *Synthesis and techniques in Inorganic Chemistry: A Laboratory Manual*, 3rd Ed., University Science Books (1999). (ISBN: 978-0935702484).
3. Jahagirdar, D. V., *Experiments in Chemistry*, Himalaya Publishing (2011). (ISBN: 978-9351421276).
4. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO3	H	M	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER VII

NCrF Level	6.0	
Course Code	CHE-001-CC-4120	
Title of the Course	Organic Chemistry IV	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course covers important organic chemistry topics, such as carbohydrate chemistry, pericyclic reactions, and organic photochemistry. It discusses the classification, configurations, interconversion, structure elucidation, synthesis, and degradation of carbohydrates. The course also covers the basic and advanced concepts of organic photochemistry and pericyclic reactions and the mechanisms involved therein. The students will learn about the qualitative analysis of binary mixtures and the application of purification techniques.

Course Outcomes

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

CO1: Know the occurrence, classification and biological importance of carbohydrates.
CO2: Know the IUPAC naming of disaccharides and their structure elucidation.
CO3: Know and understand photochemistry, mechanism and different rearrangement reactions.
CO4: Have good insights into different types of pericyclic reactions and selection rules that decide the stereochemistry thereof.
CO5: Perform qualitative analysis of binary organic mixtures.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Carbohydrates Occurrence, classification and their biological importance. Monosaccharides: Constitution and absolute configuration of glucose and fructose, epimers and anomers, mutarotation, determination of ring size of glucose and fructose, reducing and non-reducing sugars, Haworth projections and conformational structures; interconversions of aldoses and ketoses; Killiani-Fischer synthesis and Ruff degradation. Disaccharides: IUPAC nomenclature, structure elucidation and reactions of maltose, lactose and sucrose. Polysaccharides: Elementary treatment of starch, cellulose and glycogen.	15	CO1, CO2
Organic Photochemistry Introduction to organic photochemistry: electronic transitions, Laws of photochemistry, quantum yield; cis-trans isomerisation, Norrish	15	CO3

type I & II reactions, photoreduction of ketones, Paterno-Buchi reaction, Lumiketone rearrangement, Di-π-methane and Di-π-methane type rearrangement, Aza-Di-π-methane type rearrangement, rearrangement of dienones and β, γ-Unsaturated ketones.		
Pericyclic Reactions Introduction, types: electrocyclic reaction, cycloaddition, 1,3-dipolar addition, cheletropic reactions, sigmatropic and group transfer reaction: Ene reaction, selection rules, general orbital symmetry rules.	15	CO4
Practical: Organic Chemistry IV 1. Qualitative Organic Analysis (Maximum three samples) of supplied organic binary mixtures: (a) Qualitative separation by physicochemical method, (b) Identification of the compounds by chemical analysis, (c) Preparation of suitable derivatives, purification and determination of melting points.	30	CO5

Recommended Books

Theory

1. Morrison, R. T.; Boyd, R. N.; Bhattacharjee, S. K., *Organic Chemistry*, 7th Ed., Pearson Education India, New Delhi (2010). (ISBN: 978-8131704813).
2. Finar, I. L., *Organic Chemistry*, Volume 1, 6th Ed., Pearson Education (2002). (ISBN: 978-8177585421).
3. Finar, I. L., *Organic Chemistry*, Volume 2, 5th Ed., Pearson Education (2002). (ISBN: 978-8177585414).
4. Graham Solomons, T.W.; Fryhle, C. B.; Snyder, S. A., *Solomon's Organic Chemistry*, Global Edition., Wiley (2024). (ISBN: 978-8126568116).
5. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press, New Delhi (2014). (ISBN: 978-0198728719).
6. Singh, J.; Singh, J., *Photochemistry and Pericyclic Reactions*, 6th Ed., New Age International Publishers (2024). (ISBN: 978-9360742720).
7. Klán, P.; Wirz, J., *Photochemistry of Organic Compounds: From Concepts to Practice: 7 (Postgraduate Chemistry Series)*, Wiley (2009). (ISBN: 978-1405161732).
8. Fleming, I., *Molecular Orbitals and Organic Chemical Reactions* - Student Edition, Wiley (1991). (ISBN: 978-0470746592).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India, New Delhi (2003). (ISBN: 978-8177589573).
2. Mann, F. G.; Saunders, B. C., *Practical Organic Chemistry*, 4th Ed., Pearson Education India, New Delhi (2009). (ISBN: 978-8131727102).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers, New Delhi (2007). (ISBN: 978-8123915012).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan, Meerut (2014). (ISBN: 978-8182835054).
5. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2004). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	-	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO2	H	-	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO3	H	-	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO4	H	-	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO5	H	H	-	-	-	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VII

NCrF Level	6.0	
Course Code	CHE-001-CC-4130	
Title of the Course	Physical Chemistry IV	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces the concept of statistical thermodynamics and different distribution laws. It aims to expand knowledge of partition function and its properties as well as different laws of non-equilibrium thermodynamics. This course will also introduce the learners to surface chemistry and surface-catalysed reactions. The students will also learn how to examine the validity of isotherms experimentally and other experiments related to surface tension.

Course Outcomes

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

CO1: Have a fair idea of the concept of statistical thermodynamics and different distribution laws.

CO2: Understand partition function and its relation with the different thermodynamic parameters.

CO3: Learn different aspects of non-equilibrium thermodynamics and postulates of non-equilibrium thermodynamics.

CO4: Acquire knowledge of different adsorption isotherms and understand the mechanism of surface-catalysed reactions.

CO5: Perform experiments to compare/investigate the cleansing and adsorption properties of different materials.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Statistical Thermodynamics Concepts of statistical thermodynamics, entropy and thermodynamic probability. Different types of ensembles, ensemble averaging; Stirling approximation. Distribution laws: Maxwell–Boltzmann, Fermi–Dirac and Bose-Einstein; limitation of applicability of various distribution laws. Partition function and its properties, thermodynamic properties in terms of partition functions, evaluation of translational, rotational, vibrational, electronic and nuclear partition functions; law of equipartition of energies; and heat capacity. Molecular partition function and its importance; determination of thermodynamic properties of a monoatomic gas.	15	CO1, CO2

Non-Equilibrium Thermodynamics Difference between equilibrium and non-equilibrium thermodynamics, Postulates of non-equilibrium thermodynamics; Curie-Prigogine principle and microscopic reversibility. Onsagar's relations: thermodynamic and kinetics point of view; phenomenological laws. The entropy of irreversible processes: Clausius inequality; entropy production due to heat flow, mass flow, chemical reactions and electrochemical reactions; rate of entropy productions-generalized fluxes and forces; thermodynamic forces and fluxes; the relation between forces and fluxes; Thermoelectric phenomenon: Peltier, Seebeck and Thomson effect. Relation between chemical potential and thermodynamic potentials.	15	CO3
Surface Chemistry and Catalysis Adsorption: Physical adsorption, chemisorption, nature of the adsorbed state; thermodynamics of adsorption; factors affecting adsorption. Adsorption from solution: surface tension and surface free energy, application of surface tension, capillary action: Young-Laplace equation; formation of bubbles: Kelvin equation. Capillary condensation; adsorption in micropores and hysteresis loop; Gibbs adsorption equation; surface active and surface inactive materials. Adsorption isotherms: Freundlich isotherm, Langmuir isotherm and BET isotherm; determination of the surface area of an adsorbent (Langmuir and BET equation); isosteric enthalpy of adsorption. Catalytic activity at surfaces: mechanism of surface reaction; Langmuir-Hinshelwood and Eley-Rideal model; kinetic effects of surface heterogeneity and interactions. Kinetics of heterogeneous catalysis: unimolecular and bimolecular surface reactions.	15	CO4
Practical: Physical Chemistry IV 1. Determination of the critical micelle concentration of a surfactant by surface tension method. 2. Comparison of the cleansing powers of two samples of detergents by surface tension method. 3. Investigation of the adsorption of oxalic acid from aqueous solutions by activated charcoal and examination of the validity of Freundlich isotherm. 4. Investigation of the adsorption of iodine from aqueous potassium iodide solutions by activated charcoal and examination of the validity of Langmuir isotherm. 5. Any other related experiment may be introduced as and when needed.	30	CO5

Recommended Books

Theory

1. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
2. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
3. Rakshit, P. C., *Physical Chemistry*, 7th Ed., Sarat Book House (2020). (ISBN: 978-9388069359).
4. Gupta, M. C., *Statistical Thermodynamics*, New Age International Publishers, New Delhi (2007). (ISBN: 978-8122410662).
5. McQuarrie, D. A., *Statistical Mechanics*, Viva Student Edition, Viva Books, New Delhi (2018). (ISBN: 978-8181282361).
6. Kalidas, C.; Sangaranarayanan, M. V., *Non-Equilibrium Thermodynamics-Principles and Applications*, Macmillan Publishers India, New Delhi (2002). (ISBN: 9780333936863).
7. Adamson, A. W.; Gast, A. P., *Physical Chemistry of Surfaces*, 6th Ed, Wiley India, New Delhi (2011). (ISBN: 978-8126534173).
8. Kapoor, K. L., *A Textbook of Physical Chemistry: Dynamics of Chemical Reactions, Statistical Thermodynamics, Macromolecules and Irreversible Processes*, Vol. V, 4th Ed., McGraw Hill Education India (2020). (ISBN: 978-9389811322).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).
3. Khosla, B. D.; Garg, V. C.; Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2008). (ISBN: 978-8180450792).
4. Sreedher, N. *A Comprehensive Guide to Physical Chemistry Experiments and Viva Questions*, Notion Press (2023). (ISBN: 979-8891861916).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	L	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VII

NCrF Level	6.0	
Course Code	CHE-001-CC-4140	
Title of the Course	Advanced Molecular Spectroscopy	
Nature of the Course	Major	
Total Credits	4 (L 3 – T 1 – P 0)	
Total Contact Hours (CH)	60 (Theory – 60; Practical – 0)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces the learners to the basics of NMR, EPR, IR, UV-Vis spectroscopy, and mass spectrometry. It aims to provide students with an understanding of these spectroscopic/spectrometric techniques, which will be needed in the structural elucidation of organic and inorganic compounds in subsequent semesters.

Course Outcomes

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

CO1: Understand the fundamentals of NMR spectroscopy and interpretation of 1D and 2D NMR spectra.

CO2: Understand the basics of EPR spectroscopy and interpret EPR spectra of organic radicals and inorganic compounds.

CO3: Know the basic principle of mass spectrometry and fragmentation patterns of different classes of organic compounds.

CO4: Know the expected region of IR bands for different vibration and their reasons thereof.

CO5: Know about various factors affecting λ_{max} and ϵ_{max} in UV-vis spectroscopy and to calculate λ_{max} using Woodward-Fieser rules.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
NMR Spectroscopy Basic principles: Zeeman effect, Magnetic properties of nuclei-resonance condition, nuclear spin, population of nuclear spin levels and NMR isotopes, relaxation methods. FT-NMR. Chemical shift, Factors influencing chemical shifts: electronegativity and electrostatic effects; Mechanism of shielding and deshielding. Spin systems: First-order and second-order coupling of AB systems, Simplifying complex spectra. Spin-spin interactions: Homonuclear coupling interactions - AX, AX_2, AX_3, AMX, AB types. Vicinal, germinal and long-range coupling-spin decoupling. Nuclear Overhauser effect (NOE), factors influencing coupling constants and relative intensities. ^{13}C NMR, DEPT and structural correlations, Satellites. A brief introduction to 2D NMR – COSY, NOESY.	15	CO1

EPR Spectroscopy Characteristic features of EPR spectra, line shapes and line widths; EPR spectrometer. The g value and the hyperfine interaction. Interpretation of EPR spectra and structure elucidation of organic radicals using EPR spectroscopy. Spin-orbit coupling and significance of g-tensors, zero/non-zero field splitting, Kramer's degeneracy, application to transition metal complexes (having one to five unpaired electrons) including biological molecules and inorganic free radicals. EPR spectra of magnetically dilute samples.	15	CO2
Mass Spectrometry Basic principle. Ionisation techniques-Electron ionisation (EI), chemical ionisation (CI), desorption ionisation (FAB/MALDI), electrospray ionisation (ESI), isotope abundance, molecular ion, base peak, fragmentation processes of organic molecules (hydrocarbons, alcohols, phenols, carbonyl compounds, carboxylic acids, esters). McLafferty rearrangement, deduction of structure through mass spectral fragmentation.	15	CO3
IR and UV-Vis Spectroscopy *IR Spectroscopy*: Fundamental and non-fundamental molecular vibrations; IR absorption positions of hydrocarbons and other important organic functional groups, including alcohols and phenols, ethers, aldehydes, ketones, esters, amides, anhydrides, carboxylic acids, amines, nitro, nitriles, azo and thiols. effect of H-bonding, conjugation, resonance and ring size on IR absorptions; Fingerprint region and its significance; application in functional group analysis. *UV Spectroscopy*: Types of electronic transitions, λ_{max}, chromophores and auxochromes, bathochromic and hypsochromic shifts, the intensity of absorption; application of Woodward-Fieser rules for the calculation of λ_{max} for the following systems: α,β-unsaturated aldehydes, ketones, carboxylic acids and esters; conjugated dienes: alicyclic, homoannular and heteroannular; extended conjugated systems (aldehydes, ketones and dienes); distinction between cis and trans-isomers.	15	CO4, CO5

Recommended Books

1. Pavia, D. L.; Lampman, G. M.; Kriz, G. S.; Vyvyan, J. A., *Introduction to Spectroscopy*, 5th Ed., Cengage Learning India (2015). (ISBN: 978-9381466476).
2. Sathyanarayana, D. N. *Handbook of Molecular Spectroscopy: From Radio Waves to Gamma Rays*, 2nd Ed., IK International Publishing, New Delhi (2019). (ISBN: 978-9386768230).
3. Silverstein, R. M.; Webster, F. X.; Kiemle, D. J.; Bryce, D. L., *Spectrometric Identification of Organic Compounds*, 8th Ed., Wiley India, New Delhi (2022). (ISBN: 978-9354642296).
4. Kemp, W., *Organic Spectroscopy*, 3rd Ed., Macmillan Publishers India, New Delhi (2019). (ISBN: 978-1403906847).
5. Nakamoto, K., *Infrared and Raman Spectra of Inorganic and Coordination compounds*, Part A and Part B, 6th Ed., Wiley Blackwell, New York (2009). (ISBN: 978-0471744924).

6. Gunther, H., *NMR Spectroscopy: Basic Principles, Concepts and Applications in Chemistry*, 3rd Ed., Wiley India, New Delhi (2013). (ISBN: 978-3527330003).
7. Drago, R. S., *Physical Methods for Chemists*, 2nd Ed., Affiliated East West Press (2016). (ISBN: 978-8176710992).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	H	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	H	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	H	-	-	-	-	-	-	-	H	H	H	-
CO4	H	H	-	-	H	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	H	-	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VIII

NCrF Level	6.0	
Course Code	CHE-001-CC-4210	
Title of the Course	Advanced Organometallic Chemistry	
Nature of the Course	Major	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course is intended for students to gain knowledge of organometallic compounds and reagents and their application in organic synthesis and catalysis. It is designed to cover a broad range of topics, such as different types of mechanisms involved in organometallic chemistry, mechanisms of various homogeneous and heterogeneous organometallic catalysis, N-heterocyclic carbene, olefin metathesis, etc. The course also introduces the students to the preparation and characterisation of organometallic compounds by various analytical techniques.

Course Outcomes

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

CO1: Know the various reactions of organometallic compounds and their characteristics.
CO2: Learn about the synthesis, structure, & reactivity of organometallic compounds and reagents.
CO3: Acquire knowledge of the various types of organometallic compounds containing M-C bonds and important metal carbene complexes, *N*-heterocyclic carbene metal complexes, etc.
CO4: Understand the mechanisms of various homogeneous and heterogeneous organometallic catalysis and their industrial importance.
CO5: Preparation and characterisation of organometallic compounds by various analytical techniques.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Reactions of Organometallic Compounds Substitution reactions-nucleophilic ligand substitution, nucleophilic and electrophilic attack on coordinated ligands. Addition and elimination reactions-1,2 additions to double bonds, carbonylation and decarbonylation, oxidative addition and reductive elimination, insertion (migration) and elimination reactions. Rearrangement reactions, redistribution reactions, fluxional isomerism.	15	CO1, CO2
Organometallic Compounds Containing M-C, M=C and M≡C Bonds Types of M-C bonds, synthesis and reactivity of metal alkyls, carbenes, alkenes, alkynes, and arene complexes; metallocenes and bent metallocenes. Metal carbene complexes: Fischer, Schrock and Grubbs type carbene complexes, comparison of their stability and	15	CO3

reactivity, reactions of Fischer carbene complexes and their synthetic utility; Alkene metathesis reactions using Schrock and Grubbs carbene metal complexes. Introduction to *N*-heterocyclic carbene metal complexes. Metal carbyne complexes: synthesis, structure and reactivity.		
Catalysis by Organometallic Compounds Homogeneous organometallic catalysis: alkene hydrogenation using Wilkinson catalyst; hydroformylation of olefins using cobalt or rhodium catalyst; Monsanto acetic acid process; oxidation of olefins by Wacker method; olefin oligomerisation and isomerisation. Palladium catalysed C-C coupling reactions: Negishi, Suzuki, Stille, Heck and Sonogashira coupling Heterogeneous organometallic catalysis: Fischer-Tropsch reaction, Ziegler Natta olefin polymerisation.	15	CO4
Practical: Advanced Organometallic Chemistry 1. Preparation and characterisation by various analytical techniques, wherever appropriate and possible: (a) Ferrocene and its derivatives. (b) Metal hydride complexes: $CoH[(P(OPh_3)_3]_4$ and $NiH[(P(OPh_3)_3]_4$. (c) Triphenylphosphine complexes of transition metals: $NiCl_2(PPh_3)_2$, $RuHCl(CO)(PPh_3)_3$, $RuH_2(CO)(PPh_3)_3$. (d) Metal-Metal bonded complexes: $[Mo_2(O_2CMe)_4]$ and $K_4[Mo_2(Cl)_8]$. *Other new novel syntheses and experiments reported in the literature from time to time may be included during the semester.*	30	CO5

Recommended Books

Theory

1. Spessard, G. O.; Miessler, G. L., *Organometallic Chemistry*, 3rd Ed., Oxford University Press, Oxford (2015). (ISBN: 978-0199342679).
2. Elschenbroich, C., *Organometallics*, 3rd Ed., Wiley-VCH, Weinheim (2016). (ISBN: 978-3527293902).
3. Elias, A.; Gupta, B. D., *Basic Organometallic Chemistry: Concepts, Syntheses and Applications*, 2nd Ed., Universities Press, Hyderabad (2013). (ISBN: 978-8173718748)
4. Crabtree, R. H., *The Organometallic Chemistry of the Transition Metals*, 6th Ed., Wiley-Blackwell, New York (2014). (ISBN: 978-1119465881).
5. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
6. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., Shriver *Atkins' Inorganic Chemistry*, 6th Ed., Oxford University Press, New Delhi (2015). (ISBN: 978-0198757177).
7. Miessler, G.; Tarr, D. A., *Inorganic Chemistry*, 3rd Ed., Pearson Education India, New Delhi (2008). (ISBN: 978-8131718858).

Practical

1. Woolins, J. D. (Ed.), *Inorganic Experiments*, 3rd Ed., Wiley-VCH (2010). (ISBN: 978-352732472-9).

2. Parshall, G. W. (Ed.), *Inorganic Syntheses*, Vol XIV, McGraw-Hill (1974). (ISBN: 978-0470131763).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	M	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	H	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

3.1.1 DEPARTMENTAL ELECTIVES

SEMESTER VIII

NCrF Level	6.0	
Course Code	CHE-001-DE-42010	
Title of the Course	Bioinorganic Chemistry	
Nature of the Course	Departmental Elective	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces students to advanced knowledge of the role of metal ions in biological systems and their structure-function relationship. It also aims to provide basic knowledge of metal-containing proteins and enzymes and their significance. The course also introduces the students to the preparation and characterisation of model compounds of biomolecules.

Course Outcomes

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

CO1: Understand the role of metal ions in biological systems and processes.

CO2: Acquire knowledge of the iron-containing proteins and enzymes and their roles in biological systems.

CO3: Understand the structure, function and role of Mo, Cu, Zn and Co-containing enzymes in biological systems.

CO4: Acquire practical experiences in the synthesis and characterisation of model compounds of bioinorganic chemistry.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Ion Transport Across Membrane and Photosynthesis Scope, inorganic elements in the biological system. Mechanism of ion transport across the membrane. Energetics of transport, kinetics and mechanism of transport, ionophores, valinomycin; ATP mediated active transport, Na^+ /K^+ pump. Ca^{2+} transport. Role of calcium in muscle contraction, blood-clotting mechanism. Photosynthesis: Chlorophyll-structural features, role of Mg^{2+}, Z-scheme of photosynthesis - PSI and PSII. Water Oxidation Centre (WOC) and model studies.	15	CO1
Iron-Containing Proteins and Enzymes Oxygen transport and oxygen uptake proteins: transport and storage of dioxygen; Heme proteins and oxygen uptake, structure and functions of haemoglobin and myoglobin, dioxygen binding, cooperativity effect, Bohr effect, Hill equation; model complexes for dioxygen binding; Non-heme systems: hemerythrin and hemocyanin. Cytochromes: cytochrome c, cytochrome P-450. Iron-sulphur proteins: rubredoxin and ferredoxin.	15	CO2

Iron-containing enzymes: peroxidase, catalase. Iron storage and transport: siderophores, ferritin and transferrins.		
Mo, Cu, Zn and Co-Containing Enzymes *Molybdenum-containing enzymes*: xanthine oxidase, nitrate reductase, nitrogenase, biological fixation of N_2. *Copper-containing enzymes*: superoxide dismutase, cytochrome c oxidase, plastocyanin and ceruloplasmin. *Zinc-containing enzymes*: zinc fingers, carbonic anhydrase, carboxypeptidase, alcohol dehydrogenase, phosphodiesterase and nuclease, interchangeability of zinc and cobalt in enzymes. *Cobalt-containing enzymes*: Vitamin B_{12} and B_{12} coenzymes and cyanocobalamin.	15	CO3
Practical: Bioinorganic Chemistry 1. The synthesis, characterisation and electrochemical studies of Cobalt-based models of water oxidation catalysts. 2. The synthesis and coordination chemistry of macrocyclic complexes. 3. Metalloporphyrin Chemistry: The synthesis and characterisation of porphyrins and their complexes. 4. Stability constants and pH titration of amino acid complexes copper and nickel. 5. Models of Vitamin B_{12}: Cobaloximes. *Other new novel syntheses and experiments reported in the literature from time to time may be included during the semester.*	30	CO4

Recommended Books

Theory

1. Kaim, W.; Schwederski, B.; Klein, A., *Bioinorganic Chemistry-Inorganic Elements in the Chemistry of Life: An Introduction and Guide*, 2nd Ed., John Wiley & Sons, West Sussex (2013). (ISBN: 978-0470975237).
2. Bertini, I.; Gray, H. B.; Lippard, S. J.; Valentine, J. S., *Bioinorganic Chemistry*, Viva Books, New Delhi (2007). (ISBN: 978-8176490009)
3. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147)
4. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins' Inorganic Chemistry*, 6th Ed., Oxford University Press, New Delhi (2015). (ISBN: 978-0198757177).
5. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 4th Ed., Pearson Education India, New Delhi (2006). (ISBN: 978-9356064485).
6. Rehder, D., *Bioinorganic Chemistry*, Oxford University Press, London (2014). (ISBN: 978-0199655199)
7. Roat-Malone, R. M., *Bioinorganic Chemistry: A Short Course*, 2nd Ed., Wiley-Blackwell, New York (2007). (ISBN: 978-1119535218).
8. Reddy, K. H., *Bioinorganic Chemistry*, New Age International Publishing, New Delhi (2009). (ISBN: 978-9387788879)

Practical

1. Woolins, J. D. (Ed.), *Inorganic Experiments*, 3rd Ed., Wiley-VCH (2010). (ISBN: 978-3527324729).
2. Girolami, G. S.; Rauchfuss, T. B.; Angelici, R. J., *Synthesis and techniques in Inorganic Chemistry: A Laboratory Manual*, 3rd Ed., University Science Books (1999). (ISBN: 978-0935702484).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	M	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO2	H	M	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO3	H	M	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO4	H	H	-	-	H	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER VIII

NCrF Level	6.0	
Course Code	CHE-001-DE-42020	
Title of the Course	Inorganic Reaction Mechanisms	
Nature of the Course	Departmental Elective	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces students to advanced concepts of inorganic reaction mechanisms and inorganic photochemistry. The students will also learn how to study the reaction kinetics of coordination complexes and their redox properties.

Course Outcomes

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

CO1: Learn about ligand substitution reaction and its mechanism in square planar and octahedral complexes.

CO2: Acquire knowledge of redox reactions and applications of electron transfer reactions in synthesising complexes.

CO3: Understand the kinetics and mechanism of inorganic photochemical reactions.

CO4: Learn about photo splitting of water and inorganic photochemistry in biological processes and their model studies.

CO5: Gain hands-on experience to study the reaction kinetics of coordination complexes and their redox properties using cyclic voltammetric techniques.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Ligand Substitution Reactions Ligand Substitution Reactions: Inner and Labile Complexes; Mechanisms of Substitution reaction and their kinetic consequences. Ligand substitution reactions in octahedral complexes: ligand and steric effect on reaction rate; water exchange, The Eigen-Wilkins mechanism; base-catalysed hydrolysis; isomerisation and racemisation reactions. Ligand substitution in square planar complexes: trans effect and its influence.	15	CO1
Redox Reactions Inner sphere electron transfer, Taube mechanism, bridging ligand effect; outer sphere electron transfer, Marcus theory, Excited state outer sphere electron transfer reactions, use of electron transfer reactions for synthesising complexes. Half-cell reaction, redox potential, electrochemical series, Nernst equation, Latimer and Frost diagram, disproportionation reactions, basics of cyclic voltammetry.	15	CO2
Inorganic Photochemistry Introduction to Inorganic Photochemistry, photophysical and photochemical processes, characteristics of the electronically excited	15	CO3, CO4

states of inorganic compounds–ligand field states, charge transfer states, Frank-Condon, and thexi states, kinetics of photochemical process. Photochemical reactions: substitution and redox reactions of chromium, cobalt and ruthenium complexes. Relevance of ruthenium polypyridine complexes in solar energy conversion and storage, photo splitting of water, Inorganic photochemistry in biological processes and their model studies.		
Practical: Inorganic Reaction Mechanisms 1. Synthesis of cobalt complexes and their ligand substitution kinetics: Aquation of $[Co(NH_3)_5Cl_2]^{2+}$ and *trans*-$[Co(en)_2Cl_2]^{+}$. 2. Kinetics of acid hydrolysis of *trans*-$[Co(en)_2Cl_2]^{+}$. 3. Determination of the diffusion coefficient of the ion $[Fe(CN)_6]^{3-}$ by cyclic voltammetry. 4. Verify the Randles-Sevcik equation for cyclic voltammetry using a reversible system (10 mM mixture of $K_3[Fe(CN)_6]$ and $K_4[Fe(CN)_6]$ in 2 M KCl). Identify the peak current and peak potential at different scan rates. Verify the reversibility of the Fe^{2+}/Fe^{3+} system by using the ratio of cathodic and anodic peak currents. 5. Investigation of the complex ion formation between Ni^{2+} and o-phenanthroline by Job's method. 6. Study of complex formation by the method of isobestic point. 7. Determination of the number of chloride ions in the $[Co(NH_3)_5]Cl_3$ and $[Co(NH_3)_5Cl]Cl_2$. *Other new novel syntheses and experiments reported in the literature from time to time may be included during the semester.*	30	CO5

Recommended Books

Theory

1. Miessler, G.; Tarr, D. A., *Inorganic Chemistry*, 3rd Ed., Pearson Education India, New Delhi (2008). (ISBN: 978-8131718858).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147)
3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins's Inorganic Chemistry*, 6th Ed., Oxford University Press, New Delhi (2015). (ISBN: 978-0198757177).
4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 4th Ed., Pearson Education India, New Delhi (2006). (ISBN: 978-9356064485)
5. Jordan, R. B.; *Reaction Mechanisms of Inorganic and Organometallic Systems*, 3rd Ed., Oxford University Press, New York (2007). (ISBN: 978-0195301007).
6. Roundhill, D. M., *Photochemistry and Photophysics of Metal Complexes*, Plenum: New York (1994). (ISBN: 978-1489914972).
7. Basolo, F.; Pearson, R. G., *Mechanisms of Inorganic Reactions: Study of Metal Complexes in Solution*, 2nd Ed., John Wiley and Sons, New Jersey (1975). (ISBN: 978-0471055457).

Practical

1. Woolins, J. D. (Ed.), *Inorganic Experiments*, 3rd Ed., Wiley-VCH (2010). (ISBN: 978-3527324729).

2. Girolami, G. S.; Rauchfuss, T. B.; Angelici, R. J., *Synthesis and techniques in Inorganic Chemistry: A Laboratory Manual*, 3rd Ed., University Science Books (1999). (ISBN: 978-0935702484).
3. Jahagirdar, D. V., *Experiments in Chemistry*, Himalaya Publishing (2011). (ISBN: 978-9351421276).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	M	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO2	H	M	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO3	H	M	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO4	H	M	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO5	H	H	-	-	-	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VIII

NCrF Level	6.0	
Course Code	CHE-001-DE-42030	
Title of the Course	Organic Synthesis	
Nature of the Course	Departmental Elective	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objective

This course will enable the students to learn about planning the synthesis of complex organic molecules and reagents and methods to achieve targeted synthetic molecules. The course also aims to help learners acquire hands-on experience in synthesising organic molecules.

Course Outcome

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

CO1: Plan the synthesis of organic molecules via retrosynthesis.
CO2: Have knowledge of different types of disconnections and the importance of the order of events in retrosynthesis.
CO3: Familiarise themselves with different reagents used in organic synthesis.
CO4: Acquire knowledge of the synthesis of organic compounds via C-N coupling and various named reactions.
CO5: Acquire practical knowledge in organic synthesis.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Planning a Synthesis Retrosynthesis, synthons and synthetic equivalents, disconnection approach, functional group inter-conversions, importance of the order of events in organic synthesis. One and two group C-X disconnection: synthesis of alcohols, ethers, sulfides, amines; chemoselectivity guidelines; One group C-C disconnections: in alcohols and carbonyl compounds, regioselectivity, Two group C-C disconnections: Diels-Alder reaction, α,β -unsaturated carbonyl compounds, control in carbonyl condensations, difunctionalised compounds, Michael addition and Robinson annulation.	15	CO1, CO2
Reagents in Organic Synthesis Boranes and Alkyl borane; 9-BBN, reduction with trialkylsilanes; tributyltin hydride (Barton-McCombie reaction, radical decarboxylation etc); IBX, Dess-Martin periodinane, Fetizon reagent, dioxiranes, Gilman's reagent, lithium disopropylamide, dicyclohexylcarbodimide, 1,3-dithiane reactivity: Umpolung effect, Phase transfer catalyst, Baker's yeast, NBS, Mosher's reagent, DDQ.	15	CO3

Modern Synthetic Methods Metal mediated C-N coupling reactions: Buchwald-Hartwig, Ullmann and Chan-Lam cross-coupling reactions; Olefination reactions: Tebbe, Petasis, McMurry, Peterson and Julia olefination reactions; Mannich reaction, Biginelli reaction, Hantzsch reaction, Passerini reaction, Ugi reaction, Mitsonobu reaction, Henry reaction, Nef reaction.	15	CO4
Practical: Organic Synthesis 1. $NaBH_4$ reduction of carbonyl compounds. 2. Oxidation of alcohol using Cr reagent. 3. Nitration of acetanilide/nitrobenzene by conventional method. 4. Benzolyation of amines (aniline/ *o*-, *m*-, *p*-toluidine/ *o*-, *m*-, *p*-anisidine). 5. Dehydration of Phthalic acid to phthalic anhydride. 6. Nitration of nitrobenzene.	30	CO5

Recommended Books

Theory

1. Warren, S., *Organic Synthesis: The Disconnection Approach*, Wiley India, New Delhi (2007). (ISBN: 978-8126511464).
2. Carruthers, W., *Modern Methods of Organic Synthesis*, 4th Ed., Cambridge University Press, New Delhi (2005). (ISBN: 978-1107567450).
3. Smith, M. B., *Organic Synthesis*, 4th Ed., Academic Press, Cambridge, Massachusetts (2016). (ISBN: 978-0128007204).
4. Kurti, L., Czako, B., *Strategic Application of Named Reactions in Organic Synthesis*, Elsevier, Amsterdam (2005). (ISBN: 978-0124297852).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education, New Delhi (2005). (ISBN: 978-8177589573).
2. Sharma, R. K.; Sidhwani, I. T.; Chaudhari, M. K. *Green Chemistry Experiment: A Monograph*, I. K. International Publishing, New Delhi (2012). (ISBN: 978-9381141557).
3. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2013). (ISBN: 978-8173714757)

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	H	-	-	-	-	-	-	-	-	-	H	H	M	-
CO2	H	-	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO3	H	-	-	-	H	-	-	-	-	-	-	-	H	H	M	-
CO4	H	-	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO5	H	H	-	-	H	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VIII

NCrF Level	6.0	
Course Code	CHE-001-DE-42040	
Title of the Course	Chemistry of Natural Products	
Nature of the Course	Departmental Elective	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces the learners to the classical and advanced concepts and theories of isolation and structure elucidation of biologically important pure molecules from natural products. It also aims to give the learners practical knowledge on synthesising natural products and their characterisation.

Course Outcomes

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

CO1: Acquire knowledge of extraction, isolation, and purification of natural products from different sources.
CO2: Gain knowledge about the classification and structure determination of terpenoids and alkaloids.
CO3: Learn the basic strategies of using natural products in drug discovery and design.
CO4: Acquire practical knowledge on extracting and isolating natural products and their characterisation.
CO5: Use computational software to learn molecular docking and simulation experiments.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Isolation and Purification of Natural Products *Introduction*: Introduction, sources (plant, animal, microbial, marine), classification on chemical basis. *Extraction of natural products*: Conventional and modern extraction methods, including maceration, percolation, Soxhlet extraction, batch extraction, continuous extraction, counter-current extraction, accelerated solvent extraction and supercritical fluid extraction. Concepts of extraction for activity-guided fractionation. *Introduction to chromatographic techniques*: High-performance thin layer chromatography (HPTLC), flash chromatography, high-performance liquid chromatography (HPLC), gas chromatography (GC), chiral chromatography and reverse phase chromatography and their use in the identification of markers/biomarkers.	15	CO1

Terpenoids and Alkaloids Terpenoids: Definition, classification and structure determination (general methods), chemistry of some important terpenoids: geraniol, limonene, carvone. Alkaloids: Introduction, isolation technique, general methods of structure determination, classification, chemistry of some well-known alkaloids: morphine, heroin, quinine, nicotine reserpine, etc.	15	CO2
Natural Products in Drug Discovery Drug Discovery, design and development. ADMET of drugs: Factors affecting Absorption, Distribution, Metabolism, Elimination and Toxicity. Structure-activity relationships: Strategies in drug design. QSAR and combinatorial synthesis. Optimization of drug target interactions and access to drug targets. Pro drugs and drug delivery systems. Source, structure and applications of Artemisinin, Ephedrines, Ergot alkaloids, Vasicine, Taxol and their derivatives.	15	CO3
Practical: Chemistry of Natural Products 1. TLC studies of natural extracts and isolation of natural products: (a) Caffeine from tea leaves (b) Nicotine from tobacco (c) *β*-Carotene from carrot (d) Lycopene from tomato (e) Euginol from cloves (f) Casein from milk (g) Piperine from black pepper (h) Any other extraction possible in the laboratory. 2. Molecular docking and simulation experiments using docking freeware such as AutoDock.	30	CO4, CO5

Recommended Books

Theory

1. Finar, I. L. *Organic Chemistry*, 5th Ed., Vol. 2, Pearson Education, New Delhi (2011). (ISBN: 978-8177585414).
2. Silverman, R. B., *The Organic Chemistry of Drug Design and Drug Action*, 2nd Ed.; Elsevier Academic Press, Cambridge, Massachusetts (2012). (ISBN: 978-9351072720).
3. Mann, J.; Davidson, R. S.; Hobbs, J. B.; Banthrope, D. V., Harborne, J. B., *Natural Products, Their Chemistry and Biological Significance*, Longman, Essex (1994). (ISBN: 978-0582060098).
4. Silverstein, R. M.; Webster, F. X.; Kiemle, D. J.; Bryce, D. L., *Spectrometric Identification of Organic Compounds*, 8th Ed., Wiley India, New Delhi (2022). (ISBN: 978-9354642296).
5. Patrick, G. L., *An Introduction to Medicinal Chemistry*. 6th Ed.; Oxford University Press, New Delhi (2017). (ISBN: 978-0198749691).
6. Nicolaou, K. C.; Sorensen, E. J. *Classics in Total Synthesis: Targets, Strategies, Methods*; Wiley-VCH: New York (1996). (ISBN: 978-3527292318).
7. Lemke, T. L.; Zito, S. W.; Roche, V. F.; Williams, D. A. *Essentials of Foye's Principles of Medicinal Chemistry*; Wolters Kluwer India: New Delhi (2016). (ISBN: 978-9351296683).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India, New Delhi (2003). (ISBN: 978-8177589573).
2. Mann, F. G.; Saunders, B. C., *Practical Organic Chemistry*, 4th Ed., Pearson Education India, New Delhi (2009). (ISBN: 978-8131727102).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers, New Delhi (2007). (ISBN: 978-8123915012).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan, Meerut (2014). (ISBN: 978-8182835054).
5. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2004). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	H	-	H	-	-	-	-	-	H	H	H	H	H	-
CO2	H	H	-	-	H	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	H	-	H	-	-	-	-	-	-	-	H	H	H	-
CO4	H	-	-	-	-	-	-	-	-	-	H	H	H	H	H	-
CO5	H	H	H	-	H	H	-	-	-	-	H	H	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER VIII

NCrF Level	6.0	
Course Code	CHE-001-DE-42050	
Title of the Course	Polymer Chemistry	
Nature of the Course	Departmental Elective	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course is designed to introduce the theory and applications of polymer chemistry to the students. They will also learn the kinetics of polymerization and study a few industrially important polymers, including conducting polymers, which are promising classes of polymeric materials for next-generation devices. The course also aims to help learners acquire hands-on experience in synthesising simple and common polymeric materials.

Course Outcomes

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

CO1: Learn the basic concepts, definitions and classifications of polymers.
CO2: Understand the concept of different types of molecular weight of polymers and the theories involved in their determination.
CO3: Understand various properties of polymers and their solutions.
CO4: Get introduced to the preparation, structure and properties of some industrially important and technologically promising polymers.
CO5: Carry out laboratory syntheses of a few simple and common polymeric materials and determine the molecular weights.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Introduction to Polymers Brief overview of polymers: Different schemes of classification of polymers, polymer nomenclature, molecular forces and chemical bonding in polymers, texture of polymers. Concept and types of molecular weight; significance of molecular weight; Methods of determining molecular weights of polymers: End group analysis; osmometry, viscometry and light scattering methods. Molecular weight distribution and its significance. Polydispersity index (PDI). Different models for describing the size and shape of dissolved macromolecules, configuration and conformation of macromolecules. Diffusion and Stokes-Einstein equation. Distribution of chain lengths: average end-to-end, root mean square end-to-end and most probable end-to-end chain length.	15	CO1, CO2

Types of polymerisations; kinetics of addition and step growth (condensation) polymerisation; degree of polymerisation and chain length.		
Properties of Polymer and Polymer Solution Determination of crystalline melting point and degree of crystallinity, morphology of crystalline polymers, Factors affecting crystalline melting point. Nature and structure of polymers, structure-property relationships. Glass transition temperature (T_g) and determination of T_g, free volume theory, Williams-Landel-Ferry (WLF) equation, factors affecting glass transition temperature (T_g). Polymer Solution: Criteria for polymer solubility, solubility parameter, thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory-Huggins theory, lower and upper critical solution temperatures. Properties of polymers (physical, thermal, flow & mechanical properties).	15	CO3
Synthesis of Polymers Criteria for synthetic polymer formation. A brief introduction to the preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro-polymers, polyamides and related polymers. Phenol formaldehyde resins (bakelite, novalac), polyurethanes, silicone polymers, polydienes, polycarbonates. Conducting polymers [polyacetylene, polyaniline, poly(*p*-phenylene sulphide polypyrrole, polythiophene)].	15	CO4
Practical: Polymer Chemistry 1. Determination of molecular weight: (a) Determination of molecular weight of a polymer (polystyrene, poly (vinylproplylidine), etc.) by viscometry method. (b) Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer. (c) Determination of molecular weight of polyethylene glycol (PEG) (OH group) by end-group analysis. 2. Polymer Synthesis: (a) Oxidative polymerisation of aniline using ammonium peroxydisulphate. (b) Free radical solution polymerisation of (i) styrene and (ii) Acrylic acid (AA). (c) Preparation of nylon 66/6 (d) Precipitation polymerisation of acrylonitrile (e) Preparation of urea-formaldehyde resin (f) Preparations of novalac resin 3. Polymer Analysis (a) Estimation of the amount of HCHO in the given solution by sodium sulphite method 4. Instrumental Techniques (a) IR studies of polymers	30	CO5

Recommended Books

Theory

1. Odian, G., *Principles of Polymerization*, 4th Ed., Wiley India (2004). (ISBN: 978-8126513918).
2. Billmeyer, F.W., *Textbook of Polymer Science*, 3rd Ed., Wiley Interscience (2007). (ISBN: 978-8126511105).
3. Ghosh, P., Polymer Science and Technology: Plastics, Rubber, Blends and Composites, 3rd Ed., Tata McGraw-Hill Education (2017). (ISBN: 978-0070707047).
4. Flory, P. J., *Principles of Polymer Chemistry*, Asian Books, New Delhi (2006). (ISBN: 978-0801401343).
5. Gowariker, V. R.; Viswanathan, N. V.; Sreedhar, J., *Polymer Science*, 5th Ed., New Age International (2023). (ISBN: 978-9389802580).

Practical

2. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, University Press (2000). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	-	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO2	H	H	-	-	M	-	-	-	-	-	-	-	H	H	M	-
CO3	H	H	-	-	M	-	-	-	-	-	-	-	H	H	M	-
CO4	H	M	-	-	-	-	-	-	-	-	-	-	H	H	M	-
CO5	H	H	-	-	H	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER VIII

NCrF Level	6.0	
Course Code	CHE-001-DE-42060	
Title of the Course	Advanced Chemical Kinetics	
Nature of the Course	Departmental Elective	
Total Credits	4 (L 2 – T 1 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This is course on physical chemistry covers advanced chemical kinetics focusing on reactions in solutions and reaction dynamics. The students will also learn how to study the kinetics of various chemical reactions.

Course Outcomes

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

CO1: Learn about the methods of studying chemical reactions.
CO2: Develop an understanding on the kinetics of reactions in solutions and molecular reaction dynamics.
CO3: Have knowledge on different theories of dynamics of unimolecular reactions.
CO4: Acquire experiences of performing least square fitting while carrying out experiments of chemical kinetics.
CO5: Determine the order of reaction and activation energy by performing conductometric titration.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Study of Chemical Reactions Methods of studying chemical reactions: molecular beam study; stopped flow technique, temperature and pressure jump methods, NMR studies in fast reactions, shock tube kinetics. Relaxation kinetics: linearized rate equation, relaxation time in single step fast reactions, determination of relaxation time and rate constant.	15	CO1
Reactions in Solutions Kinetics of ion – ion and ion – dipole reactions, effect of dielectric constant on reaction rate; effect of pressure on reaction rate; cage reactions, cluster reactions, electron transfer reactions, kinetics of diffusion-controlled reactions; transport phenomena; Linear free energy relationship, Hammet equation, Taft equation and their applications.	15	CO2
Molecular Reaction Dynamics Potential energy surfaces; features of potential energy surfaces; estimation of activation energy and calculation of potential energy surfaces; collisions of real molecules; trajectory calculations. Dynamics of unimolecular reactions: limitations of Lindemann and	15	CO3

Hinshelwood theory, RRK theory, RRKM theory (quantitative treatment). Femtochemistry: dynamics and chemical reactivity.		
Practical: Advanced Chemical Kinetics 1. To study the kinetics of the reaction between $K_2S_2O_8$ and KI and hence determine the rate constant and order of the reaction. Also, study the influence of ionic strength on the reaction rate. 2. To determine the relative strengths of two acids by studying the acid-catalysed hydrolysis of methyl acetate (use least square fitting). 3. To study the saponification of ethyl acetate by sodium hydroxide conductometrically and determine the order of reaction and activation energy. 4. Determine the dissociation constant of methyl red by spectrophotometric method. 5. To study the autocatalytic reaction between potassium permanganate and oxalic acid.	30	CO4, CO5

Recommended Books

Theory

1. Laidler, K. J., Chemical Kinetics, 3rd Ed., Pearson Education, New Delhi (2011). (ISBN: 978-8131709726).
2. Rajaram, V.; Kuriakose, J. C., Kinetics and Mechanism of Chemical Transformation, McMillan India, New Delhi (2009). (ISBN: 978-0333926581).
3. Pilling, M. J.; Pilling, S.; Seakins, P. W., Reaction Kinetics, Oxford University Press, London (1996). (ISBN: 978-0198554813).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books, India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).
3. Khosla, B. D.; Garg, V. C.; Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2008). (ISBN: 978-8180450792).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	-	-
CO5	H	H	-	-	M	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

3.2 MINOR COURSES (MC)

SEMESTER I

NCrF Level	4.5	
Course Code	CHE-001-MC-1110	
Title of the Course	Fundamentals of Chemistry I	
Nature of the Course	Minor	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course reviews the structure of the atom, which is a necessary prerequisite to understanding the nature of chemical bonding in compounds. It is designed to teach the concept of aromaticity and its applications in detail so that the students can acquire the foundation for a better understanding of other organic chemistry topics in subsequent semesters. The course further covers the basic and advanced concepts regarding gaseous states of matter. It deals with various mathematical equations that express different physical properties of gases. The course also provides insight into laboratory courses involving acid-base and redox titrations.

Course Outcomes

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

CO1: Understand the quantum mechanical model of atoms, quantum numbers, electronic configuration, radial and angular distribution curves, and shapes of *s*, *p*, and *d* orbitals.

CO2: Apply the concept of aromaticity to explain the various physical and chemical properties of different organic compounds.

CO3: Acquire knowledge on methods of determination of organic reaction mechanism, kinetically and thermodynamically controlled products and reactions.

CO4: Understand the differences between ideal and real gases, derive the kinetic gas equation, and determine the deviation from ideal behaviour and its reason.

CO5: Estimate metal contents in different samples using acid-base and redox titration techniques.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Atomic Structure Bohr's theory, limitations, and the atomic spectrum of hydrogen. Wave mechanics: de Broglie equation, Heisenberg's uncertainty principle and its significance, Schrödinger's wave equation, the significance of ψ and ψ^2. Quantum numbers and their significance. Normalised and orthogonal wave functions. Sign of wave functions. Radial and angular wave functions for hydrogen atoms. Radial and angular distribution curves. Shapes of *s*, *p*, *d* and *f* orbitals. Pauli's exclusion principle, Hund's rule of maximum multiplicity, Aufbau's principle and its limitations, Variation of orbital energy with atomic number.	15	CO1

Conceptual Organic Chemistry Aromaticity: Hückel's rule, aromatic, non-aromatic, antiaromatic, homoaromatic compounds, *n*-annulenes. Applications of concept of aromaticity: acidity & basicity, stability, reaction kinetics. Effect of magnetism on aromaticity. Reaction mechanisms: thermodynamic and kinetic requirements of reactions, Hammond postulate, intermediate and transition states, kinetically and thermodynamically controlled products and reactions, methods of determining mechanism, and primary and secondary kinetic isotope effect. Linear free energy relationship and their applications (Hammet equation & modification).	15	CO2, CO3
States of Matter I *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, the relation between mean free path and coefficient of viscosity, calculation of σ from η; variation of viscosity with temperature and pressure. *Behaviour of Real Gases*: Deviations from ideal gas behaviour, compressibility factor, *Z*, and its variation with pressure for different gases. Causes of deviation from ideal behaviour. van der Waals equation of state, its derivation and application in explaining real gas behaviour, introduction of equations of state; virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, and law of corresponding states.	15	CO4
Practical: Fundamentals of Chemistry I 1. Acid-Base Titrations (a) Determination of alkali content of antacid tablets using HCl. (b) Estimation of calcium content in chalk as calcium oxalate. (c) Estimation of carbonate and hydroxide present together in mixture. (d) Estimation of carbonate and bicarbonate present together in a mixture. (e) Estimation of free alkali present in different soaps/detergents 2. Redox Titrations (a) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution. (b) Estimation of oxalic acid and sodium oxalate in a given mixture. (c) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicators.	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins's Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015). (ISBN: 978-0198757177).
4. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2020). (ISBN: 978-8192143330).
5. Sykes, P., *A Guidebook to Mechanism in Organic Chemistry*, 6th Ed., Pearson Education India (2003). (ISBN: 978-8177584332).
6. Kalsi, P. S., *Organic Reactions and Their Mechanisms*, 5th Ed., New Age Science (2022). (ISBN: 978-9389802085).
7. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015). (ISBN: 978-8126556588).
8. Greeves, N.; Clayden, J.; Warren, S., *Organic Chemistry*, 2nd Ed., Oxford University Press, New Delhi (2014). (ISBN: 978-0198728719).
9. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
10. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
11. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019). (ISBN: 978-9353165185).
12. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093).

Practical

1. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).
2. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Pearson Education India (2009). (ISBN: 978-8131723258).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO2	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO3	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO4	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	M	H	M

H = High; M = Medium; L = Low

SEMESTER II

NCrF Level	4.5	
Course Code	CHE-001-MC-1210	
Title of the Course	Fundamentals of Chemistry II	
Nature of the Course	Minor	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course introduces students to *s*-, *p*-block elements and compounds. Stereochemistry is introduced to visualise organic molecules in a three-dimensional space. The course also aims to provide perceptions on various mathematical equations that express different physical properties of gases, liquids and solids.

Course Outcomes

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

CO1: Understand the relative stability of different oxidation states, structure, bonding, preparation, properties and uses of *s*- & *p*-block elements.

CO2: Understand the stereochemical and conformational aspects of acyclic and cyclic organic molecules.

CO3: Evaluate molecular velocities (average, root mean square and most probable) and average kinetic energy of gases.

CO4: Derive mathematical expressions for different properties of gas, liquid, and solids to understand their physical significance.

CO5: Have practical experience in the measurement of surface tension and viscosity.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemistry of *s*- and *p*-Block Elements Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of the first member of each group. Allotropy and catenation. Complex formation tendency of *s*- and *p*-block elements. Study the following compounds with emphasis on structure, bonding, preparation, properties and uses. (a) Boron: Boric acid and borates, boron nitrides, borohydrides (diborane). (b) Carbon: Types of carbide, CaC_2, SiC, Al_4C_3- preparation, properties and uses (c) Silicon: Silanes, silicon halides. (d) Nitrogen & Phosphorus: ammonia-manufacture (Haber's process), Oxides and oxoacids of nitrogen and phosphorus.	15	CO1

(e) Sulphur: Sulphuric acid and its properties as dehydrating agent, oxidizing property and action on metals and non-metals. Peroxo acids of sulphur. (f) Halogen: Basic properties of halogens, interhalogen compounds, polyhalide ions, pseudohalogens.		
Stereochemistry I Stereoisomerism in organic compounds. Constitutional, conformational and configurational isomers. Nomenclature for conformers: American and British systems of nomenclature, Klyne-Prelog conformational terminology. Optical activity & isomerism. Homomers, enantiomers, diastereomers. Chiral centres. Projection formulae and interconversion. Chiral axis and chiral planes, helical chirality. Conformational analysis of simple cyclic & acyclic systems. Optical purity. Atropisomerism.	15	CO2
States of Matter II *Gaseous State*: Maxwell distribution and its use in evaluating molecular velocities (average, root mean square and most probable) and average kinetic energy, the law of equipartition of energy, degrees of freedom and molecular basis of heat capacities. *Liquid State*: Physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Temperature variation of viscosity of liquids and comparison with that of gases. Qualitative discussion of the structure of water. *Solid State:* Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices, elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices; X-ray diffraction, Bragg's law. Defects in crystals.	15	CO3, CO4
Practical: Fundamentals of Chemistry II 1. Surface tension measurements. (a) Determine the surface tension by the drop number method. (b) Study the variation of surface tension of detergent solutions with concentration. 2. Viscosity measurement using Ostwald's viscometer. (a) Determination of viscosity of aqueous solutions of (i) polymer, (ii) ethanol, and (iii) sugar at room temperature. (b) Study the variation of viscosity of sucrose solution with the concentration of solute. 3. Determination of water of crystallisation.	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).

3. Atkins, P.; Overton, T.; Rouke, J.; Weller, M.; Armstrong, F.; Hagerman, M., *Shriver Atkins' Inorganic Chemistry*, 6th Ed., Oxford University Press India (2015). (ISBN: 978-0198757177).
4. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
5. Sykes, P., *A Guidebook to Mechanism in Organic Chemistry*, 6th Ed., Pearson Education India (2003). (ISBN: 978-8177584332).
6. Smith, M. B.; March, J., *March's Advanced Organic Chemistry: Reactions, Mechanisms and Structure*, 7th Ed., Wiley India (2015). (ISBN: 978-8126556588).
7. Sengupta, S., *Basic Stereochemistry of Organic Molecules*, 2nd Ed., Oxford University Press India (2018). (ISBN: 978-0199492213).
8. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
9. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
10. Kapoor, K. L., *A Textbook of Physical Chemistry: States of Matter and Ions in Solution*, Vol. I, 6th Ed., McGraw Hill Education India (2019). (ISBN: 978-9353165185).
11. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	M	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	M	H	H

H = High; M = Medium; L = Low

SEMESTER III

NCrF Level	5.0	
Course Code	CHE-001-MC-2110	
Title of the Course	Fundamentals of Chemistry III	
Nature of the Course	Minor	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course provides general and advanced knowledge about chemical bonding *viz*. ionic and covalent bonding. It deals with the chemistry of organic molecules such as alcohols, phenols, thiols, esters, thioesters and epoxides. The course also encompasses various named reactions associated with these functional groups and their mechanisms. It further discusses important topics in physical chemistry, such as thermodynamic concepts, laws of thermodynamics, thermochemistry, and dependence of thermodynamic parameters on composition. This course will also provide a basic understanding of chromatography, crystallisation techniques and detection of elements.

Course Outcomes

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

CO1: Acquire knowledge on chemical bonding viz. ionic and covalent bonding.
CO2: Deduce the shape (geometry) of molecules using radius ratio rules & VSEPR theory.
CO3: Understand the preparation, properties and reactions of alcohols, phenols, thiols, ethers, thioethers and epoxides.
CO4: Understand the laws of thermodynamics, thermochemistry and free energy functions.
CO5: Purify organic compounds using crystallisation techniques and to detect different elements present in unknown organic compounds.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemical Bonding I *Ionic Bond*: General characteristics, types of ions, size effects, radius ratio rule and its limitations. Packing of ions in crystals. Born-Landé equation with derivation and importance of Kapustinskii expression for lattice energy. Madelung constant, Born-Haber cycle and its application, solvation energy. Covalent character in ionic bonds (Fajan's Rule) and its application. *Covalent Bond*: Ionic and covalent bonding (characteristics and properties), Valence bond theory. Application of hybridisation (*sp*, sp^2, sp^3, dsp^3 and d^2sp^3) to explain the structure of simple molecules. Bent's rule, resonance and resonance energy. Polarity in covalent molecules, dipole moment, percentage ionic character and electro-negativity difference. Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs	15	CO1, CO2

and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths.		
Alcohols, Phenols, Thiols, Ethers, Thioethers and Epoxides Alcohols: preparation, properties and relative reactivity of 1º, 2º, 3º 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. Preparation and reactions of thiols and thioethers. Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$.	15	CO3
Chemical Thermodynamics I A brief overview of the laws of thermodynamics. Thermodynamic criteria for the processes in terms of entropy change, internal energy change, enthalpy and free energy (Gibbs and Helmholtz) change. *Thermochemistry*: 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) and pressure on enthalpy of reactions. Adiabatic flame temperature, explosion temperature. *Free Energy Functions*: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; Free energy change and spontaneity. The relation between Joule-Thomson coefficient and other 22 thermodynamic parameters; inversion temperature; Gibbs – Helmholtz equation and its utility in reaction thermodynamics; Maxwell relations; thermodynamic equation of state.	15	CO4
Practical: Fundamentals of Chemistry III 1. Purification of organic compounds by crystallisation using Water /Alcohol/Alcohol-Water and determination of their melting points. 2. Detection of elements (nitrogen, sulphur and halogens) in unknown organic compounds.	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).

4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2020). (ISBN: 978-8192143330)
6. Morrison, R. T.; Boyd, R. N.; Bhattacharjee, S. K., *Organic Chemistry*, 7th Ed., Pearson Education India, New Delhi (2010). (ISBN: 978-8131704813).
7. Finar, I. L., *Organic Chemistry*, Volume 1, 6th Ed., Pearson Education (2002). (ISBN: 978-8177585421).
8. Finar, I. L., *Organic Chemistry*, Volume 2, 5th Ed., Pearson Education (2002). (ISBN: 978-8177585414).
9. Graham Solomons, T.W.; Fryhle, C. B.; Snyder, S. A., *Solomons Organic Chemistry*, Global Edition., Wiley (2024). (ISBN: 978-8126568116).
10. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
11. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).
12. Bahl, A.; Bahl, B. S.; Tuli, G. D., *Essentials of Physical Chemistry*, 28th Ed., S. Chand and Company (2020). (ISBN: 978-9352836093).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India, New Delhi (2003). (ISBN: 978-8177589573).
2. Mann, F. G.; Saunders, B. C., *Practical Organic Chemistry*, 4th Ed., Pearson Education India, New Delhi (2009). (ISBN: 978-8131727102).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers, New Delhi (2007). (ISBN: 978-8123915012).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan, Meerut (2014). (ISBN: 978-8182835054)
5. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2004). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	M	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO2	H	-	-	-	-	-	-	-	-	-	-	-	H	M	H	-
CO3	H	-	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	M	M	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER IV

NCrF Level	5.0	
Course Code	CHE-001-MC-2210	
Title of the Course	Fundamentals of Chemistry IV	
Nature of the Course	Minor	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course aims to provide students with knowledge of bonding theories used to explain the various types of bonds. The students are also introduced to semiconductors and insulators. This course covers details of nitrogen-containing functional groups—their preparation, properties, reactivity, and distinction. Students will study the use of steady-state approximation in deriving rate expressions for simple and complex reaction systems. Students will be introduced to basic experiments on chemical kinetics.

Course Outcomes

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

CO1: Acquire knowledge of the bonding theories and weak chemical forces used to explain various types of bonds (ionic, covalent and metallic).
CO2: Have an understanding of band theory, semiconductors and insulators.
CO3: Acquire a better understanding of the chemistry of compounds having nitrogen-containing functional groups.
CO4: Derive rate expressions for simple and complex reactions using steady-state approximations.
CO5: Acquire practical knowledge on rate determination of simple first and second-order reactions.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemical Bonding II Molecular orbital theory. Molecular orbital diagrams of diatomic (N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions) and simple polyatomic (HCl, BeH_2, CO_2, XeF_2) molecules. *s-p* mixing and orbital interaction. *Metallic Bond*: Qualitative idea of band theory. Semiconductors and insulators. *Weak Chemical Forces*: van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment). Effects of chemical force, melting and boiling points, solubility energetics of dissolution process.	15	CO1, CO2

Nitrogen-Containing Functional Groups Preparation and important reactions of nitro 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 their synthetic applications.	15	CO3, CO4
Chemical Kinetics I Brief overview of reaction rate, rate equation, order and molecularity Steady-state approximation and kinetics of simple reactions (e.g., decomposition of ozone, reaction between NO and O_2, iodination of acetone, decomposition of gaseous N_2O_5). Kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions, (iii) consecutive reactions. Chain reactions: general treatment and explanation of explosions; reaction mechanism and kinetics of H_2-Br_2 reaction and pyrolysis of alkane. Enzyme catalysis: mechanism and kinetics of enzyme catalysis reaction Oscillatory reactions: mechanism and kinetics. Reactions in flow systems; kinetics of fast reaction.	15	CO5, CO6
Practical: Fundamentals of Chemistry IV 1. To determine the rate constant of acid-catalysed hydrolysis of esters. 2. To determine the rate constant of base-catalysed hydrolysis of esters. 3. To investigate the reaction between acetone and iodine in the presence of an acid and to determine the order with respect to each reactant. 4. Determination of relative strengths of HCl and H_2SO_4 by studying the kinetics of hydrolysis of methyl acetate. 5. To determine the rate constant of reaction between KI and $K_2S_2O_8$.	30	CO7

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).

3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).
4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Morrison, R. T.; Boyd, R. N.; Bhattacharjee, S. K., *Organic Chemistry*, 7th Ed., Pearson Education India, New Delhi (2010). (ISBN: 978-8131704813).
6. Finar, I. L., *Organic Chemistry*, Volume 1, 6th Ed., Pearson Education (2002). (ISBN: 978-8177585421).
7. Finar, I. L., *Organic Chemistry*, Volume 2, 5th Ed., Pearson Education (2002). (ISBN: 978-8177585414).
8. Graham Solomons, T.W.; Fryhle, C. B.; Snyder, S. A., *Solomons Organic Chemistry*, Global Edition., Wiley (2024). (ISBN: 978-8126568116).
9. Laidler, K. J., *Chemical Kinetics*, 3rd Ed., Pearson Education, New Delhi (2003). (ISBN: 978-8131709726).
10. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
11. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).

Practical

1. Viswanathan, B.; Raghavan, P. S., *Practical Physical Chemistry*, Viva Books India (2014). (ISBN: 978-8130920696).
2. Yadav, J. B., *Advanced Practical Physical Chemistry*, Krishna Prakashan, Meerut (2015). (ISBN: 978-8182839168).
3. Khosla, B. D.; Garg, V. C.; Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2008). (ISBN: 978-8180450792).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	M	-	-
CO2	H	M	-	-	-	-	-	-	-	-	-	-	H	M	M	-
CO3	H	H	M	-	-	-	-	-	-	-	-	-	H	M	H	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	M	M	-
CO5	H	M	-	-	-	H	-	-	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER V

NCrF Level	5.5	
Course Code	CHE-001-MC-3110	
Title of the Course	Fundamentals of Chemistry V	
Nature of the Course	Minor	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course introduces the students to various theories used to explain acid & base chemistry including the Pearson acid-base concept. It also covers the chemistry of carboxylic acids and their derivatives. Further, it introduces to the learners chemical equilibrium, equilibrium constants and the relationship between three different types of equilibrium constants in detail. Students will be introduced to the iodometric titration and preparation of inorganic compounds.

Course Outcomes

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

CO1: Understand various theories of acids and bases, Pearson's HSAB principle and its applications.
CO2: Acquire knowledge about carboxylic acid and its derivatives, their reactions with mechanisms.
CO3: Learn a few named organic reactions.
CO4: Apply the concepts of gas equations, Le Chatelier's principle, Gibbs free energy of reaction etc., while studying other chemistry courses and everyday life.
CO5: Acquire knowledge of iodometric titration and preparation of inorganic compounds.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Acids and Bases Arrhenius, Brönsted-Lowry, and Lewis concepts of acids and bases, Proton transfer equilibria in water, solvent levelling, classification of acids and bases as hard and soft. Pearson's HSAB concept, acid-base strength and hardness and softness. Theoretical basis of hardness and softness, electronegativity and hardness and softness. Applications of acid-base chemistry in qualitative analysis and catalysis, superacids and superbases.	15	CO1
Carboxylic Acids and their Derivatives 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 sulphonic acids. Preparation and reactions of acid chlorides, anhydrides, esters and amides; Mechanism of acidic and alkaline hydrolysis of esters,	15	CO2, CO3

Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.		
Chemical Equilibrium Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases, concept of fugacity. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Coupling of exoergic and endoergic reactions. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between the various equilibrium constants K_p, K_c and K_x. Le Chatelier's principle (quantitative treatment); equilibrium between ideal gases and a pure condensed phase.	15	CO4
Practical: Fundamental of Chemistry V 1. Iodometric titrations (a) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution. (b) Estimation of (i) arsenite and (ii) antimony in antimony potassium tartrate. (c) Estimation of available chlorine in bleaching powder. 2. Inorganic preparations (a) Cuprous Chloride (Cu_2Cl_2) from copper sulphate. (b) Preparation of Manganese phosphate ($MnPO_4 \cdot xH_2O$) from manganese nitrate [$Mn(NO_3)_2$]. (c) Preparation of chrome alum [$K_2SO_4 \cdot Cr_2(SO_4)_3 \cdot 24H_2O$] and potash alum [$K_2SO_4 \cdot Al_2(SO_4)_3 \cdot 24H_2O$].	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).
4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Morrison, R. T.; Boyd, R. N.; Bhattacharjee, S. K., *Organic Chemistry*, 7th Ed., Pearson Education India, New Delhi (2010). (ISBN: 978-8131704813).
6. Finar, I. L., *Organic Chemistry*, Volume 1, 6th Ed., Pearson Education (2002). (ISBN: 978-8177585421).
7. Finar, I. L., *Organic Chemistry*, Volume 2, 5th Ed., Pearson Education (2002). (ISBN: 978-8177585414).
8. Graham Solomons, T.W.; Fryhle, C. B.; Snyder, S. A., *Solomons Organic Chemistry*, Global Edition., Wiley (2024). (ISBN: 978-8126568116).
9. Laidler, K. J., *Chemical Kinetics*, 3rd Ed., Pearson Education, New Delhi (2003), (ISBN: 978-8131709726).
10. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018), (ISBN: 978-0198814740).

11. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).

Practical

1. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).
2. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Pearson Education India (2009). (ISBN: 978-8131723258).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	M	-	-	M	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VI

NCrF Level	5.5	
Course Code	CHE-001-MC-3210	
Title of the Course	Fundamentals of Chemistry VI	
Nature of the Course	Minor	
Total Credits	4 (L 3 – T 0 – P 1)	
Total Contact Hours (CH)	75 (Theory – 45; Practical – 30)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course covers the chemistry of carbonyl and heterocyclic compounds and their derivatives. It also discusses the coordination compounds which find manifold applications in diverse areas. It also aims to provide fair knowledge of the four colligative properties and their application in daily life. Students will also learn about the detection of functional groups and the preparation of organic compounds.

Course Outcomes

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

CO1: Have a good understanding of chemical bonding in metal complexes, and application of Valence Bond Theory to predict the structure and magnetic behaviour of complexes.

CO2: Know the terms Δ_o, Δ_t pairing energy, CFSE, high spin and low spin complexes etc. as well as their significance on physicochemical properties like colour, magnetism, lattice enthalpy, hydration enthalpy etc.

CO3: Know about carbonyl compounds, their structure, synthesis and reactivity

CO4: Have fair knowledge of the four colligative properties and their application.

CO5: Carry out identification of functional groups like alcohols, phenols, carbonyl and carboxylic acid and to perform organic preparations.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Coordination Chemistry Isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Chelate effect, polynuclear complexes, Labile and inert complexes. Werner's theory, valence bond theory, electroneutrality principle and back bonding. Crystal field theory, measurement of 10 D*q* (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 D*q* (Δ_o, Δ_t). Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry (Jahn-Teller theorem), square planar geometry. Molecular orbital (MO) theory of selected octahedral and tetrahedral complexes; thermodynamic aspects of CFSE.	15	CO1, CO2
Carbonyl and Heterocyclic Compounds Structure, reactivity and preparation; nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia	15	CO3

derivatives and their mechanisms; mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisen-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements and haloform reaction. Addition reactions of unsaturated carbonyl compounds: Michael addition. Classification and nomenclature, Structure, aromaticity in 5- and 6-membered rings containing one heteroatom (pyrrole, furan, thiophene and pyridine); synthesis, reactions and mechanism of substitution reactions of furan, pyrrole, and thiophene.		
Solutions and Colligative Properties Dilute solutions; lowering of vapour pressure, Raoult's and Henry's Laws and their applications. Thermodynamic derivation using chemical potential to derive relations between the four colligative properties [(i) relative lowering of vapour pressure, (ii) elevation of boiling point, (iii) Depression of freezing point, (iv) osmotic pressure] and amount of solute. Applications in calculating molar masses of normal, dissociated and associated solutes in solution.	15	CO4
Practical: Fundamental of Chemistry VI 1. Functional group tests for alcohols, phenols, carbonyl and carboxylic acid group. 2. Organic preparations: (a) Benzolyation of phenols (β-naphthol/resorcinol/p-cresol) by Schotten-Baumann reaction. (b) Oxidation of ethanol/ acetone (Iodoform reaction). (c) Nitration of Salicylic acid by green approach (using ceric ammonium nitrate). (d) Reduction of p-nitrobenzaldehyde/ m-nitrobenzaldehyde by sodium borohydride. (e) Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde. (h) Benzil-Benzilic acid rearrangement.	30	CO5

Recommended Books

Theory

1. Lee, J. D., *Concise Inorganic Chemistry*, 5th Ed., Wiley India (2008). (ISBN: 978-8126515547).
2. Housecroft, C. E; Sharpe, A. G., *Inorganic Chemistry*, 5th Ed., Pearson Education (2018). (ISBN: 978-1292134147).
3. Cotton, F. A.; Wilkinson, G.; Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley India (2007). (ISBN: 978-8126511143).
4. Huheey, J. E.; Keiter, E. A.; Keiter, R. L.; Medhi, O. K., *Inorganic Chemistry: Principles of Structures and Reactivity*, 5th Ed., Pearson Education India (2022). (ISBN: 9789356064485).
5. Puri, B. R.; Sharma, L. R.; Kalia, K. C., *Principles of Inorganic Chemistry*, 33rd Ed., Vishal Publishing (2020). (ISBN: 978-8192143330).
6. Morrison, R. T.; Boyd, R. N.; Bhattacharjee, S. K., *Organic Chemistry*, 7th Ed., Pearson Education India, New Delhi (2010). (ISBN: 978-8131704813).

7. Finar, I. L., *Organic Chemistry*, Volume 1, 6th Ed., Pearson Education (2002). (ISBN: 978-8177585421).
8. Finar, I. L., *Organic Chemistry*, Volume 2, 5th Ed., Pearson Education (2002). (ISBN: 978-8177585414).
9. Graham Solomons, T.W.; Fryhle, C. B.; Snyder, S. A., *Solomons Organic Chemistry*, Global Edition., Wiley (2024). (ISBN: 978-8126568116).
10. Atkins, P. W.; de Paula, J.; Keeler, J., *Physical Chemistry*, 11th Ed., Oxford University Press India (2018). (ISBN: 978-0198814740).
11. Puri, B. R.; Sharma, L. R.; Pathania, M. S., *Principles of Physical Chemistry*, 47th Ed., Vishal Publishing (2020). (ISBN: 978-9382956013).

Practical

1. Furniss, B. S.; Hannaford, A. J.; Smith, P. W. G.; Tatchell, A. R., *Vogel's Textbook of Practical Organic Chemistry*, 5th Ed., Pearson Education India, New Delhi (2003). (ISBN: 978-8177589573).
2. Mann, F. G.; Saunders, B. C., *Practical Organic Chemistry*, 4th Ed., Pearson Education India, New Delhi (2009). (ISBN: 978-8131727102).
3. Clarke, H. T., *A Handbook of Organic Analysis: Qualitative and Quantitative*, 4th Ed., CBS Publishers, New Delhi (2007). (ISBN: 978-8123915012).
4. Agarwal, O. P., *Advanced Practical Organic Chemistry*, Krishna Prakashan, Meerut (2014). (ISBN: 978-8182835054).
5. Ahluwalia, V. K.; Aggarwal, R., *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis*, Universities Press (2004). (ISBN: 978-8173714757).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO2	H	H	-	-	M	-	-	-	-	-	-	-	H	H	H	-
CO3	H	H	-	-	M	-	-	-	-	-	-	-	H	H	H	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	H	H	-
CO5	H	M	-	-	M	H	-	-	-	-	-	-	H	H	H	-

H = High; M = Medium; L = Low

SEMESTER VII

NCrF Level	6.0
Course Code	CHE-001-RC-4110
Title of the Course	Research Methodology
Nature of the Course	Minor
Total Credits	4 (L 3 – T 1 – P 0)
Total Contact Hours (CH)	60 (Theory – 60; Practical – 0)
Distribution of Marks	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course is designed to help students formulate appropriate research aims and objectives and frame a good research hypothesis. It also aims to impart knowledge about sampling techniques and data collection and analysis using software. Further, students will acquire knowledge about effective scientific report writing.

Course Outcomes

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

CO1: Understand the aims and objectives of research and formulate a research hypothesis and work plan scientifically.
CO2: Design appropriate sampling techniques and collect data for their experiments.
CO3: Obtain and evaluate information from a variety of databases.
CO4: Process and analyse the data using computer software.
CO5: Communicate effectively in various forms like research publications, patents, etc.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Introduction to Research Methodology An introduction to the basics of scientific research: research objectives, types of research, research process and steps involved. Identification, selection and formulation of a research problem. Intellectual property rights.	15	CO1
Sampling and Data Collection Sampling: design and types; steps involved in sampling; sample size; advantages and limitations. Data types and collection: qualitative and quantitative, data processing, data analysis. Use of databases (SciFinder, Cambridge Structural Database, etc.).	15	CO2, CO3
Computational Methods for Data Analysis and Presentation The application of mean, mode, median, variance, bivariate data: scatterplots, correlation coefficient, standard deviation, least squares fitting methods (linear and non-linear regression analyses). Measures of relative standings: sample *z*-score, concept of percentile. Software packages for data analysis- MS Excel, Origin (introduction only). Use of computational chemistry software (Gaussian 09, GAMESS); construction of z-matrix and concept of force field. Classical Molecular Dynamics (MD) simulation.	15	CO4

Scientific Report Writing and Publication Process Forms and types of scientific reports. Steps involved in scientific article writing. Publication process, selection of journals. Writing research proposals and steps involved. Dissertation/Thesis writing: format and content. Bibliography and references, referencing styles. Appendices.	15	CO5

Assignment: Literature survey/ review writing on selected topics

Recommended Books

1. Kothari, C. K.; Garg, G. *Research Methodology-Methods and Techniques*, 5th Ed., New Age International, New Delhi (2023). (ISBN: 978-9389802559).
2. Kumar, R. *Research Methodology–A Step-By-Step Guide for Beginners*; 2nd Ed., SAGE Publications (2024). (ISBN: 978-9351501336).
3. Montgomery, D. C. *Design & Analysis of Experiments*; 8th Ed., Wiley India (2013). (ISBN: 978-8126540501).
4. Mendenhall, W.; Beaver, R. J.; Beaver, B. M. *Introduction to Probability and Statistics*; 14th Ed., Cenage Learning: New Delhi (2013). (ISBN: 978-8131533048).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	H	-	H	-	-	-	-	-	-	-	H	-	H	-
CO2	H	H	H	-	H	-	-	M	-	-	-	-	H	-	H	M
CO3	H	H	-	-	H	M	-	H	-	-	-	-	H	M	H	-
CO4	H	H	-	-	H	-	-	H	-	-	-	-	H	H	H	H
CO5	H	M	H	H	H	H	-	H	-	-	-	-	H	M	H	-

H = High; M = Medium; L = Low

SEMESTER VIII

NCrF Level	6.0
Course Code	CHE-001-RC-4210
Title of the Course	Research and Publication Ethics
Nature of the Course	Minor
Total Credits	4 (L 3 – T 1 – P 0)
Total Contact Hours (CH)	60 (Theory – 60; Practical – 0)
Distribution of Marks	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course aims to help students understand the philosophy of science and ethics, research integrity, and publication ethics. It also imparts hands-on sessions to identify research misconduct and predatory publications. The course introduces the learners to Indexing and citation databases, open-access publications, research metrics (citations, h-index, Impact Factor, etc.) and plagiarism tools.

Course Outcomes

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

CO1: Understand the philosophy of ethics in science and scientific research, as well as intellectual honesty and research integrity.
CO2: Learn to avoid scientific misconduct such as falsification, fabrication, and plagiarism.
CO3: Follow ethical practices in scientific publications, misrepresentation of data, etc.
CO4: Use Indexing and citation databases and understand the importance of research metrics.
CO5: Handle the plagiarism software for their research work.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Philosophy, Ethics and Scientific Conduct Introduction to philosophy: definition, nature and scope, concept, branches. Ethics: definition, moral philosophy, nature of moral judgements and reactions. Ethics concerning science and research. Intellectual honesty and research integrity. Scientific misconducts: Falsification, Fabrication, and Plagiarism (FFP). Redundant publications: duplicate and overlapping publications, salami slicing. Selective reporting and misrepresentation of data.	15	CO1
Publication Ethics Publication ethics: definition, introduction and importance. Best practices/ standards setting initiative and guidelines: COPE, WAME, etc. Conflicts of interest. Publication misconduct: definition, concept, problems that lead to unethical behaviour and vice versa, types. Violation of publication ethics, authorship and contributorship. Identification of publication misconduct, complaints and appeals. Predatory publishers and journals.	15	CO2

Open Access Publication and Publication Misconduct Open access publications and initiatives**.** SHERPA/RoMEO online resource to check publisher copyright and self-archiving policies. Software tools to identify predatory publications developed by SPPU. Journal finder/ journal suggestion tools. Subject-specific ethical issues, FFP, authorship. Conflicts of interest. Complaints and appeals: examples and fraud from India and abroad.	15	CO3
Research Metrics Impact Factor of journal as per Journal Citation Report, SNIP, SJR, IPP, Cite Score. Metrics: *h*-index, g index, i10 index, altmetrics. **Practice** Use of Journal Suggestion Tools Use of Plagiarism Software Group Discussions on Publication Misconduct	15	CO4, CO5

Recommended Books

1. Bird, A. *Philosophy of Science*; Routledge: London, U.K. (1998). (ISBN: 978-1857285048).
2. MacIntyre, A., *A Short History of Ethics: A History of Moral Philosophy from the Homeric Age to the 20th Century*; 2nd Ed., Routledge: London, U.K. (1998). (ISBN: 978-0415287494).
3. National Academy of Sciences, National Academy of Engineering and Institute of Medicine. *On Being a Scientist: A Guide to Responsible Conduct in Research*; 3rd Ed., The National Academic Press: Washington DC, USA (2009). (ISBN: 978-0309119702).
4. Muralidhar, K.; Ghosh. A.; Singhvi, A. K., Eds. *Ethics in Science Education, Research and Governance*; Indian National Science Academy: New Delhi, India (2019). (ISBN: 978-8193948217).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	M	M	-	-	H	-	-	-	-	-	-	-	H	-	H	-
CO2	M	H	-	-	H	-	-	H	-	-	-	-	H	-	H	M
CO3	M	H	-	H	H	-	-	H	-	-	-	-	H	-	H	M
CO4	H	H	-	-	H	-	-	H	-	-	-	-	H	-	H	H
CO5	H	M	-	-	H	-	-	H	-	-	-	-	H	H	H	H

H = High; M = Medium; L = Low

3.3 MULTIDISCIPLINARY COURSES (MDC)

SEMESTER I

NCrF Level	4.5
Course Code	CHE-001-MD-1110
Title of the Course	Chemistry of Food, Cosmetics and Perfumes
Nature of the Course	Multidisciplinary
Total Credits	3 (L 3 – T 0 – P 0)
Total Contact Hours (CH)	45 (Theory – 45; Practical – 0)
Distribution of Marks	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course will introduce students to the basic concepts of food chemistry, cosmetics, and perfumes. It is designed to provide students with a basic understanding of the analysis of food products and cosmetics.

Course Outcomes

After the completion of the course, the students will be able to:

CO1: Learn about food processing, preservation, adulteration and analyses of food products.
CO2: Have basic knowledge of food standards and associated terms like ISI, Agmark, FPO, MPO, PFA, FSSAI, etc.
CO3: Know about natural and artificial food colourants.
CO4: Have an idea about the constituents of deodorants and antiperspirants.
CO5: Know about the use of coal tar in the cosmetic industry.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Food Preservations, Additives and Contaminants *Food Preservation*: The idea about food preservations. Food preservatives definition, use of food preservatives, when and when not to use food preservatives. Classes of food preservatives and examples with application: benzoates, parabens, propionates, sorbates, sulphites, nitrates and nitrites, and antioxidants. Analysis of preservatives. Food additives definition, intentional additives and incidental additives and contaminants; heavy metals, toxins, pesticides. Food flavours: definition of flavour, basic taste, sweet salty, bitter, sour, areas of taste sensitivity on the tongue. Taste inhibition and modification. Flavour enhancers and artificial sweeteners (Aspartame, saccharin, and sucralose, sodium cyclamate and monosodium glutamate).	15	CO1
Food Processing, Colourants and Adulteration Idea about food processing, packaging and adulteration. Artificial food colourants: Natural and synthetic colourants, Food colourants: tetrapyrrole pigments, chlorophyll, carotenoids,	15	CO2, CO3

anthocyanins and betalanins. Application of colours in the food industry. Analysis of colouring matter. Food adulteration: definition and its importance, adulterants present in- coffee, tea, milk, spices, grains and food colour; Difference between food adulteration and contamination. Identification of adulterants in some common food items. Food Standards: ISI, Agmark, FPO, MPO, PFA, FSSAI.		
Chemistry of Cosmetics and Perfumes A general study including preparation and uses of the following: Hair dye, hair spray, shampoo, suntan lotions, face powder, lipsticks, talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants and artificial flavours. Essential oils and their importance in cosmetic industries with reference to Eugenol, Geraniol, sandalwood oil, eucalyptus, rose oil, 2-phenyl ethyl alcohol, Jasmone, Civetone, Muscone. Coal tar dyes and non-permitted colors and metallic salts. Utility of coal tar dyes in cosmetics and its harmful effect.	15	CO4, CO5

Recommended Books

1. Srilakshmi, B., *Food Science*, 7th Ed., New Age International, New Delhi (2018), (ISBN: 978-9386418890).
2. Subhalakshmi, G.; Udipi, S. A., *Food Processing and Preservation*, 2nd Ed., New Age International, New Delhi (2021), (ISBN: 978-8122472332).
3. Potter, N. N.; Hotchkiss, J. H., *Food Science*, 5th Ed., Springer (1999), (ISBN: 978-8123904726).
4. Sharma, B. K., *Industrial Chemistry (Including Chemical Engineering)*, Goel Publishing House, Meerut (2016), (ISBN: 978-8187224006).
5. Poornima, B., *Food Science & Quality Control*, 1st Ed., Centrum Press (2012), (ISBN: 978-9350844625).
6. Gaur, S.C., *A Handbook of Agn. Food processing and marketing*, Agro. Bios India (2012), (ISBN: 978-8177544541).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	-	M	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	-	M	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	-	M	-
CO4	H	H	-	-	-	-	-	-	-	-	-	-	H	-	M	-
CO5	H	H	-	-	-	-	-	-	-	-	-	-	H	-	M	-

H = High; M = Medium; L = Low

SEMESTER II

NCrF Level	4.5
Course Code	CHE-001-MD-1210
Title of the Course	Chemistry in Daily Life
Nature of the Course	Multidisciplinary
Total Credits	3 (L 3 – T 0 – P 0)
Total Contact Hours (CH)	45 (Theory – 45; Practical – 0)
Distribution of Marks	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

This course aims to introduce learners (without a chemistry background) to the chemistry of substances and materials used in daily life. It will discuss the interesting chemistry principles involved in soaps, detergents, colours, dyes, and pigments. It will also cover polymerisation processes and different commonly used polymer and plastic materials in today's world.

Course Outcomes

After successful completion of the course, students will be able to:

CO1: Gain knowledge about types, manufacture and applications of soap and detergents.
CO2: Learn about theories, classification and applications of colours, dyes and pigments.
CO3: Know various polymerisation processes, types of plastics and uses of some common plastics and polymers.
CO4: Gain insight into recycling and environmental hazards of plastics.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Soaps and Detergents Soaps and Detergents: Definition, saponification, types of soaps, classification: anionic detergents, cationic detergents, non-ionic detergents, cleansing action of soap and detergents, manufacture of soaps, toilet and transparent soaps, manufacture of detergents, shampoo, additives, fillers, flavours, bleaching agents and enzymes used in commercial detergents, environmental hazards of soaps and detergents.	15	CO1
Colours, Dyes and Pigments Witts theory of colour; chromophore and chromogen; Modern theory of colour: colour and absorption of light; colour and conjugated systems; colour wheel of Munsell; dyes: definition; classification of dyes based on application: Direct dyes, Mordant dyes, Vat dyes, Ingrain dyes, Disperse dyes; structure and uses of common dyes: phenolphthalein, indigo, congo red, butter yellow, rosaniline, fluorescein; raw materials for the manufacture of dyes: dye intermediates; non-textiles use of dyes; difference between dyes and pigments; example of pigments.	15	CO2
Polymers Definition; Polymerization process: addition and condensation polymerisation; thermoplastic and thermosetting polymers; copolymers (definition); common properties, uses and limitation of	15	CO3, CO4

various plastics: polyethylene (LDPE and HDPE), polyvinyl chloride, polyvinyl acetate, teflon (PTFE), polypropylene, polystyrene, terylene, nylon 66 etc.; Natural and synthetic rubber: polyisoprene, neoprene, buna-S; recycling of plastics; biodegradable plastics; environmental hazards of plastics.		

Recommended Books

1. Sharma, B. K., *Introduction to Industrial Chemistry*, Goel Publishing, Meerut (1998). (ISBN: 978-8187224006).
2. Jain, P. C.; Jain, M., *Engineering Chemistry*, Dhanpat Rai Publication Co., 17th Ed., (2015). (ISBN: 978-9352165728).
3. Bhal, A.; Bhal, B. S., *Textbook of Organic Chemistry*, 11th & 18th Eds., S. Chand, New Delhi (2006). (ISBN: 978-9352837304).
4. Benvenuto, M. A., *Industrial Inorganic Chemistry*, 2nd Ed., De Gruyter (2024). (ISBN: 978-3111329444).
5. Dara, S. S.; Umare, S. S., *A Textbook of Engineering Chemistry*, S. Chand & Company, New Delhi (2004). (ISBN: 978-8121903592).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	-	H	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	-	H	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	-	H	-
CO4	H	H	-	-	-	-	-	-	-	-	H	-	H	-	H	-

H = High; M = Medium; L = Low

SEMESTER III

NCrF Level	5.0
Course Code	CHE-001-MD-2110
Title of the Course	Introduction to Medicinal Chemistry
Nature of the Course	Multidisciplinary
Total Credits	3 (L 3 – T 0 – P 0)
Total Contact Hours (CH)	45 (Theory – 45; Practical – 0)
Distribution of Marks	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The objective of this paper is to develop basic understanding of drugs discovery, drug design, development and their side effects. It also covers the synthesis of major classes of drug. The course is also designed to introduce the learners to some common Indian medicinal plants and their uses.

Course Outcomes

After the completion of the course, the students will be able to:

CO1: Learn about drugs, drug discovery and their classification.
CO2: Have an idea about lead compounds.
CO3: Gain an insight into drug-target interaction, uses and common side effects of different classes of drugs.
CO4: Know common Indian medicinal plants and their uses in traditional medicine.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Introduction to Drugs Drugs, drug discovery, design and development: lead compounds, analogues, chemotherapeutic index, therapeutic index, structure-activity relationship (SAR, definition only), quantitive-structure activity relationship (QSAR, definition only), pharmacophore; sources of drugs and lead compounds: natural sources, drug synthesis, market forces and me-too drugs; pharmacokinetics and pharmacokinetic phase of drugs: absorption, distribution, metabolism and elimination; bioavailability of a drug; pharmacodynamic phase; classification of drugs: by pharmacological effect, by chemical structure, by target system, by target molecule; naming of drugs and medicines.	15	CO1, CO2
Interaction and Therapeutic Action of Drugs Drug-Target interaction: enzyme and receptors as drug target; therapeutic action, uses and common side effects of different classes of drugs: antacid, antihistamines, analgesics, antipyretic, anti-inflammatory agent (aspirin, paracetamol, ibuprofen), antibiotic (chloramphenicol) antibacterial and antifungal agents, antiviral agents (acyclovir), antiseptics and disinfectants, antifertility drugs, central nervous system agents (phenobarbital, diazepam), cardiovascular (glyceryl trinitrate), antilaprosy (dapsone), HIV-AIDS related drugs (AZT-zidovudine).	15	CO3

Common Indian Medicinal Plants and Their Uses The common name, scientific name, habitat and uses in traditional medicine of common medicinal plants: *Phyllanthus emblica* L. (Amla-Indian gooseberry), *Withania somnifera* (L.) (Dunal) (Aswagandha), *Bacopa monnieri* (L.) Pennel (Brahmi), *Tinospora cordifolia* (Thunb.) Miers (Giloy), *Curcuma longa* (Turmeric), *Aloe barbadensis* Mill (Aloe vera), *Centella asiatica* (L.) Urb. (Indian pennywort), *Azadiracta indica* (Neem), *Moringa oleifera* Lam. (Drumstick), *Zinziber officinale* Roscoe. (Ginger), *Ocimum tenuiflorum* L. (Tulsi), *Boerhavia diffusa* (Punarnava), *Taxus baccata* (English yew).	15	CO4

Recommended Books

1. Lemke, T. L.; Zito, S. W.; Roche, V. F.; Williams, D. A., *Essentials of Foye's Principles of Medicinal Chemistry*. Wolters Kluwer India, New Delhi (2016), (ISBN: 978-9351296683).
2. Patrick, G. L., *An Introduction to Medicinal Chemistry*. 7th Ed.; Oxford University Press, New Delhi (2023), (ISBN: 978-0198866664).
3. Singh, H.; Kapoor, V. K., *Medicinal and Pharmaceutical Chemistry*, Vallabh Prakashan, New Delhi (2012), (ISBN: 978-8185731773).
4. *Common Medicinal Plants and their use*, AYUSH Health & Wellness Centres, Ministry of AYUSH, Government of India, New Delhi (2020).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	-	-	H	M	H	-
CO2	H	H	-	-	-	-	-	-	-	-	-	-	H	M	H	-
CO3	H	H	-	-	-	-	-	-	-	-	-	-	H	H	L	-
CO4	H	-	-	-	-	-	-	-	-	-	-	-	H	-	L	-

H = High; M = Medium; L = Low

3.4 SKILL ENHANCEMENT COURSES (SEC)

SEMESTER I

NCrF Level	4.5	
Course Code	CHE-001-SE-0010	
Title of the Course	Water Treatment and Analysis	
Nature of the Course	Skill Enhancement	
Total Credits	3 (L 1 – T 0 – P 2)	
Total Contact Hours (CH)	75 (Theory – 15; Practical – 60)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The objective of the course is to develop a basic understanding of water qualities and ability to use principles of water chemistry for water treatment and water quality control in the natural systems. The students will develop basic understanding of hard water, its treatment and analyses of water samples.

Course Outcomes

After the completion of the course, the students will be able to:

CO1: Learn about various parameters for determining the water quality such as alkalinity, hardness, total dissolved solids, etc.
CO2: Understand the basic concepts of water chemistry to deal with problems associated with water/ wastewater treatment and natural water quality.
CO3: Learn about hard water, its effect and industrial methods of water softening.
CO4: Learn about various desalination processes for water treatment.
CO5: Acquire basic practical knowledge for water sample analyses.
CO6: Analyse water for chemical and biological substances present therein.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Water Quality Parameters and Analysis Characteristics of water, alkalinity. Hardness: unit of hardness, total solids, oxidation, transparency, silica content. Determination of hardness of water: titration method, complexometric method using EDTA. Expressing hardness: equivalents of calcium carbonate. Problems to determine temporary and permanent hardness. Analysis of chemical substances affecting health: NH_3, nitrate, nitrite, cyanide, sulphate, sulphide, chloride, fluoride. Measurement of toxic chemical substances, analysis of chemical substances indicative of pollution, dissolved oxygen, biochemical oxygen demand (BOD), chemical oxygen demand (COD).	8	CO1, CO2
Water Purification Purification of water for drinking purposes: potability of water, clarification, coagulation, contact and electrochemical coagulation, sterilisation and disinfection of water, precipitation, aeration, ozonisation, chlorination. Water softening methods: Clark's process,	7	CO3, CO4

lime soda process, modified lime soda process, permutit or zeolite process, ion exchange process, demineralisation of water. Hard water and industries, industrial water treatment, boiler feed water method of softening, prevention of plumbo solvency, scales in boilers and consequences, internal conditioning methods.		
Practical: Water Treatment and Analysis 1. Water analysis: Sampling techniques for water analysis. 2. Preliminary examination: alkalinity (bicarbonate, carbonate, hydroxide, acidity), chloride, nitrate, sulphate and calcium; temperature, pH and conductivity. 3. Analysis of solids present in water: suspended solids, dissolved solids, free Mg, Fe, Mn, Ag and Zn.	60	CO5, CO6

Recommended Books

Theory

1. Sharma, B. K., *Industrial Chemistry (including Chemical Engineering)*, Goel Publishing House, Meerut (2000). (ISBN: 978-8187224006).
2. Varshney, C. K., *Water Pollution and Management*, 2nd Ed, New Age International (2018). (ISBN: 978-9386418470).
3. Srivastava, A., *Waste Water Treatment and Water Management: Water Treatment and Management*, Notion Press (2018). (ISBN: 978-1642497830).

Practical

1. APHA, *Standard Methods for the Examination of Water, Sewage and Industrial Wastes*. 20th Ed., American Public Health Association: Washington, USA (1995).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	H	-	-	-	-	-	H	-	H	-	H	-
CO2	H	H	-	-	H	-	-	-	-	-	M	H	H	H	H	H
CO3	H	H	-	-	H	-	-	-	-	-	M	H	H	H	H	H
CO4	H	H	-	-	H	-	-	-	-	-	M	H	H	H	H	H
CO5	H	H	M	-	H	-	-	-	-	-	M	H	H	H	H	H
CO6	H	M	H	-	H	-	-	-	-	-	M	H	H	H	H	H

H = High; M = Medium; L = Low

SEMESTER II

NCrF Level	4.5	
Course Code	CHE-001-SE-0020	
Title of the Course	Soil Chemistry and Analysis	
Nature of the Course	Skill Enhancement	
Total Credits	3 (L 1 – T 0 – P 2)	
Total Contact Hours (CH)	75 (Theory – 15; Practical – 60)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objective

The objective of the course is to impart basic knowledge about physical properties of soil, soil chemistry, soil fertility and different nutrients in soil, fertilizers and pesticides. The students will become aware of the importance and effect of fertilizer and manure on plant growth. In addition, it aims to Imparts knowledge on pesticides and their effect on environment.

Course Outcomes

After the completion of the course, the students will be able to:

CO1: Get introduced to various concepts of soil science like soil profile, soil texture, particle density of soil particles, porosity of soils, etc.

CO2: Learn about soil fertility, essential and beneficial elements present in soil as source of plant nutrients, reclamation of soil fertility, etc.

CO3: Have fair knowledge on different types of fertilizers and manures and their method of production.

CO4: Learn about the effect of fertilizers and pesticides on soil fertility and the method of evaluation of soil fertility.

CO5: Determine bulk density and particle density, water holding capacity and NPK content of soils.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Introduction to Soil Chemistry Components of soil, soil profile, soil physical properties, soil texture, textural classes, particle size analysis, soil structure, classification, soil aggregates, significance, bulk density and particle density of soils and porosity, their importance and manipulation, soil compaction, soil colour, elementary knowledge of soil classification of India, retention and potentials, soil moisture constants, soil colloids, properties, types and significance, adsorption of ions, ion exchange, CEC and AEC, factors influencing ion exchange and its significance. Soil as a source of plant nutrients, essential and beneficial elements, criteria of essentiality, forms of nutrients in soil, acid, salt affected and calcareous soils, characteristics, nutrient availabilities, reclamation: mechanical, chemical and biological methods. Soil organic matter, composition, decomposability, Humus.	8	CO1

Methods of soil testing: chemical methods, critical levels of different nutrients in soil.		
Soil Fertility, Fertilisers, Manures and Pesticides *Soil fertility*: different approaches for soil fertility evaluation. *Fertilisers*: Effect of nitrogen, potassium and phosphorous on plant growth, classification of fertilisers, requisites of good fertilisers, nitrogenous fertilisers, phosphatic fertilisers, superphosphate of lime, triple super phosphate, NPK fertilisers, ill effects of fertilisers, effect of mixed fertilisers on soil pH. *Manures*: Organic manures, farmyard manure. *Pesticides*: General introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides, uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene); Organophosphates (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor).	7	CO2, CO3, CO4
Practical: Soil Chemistry and Analysis 1. Soil Analysis (a) Collection and processing of soil for analysis. (b) Soil texture and mechanical analysis. (c) Determination of bulk density and particle density, water holding capacity. (d) Estimation of available N, P, K, S and Zn in soils, Determination of organic carbon, pH and EC (Soluble cations and anions in soil water extracts). (e) Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.	60	CO5

Recommended Books

Theory

1. Biswas, T. D.; Mukherjee, S. K., *Text Book of Soil Science*, 2nd Ed., McGraw Hill Publishing Company, New Delhi (2017). (ISBN: 978-0074620434).
2. Brady, N. C.; Well, R. R., *The Nature and Properties of Soil*, 15th Ed., Pearson Education India (2022). (ISBN: 978-9356062719).
3. Troeh, F. R.; Thompson, L. M., *Soils and Soil Fertility*, Wiley India, New Delhi (2008). (ISBN: 978-0813809557).
4. Jaiswal, P. C., *Soil, Plant and Water Analysis*, 3rd Ed., Kalyani Publishers: New Delhi (2014). (ISBN: 978-9327210170).
5. Ghosh, J., *Fundamental Concept of Applied Chemistry*, S. Chand & Company, New Delhi (2010). (ISBN: 978-8121926249).
6. Cremlyn R., *Pesticide: Preparation and Modes of Action*, John Wiley & Sons, New York (1978). (ISBN: 978-0471996316).

Practical

1. Sarkar, D.; Haldar, A. *Physical and Chemical Methods in Soil Analysis*, 2nd Ed., New Age International (2010). (ISBN: 978-8122427257).

2. Saha, A. K. *Methods of Physical and Chemical Analysis of Soil*, Kalyani Publishers (2008). (ISBN: 978-8127242084).
3. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).
4. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Pearson Education India (2009). (ISBN: 978-8131723258).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	M	-	H	-	H	-
CO2	H	H	-	-	-	-	-	-	-	-	M	-	H	-	H	-
CO3	H	H	-	-	-	-	-	-	-	-	M	-	H	-	H	-
CO4	H	H	-	-	-	-	-	-	-	-	M	-	H	-	H	-
CO5	H	M	-	-	M	H	-	-	-	-	M	M	H	-	H	H

H = High; M = Medium; L = Low

SEMESTER III

NCrF Level	5.0	
Course Code	CHE-001-SE-0030	
Title of the Course	Air Pollution	
Nature of the Course	Skill Enhancement	
Total Credits	3 (L 1 – T 0 – P 2)	
Total Contact Hours (CH)	75 (Theory – 15; Practical – 60)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)
	Practical	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The objective of the course is to make the students aware of atmospheric chemistry. It aims to impart knowledge on the various pollutants affecting atmosphere. The students will be aware of the various effects of air pollution. In addition, it aims to impart knowledge on soil and water analysis.

Course Outcomes

After the completion of the course, the students will be able to:

CO1: Learn the chemistry of atmosphere and air pollution.
CO2: Have fair knowledge about the various pollutants in atmosphere.
CO3: Acquire knowledge of greenhouse effect, global warming and ozone layer depletion.
CO4: Determine hardness, dissolved oxygen of water practically.
CO5: Learn to analyse fertilizers, pesticides and estimate nitrogen in chemical fertilizers.
CO6: Learn to prepare organophospates.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Air Pollution Chemistry of the atmosphere. Air pollutants: types, sources, particle size, and chemical nature; photochemical smog and its constituents; London smog disaster of 1952; pollution by SO_2, CO_2, CO, NO_x, H_2S, and other foul-smelling gases and their control measures. Volatile Organic Compounds. Effects of air pollution on living organisms and vegetation. Acid rain, Greenhouse effect, and Global warming. Environmental effects of ozone, ozone depletion by oxides of nitrogen and chlorofluorocarbons.	15	CO1, CO2, CO3
Practical: 1. Determination of hardness of water. 2. Determination of dissolved oxygen in water. 3. Determination of chemical oxygen demand (COD). 4. Determination of Biological oxygen demand (BOD). 5. Fertilizer and Pesticide Analysis 6. Estimation of available N in Urea and commercial fertilizers. 7. Calculation acidity/alkalinity in a given sample of commercial pesticide as per BIS specification. 8. Preparation of simple organophosphates and diethyldithiocarbamate.	60	CO4, CO5, CO6

Recommended Books

Theory

1. De, A. K., De, A. K., *Environmental Chemistry*, 11th Ed., New Age International, New Delhi (2023). (ISBN: 978-9389802801).
2. Khopkar, S. M., *Environmental Pollution Analysis*, 2nd Ed, New Age International, New Delhi (2020). (ISBN: 978-8122427479).
3. Manahan, S. E., *Environmental Chemistry*, 11th Ed, CRC Press (2022). (ISBN: 978-0367558871).
4. Benvenuto, M. A., *Industrial Inorganic Chemistry*, 2nd Ed., De Gruyter (2024). (ISBN: 978-3111329444).
5. Dara, S. S.; Umare, S. S., *A Textbook of Engineering Chemistry*, S. Chand & Company, New Delhi (2004). (ISBN: 978-8121903592).

Practical

1. Sarkar, D.; Haldar, A. *Physical and Chemical Methods in Soil Analysis*, 2nd Ed., New Age International (2010). (ISBN: 978-8122427257).
2. Saha, A. K. *Methods of Physical and Chemical Analysis of Soil*, Kalyani Publishers (2008). (ISBN: 978-8127242084).
3. Raj, G., *Advanced Practical Inorganic Chemistry*, Krishna Prakashan, Meerut (2013). (ISBN: 978-8185842837).
4. Mendham, J.; Denney, R. C., Barnes, J. D.; Thomas, M.; Sivasankar, B., *Vogel's Quantitative Chemical Analysis*, 6th Ed., Pearson Education India (2009). (ISBN: 978-8131723258).
5. APHA, *Standard Methods for the Examination of Water, Sewage and Industrial Wastes*. 20th Ed., American Public Health Association: Washington, USA (1995).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	H	-	-	-	-	-	-	-	-	H	-	H	-	H	-
CO2	H	H	-	-	-	-	-	-	-	-	H	-	H	-	H	-
CO3	H	H	-	-	-	-	-	-	-	-	H	-	H	-	H	-
CO4	H	H	-	-	M	H	-	-	-	-	M	M	H	H	H	H
CO5	H	H	-	-	M	H	-	-	-	-	M	M	H	H	H	H
CO6	H	H	-	-	M	H	-	-	-	-	M	M	H	H	H	H

H = High; M = Medium; L = Low

3.5 VALUE ADDED COURSE (VAC)

SEMESTER III

NCrF Level	4.5	
Course Code	CHE-001-VA-2110	
Title of the Course	Indian Knowledge System: Chemistry in Ancient India	
Nature of the Course	Value Added	
Total Credits	2 (L 2 – T 0 – P 0)	
Total Contact Hours (CH)	30 (Theory – 30; Practical – 0)	
Distribution of Marks	Theory	80 (End Sem) + 20 (Internal Assessment)

Course Objectives

The course intends to introduce the students to major sequential development in ancient Indian chemistry. Students will be able to trace, identify and develop the ancient knowledge systems to make meaningful contributions to the development of science today.

Course Outcomes

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

CO1: To familiarise learners with the major sequential development and evolution of ancient Indian chemistry through different periods of time.

CO2: To understand the concepts of early chemical techniques and processes in chemistry and metallurgy in ancient India.

CO3: To familiarise learners with the applications of ancient Indian chemistry in day-to-day utilities of dyes, pigments, paintings, fabrics, beads, etc.

CO4: To help students trace and identify the ancient knowledge systems from prominent texts on chemistry, material science and metallurgy to make meaningful contributions to the development of science today.

CO5: To help understand the rational, verifiable and universal solution in chemistry, material science and metallurgy for scientific and technological development.

Contents	Contact Hour	Mapping to Course Outcomes (COs)
Chemistry in Ancient India Outlook of Nyāya-Vaiśeṣika darśana. The contributions of ancient and medieval Indians in chemistry – Rishi Kanad, Nagarjuna, Al-Bīrūnī', Vāgbhaṭa, Sushruta, Carak, Yaśodhara Bhaṭṭa and others. Early Chemical Techniques: Building of the ras-shala (laboratory), working arrangements of ras-shala, material and equipment, distillation process, apparatus etc. Chemistry of dyes, pigments, and other colouring materials used in paintings, fabrics, beads, and other day-to-day utilities since ancient times and their constant evolution through different periods of time.	15	CO1, CO2, CO3

Concepts of acid and bases in Indian chemistry from organic fruit, vegetable-based. Acids, plant-ash-based bases to mineral acids of the medieval period.		
Material Science and Metallurgy in Ancient India Survey of prominent texts on chemistry, material science and metallurgy. Gold, silver, copper and other metals from Vedic times through different times and texts. Zinc, brass and bronze.	15	CO4, CO5

Recommended Books

1. Mahadevan, B.; Bhat, V. R.; Nagendra, P. R. N. Introduction to Indian Knowledge System: Concepts and Application, PHI Learning (2024). (ISBN: 978-9391818203).
2. Seal. B., *Positive Sciences of the Ancient Hindus*, 4th Ed., Motilal Banarsidass (2016). (ISBN: 978-8120809253)
3. Subbarayappa, B. V., *Science in India: A Historical Perspective*, Rupa & Co (2013). (ISBN: 978-8129120960)
4. Ray, P. C. *History of Chemistry in Ancient and Medieval India: Incorporating the History of Hindu Chemistry*, Reprint Ed., Chowkhamba Krishnadas Academy (2014). (ISBN: 978-8121801540).
5. Bose, D. M.; Sen, S. N.; Subbarayappa, B. V. *A Concise History of Science in India*, INSA (2009). (ISBN: 978-8173716195).

CO-PO/PSO Mapping Matrix

	PO												PSO			
	1	2	3	4	5	6	7	8	9	10	11	12	1	2	3	4
CO1	H	M	-	-	-	-	-	-	H	H	-	-	H	-	-	-
CO2	H	M	-	-	-	-	-	-	H	H	-	-	H	-	-	-
CO3	H	M	-	-	-	-	-	-	H	H	-	-	H	-	-	-
CO4	H	M	-	-	-	-	-	-	H	H	-	-	H	-	-	-
CO5	H	M	-	-	-	-	-	-	H	H	-	-	H	-	-	-

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