दिल्ली विश्वविद्यालय

UNIVERSITY OF DELHI

Bachelor of Science in Industrial Chemistry
or
Bachelor of Science (Hons.) Industrial Chemistry with Dissertation/ Academic Projects/ Entrepreneurship
or
Bachelor of Science (Hons.) Industrial Chemistry with Dissertation/ Academic Projects/ Entrepreneurship (Discipline-1 Major)
or
Bachelor of Science (Hons.) Industrial Chemistry with Discipline-1(Major) & Discipline-2 (Minor)

Under UGCF-2022 based on NEP-2020

(Effective from Academic Year 2022-23)

Syllabus as approved by

Academic Council

Date: No:

Executive Council

Date: No:

Syllabus for Semester I and II is complete and finalized

Syllabus for Semester III to VI is subject to minor changes

Syllabus for Semester VII and VIII is yet to be decided

The syllabus for undergraduate programme in Industrial Chemistry has been drafted in accordance with the recommendations of the Undergraduate Curriculum Framework-2022. The preamble, definitions and abbreviations, features and important aspects of UGCF have been incorporated in this document as mentioned in UGCF 2022. In step with the evolving trends and developments in higher education globally, UGCF-2022 distinctly integrates the objectives and underlying philosophy of National Education Policy (NEP) 2020 in its attributes. The salient features such as holistic development, academic flexibility, life-long learning, multidisciplinary education, multilingualism, intra- and inter- university mobility, apprenticeship, research, innovation, entrepreneurship, social outreach, and the like, aim to enrich the learning experience, creativity, innovation, and skill development of the youth of our nation.

-Drafting Committee

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11.2.9 **To be decided**

11.2.10 **To be decided**

11.2.11 **To be decided**

11.2.12 **To be decided**

11.2.13 **To be decided**

11.2.14 **To be decided**

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11.3.12 **To be decided**

11.3.13 **To be decided**

11.3.14 **To be decided**

11.3.15 **To be decided**

11.3.16 **To be decided**

11.3.17 **To be decided**

11.3.18 **To be decided**

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11.4.5 Chemistry GE-5 Radio-chemistry in Energy, Medicine and Environment

11.4.6 Chemistry GE-6 Molecular Modelling and Artificial Intelligence & Machine Learning in Chemistry

The students can take the GE's paper from B Sc (Honours) Chemistry in addition to above mentioned GE papers.

Undergraduate Curriculum Framework – 2022

Preamble

The University of Delhi is one of the premier Institutions of India which is continuously imparting knowledge to the citizens of India and abroad and in the current year completed its 100 years of excellence. All undergraduate courses offer a new vision whenever the University upgrades its syllabus. The UNDERGRADUATE CURRICULUM FRAMEWORK (UGCF- 2022) is based on the New Education Policy 2020 and this approach is envisioned to provide the academic knowledge along with values related to well-being, emotional stability, critical thinking, social justice and its utility in the employment and social life. The undergraduate programs in UGCF 2022 provide an opportunity for the student to strengthen in the field of their choice keeping different combinations of subjects. Each program widely elaborates its nature and the outcomes of studying the courses. The programmes also state the attributes that it inculcates at the graduation level.

1. UGCF-2022: Definitions and Abbreviations

(a) Academic credit – An academic credit is a unit by which the course work is measured. It determines the number of hours of instructions required per week. One credit is equivalent to one hour of teaching (lecture or tutorial) or two hours of practical work/field work per week.

(b) Courses of study – Courses of the study indicate pursuance of study in a particular discipline. Every discipline shall offer four categories of courses of study, viz. Discipline Specific Core courses (DSCs), Discipline Specific Electives (DSEs), Skill Enhancement Courses (SECs) and Generic Electives (GEs). Besides these four courses, a student will select Ability Enhancement Courses (AECs) and Value-Added Courses (VACs) from the respective pool of courses offered by the University.

(i) Discipline Specific Core (DSC): Discipline Specific Core is a course of study, which should be pursued by a student as a mandatory requirement of his/her programme of study. In Undergraduate Programme in Industrial Chemistry, DSCs are the core credit courses of Industrial Chemistry, Chemistry and Mathophysics which will be appropriately graded and arranged across the semesters of study, being undertaken by the student, with multiple exit options as per NEP 2020. A student will study three Core Courses each, in Semesters I to VI and one core course each in semesters VII and VIII.

(ii) Discipline Specific Elective (DSE): The Discipline Specific Electives (DSEs) are a pool of credit courses of Industrial Chemistry, Chemistry and Mathophysics from which a student will choose to study based on his/her interest. A student in Undergraduate Programme in Industrial Chemistry gets an option of choosing one DSE of Chemistry/Industrial Chemistry/Mathophysics in each of the semesters III to VI, while the student has an option of choosing a maximum of three DSE courses of chemistry in semesters VII and VIII.

(iii) Generic Elective (GE): Generic Electives is a pool of courses offered by various disciplines of study (excluding the GEs offered by the parent discipline) which is meant to provide multidisciplinary or interdisciplinary education to students. In case a student opts for DSEs beyond his/her discipline specific course(s) of study, such DSEs shall be treated as GEs for that student. In semesters I, II, V and VI, a student has to compulsorily study one GE course from a pool of courses offered by the institution. However, in semesters III and IV a student has an option of choosing between a DSE course in discipline specific courses and a GE course of another discipline. Similarly, in semester VII and VIII a student can exercise an option of choosing a maximum of two Generic elective courses out of a combination of three DSE and GE courses.

(iv) Ability Enhancement course (AEC), Skill Enhancement Course (SEC); Value Addition Course (VAC)

These three courses are a pool of courses offered by all the Departments in groups of odd and even semesters from which a student can choose. A student who desires to make Academic Project/Entrepreneurship as Minor has to pick the appropriate combination of courses of GE,

SEC, VAC; Internship/Apprenticeship/Project/ Community outreach (IAPC) which shall be offered in the form of various modules as specified in the scheme of studies.

- **AEC courses** are the courses based upon the content that leads to knowledge enhancement through various areas of study. They are Language and Literature and Environmental Science and Sustainable Development which are mandatory for all disciplines. Every student has to study "Environmental Science and Sustainable Development" courses I and II of two credits each in the first year (I/II semester) and the second year (III/IV semester), respectively. The AEC pool consists of credit courses in languages listed in the Eighth Schedule of the Constitution of India, as updated from time to time.

- **SEC courses** are skill-based courses in all disciplines and are aimed at providing hands-on training, competencies, proficiency and skills to students. SEC courses may be chosen from a pool of courses designed to provide skill-based instruction. Some of these courses may be offered to students of chemistry while the rest can be open to students of all other disciplines.

A student will study one Skill Enhancement Course of 2 credits each (following 1T+ 1P/ 0T+2P credit system) in all the semesters from I to VI. It is to be noted that in the semesters III, IV, V and VI, students can choose either one SEC paper or can join any Internship/ Apprenticeship/ Project /Community outreach (following two credit system).

- **VAC courses** are common pool of courses offered by different disciplines and aimed towards personality building, embedding ethical, cultural & constitutional values; promote critical thinking, Indian Knowledge Systems, scientific temperament, communication skills, creative writing, presentation skills, sports & physical education and team work which will help in all round development of students.

2. Features of UGCF-2022

The Undergraduate Curriculum Framework- 2022 (UGCF) is meant to bring about systemic change in the higher education system in the University and align itself with the NEP 2020. The objectives of the NEP 2020 have been reflected in the following features of UGCF:

a) Holistic Development

Holistic development of the students shall be nurtured through imparting life skills in initial years. These life skill courses shall include courses on 'Environment and Sustainable Development Studies', 'Communication Skills', 'Ethics and Culture', 'Science and Society', 'Computational Skills', 'IT & Data Analytics', and similar such skills which shall make the students better equipped to deal with the life's challenges.

b) Academic Flexibility

Flexibility to the students to determine their learning trajectories and pursuance of programmes of study has been well ingrained in the UGCF. The Framework allows students to opt for one, two or more discipline(s) of study as a core discipline(s) depending on his/her choice. He/she has been provided the option of focusing on studying allied courses of his/her selected discipline(s) (DSEs) or diversifying in other areas of study of other disciplines. Students have also been provided with the flexibility to study SECs or opt for Internships or Apprenticeship or Projects or Research or Community Outreach at an appropriate stage. In the fourth year, students are provided flexibility to opt for writing a dissertation (on major, minor or combination of the two) or opt for Academic Projects or Entrepreneurship depending upon their choice and their future outlook, post completion of their formal education.

c) Multiple Exits/ Re-entry/ Academic Bank of Credit (ABC)/ Academic Outreach

Given the extent of plurality of the Indian society and the diverse background to which students belong, multiple exits and provision of re-entry have been provided at various stages of the undergraduate programme to accommodate their requirement and facilitate them to complete their studies depending upon their priorities of life. The earning and accumulation of credits in the Academic Bank of Credit (ABC), and the flexibility to redeem the requisite credit for award of appropriate Certificate / Diploma/ Degree, as the per the norms laid down by the UGC and the University, shall be made available to the students to provide the opportunity for lifelong learning as well as for availing academic outreach beyond the superstructure of the programme of study in another University / Institution at the national /international level depending upon individual choice of the student(s).

d) **Multidisciplinary Education**

UGCF has incorporated multidisciplinary education by embedding within the framework the need to opt for at least four elective papers from any other discipline(s) other than the one opted as core discipline(s). In fact, a student who pursues a single-core discipline programme may obtain minor in a particular discipline, other than the core discipline, if he/she earns at least 28 credits in that particular discipline.

The framework does not maintain/support hierarchy among fields of study/disciplines and silos between different areas of learning. As long as a student fulfils the pre-requisites of a course of study, he/she shall be able to study it. Modules or systems of study shall be meaningfully laid down so as to guide the students in choosing the track/academic paths for the desired outcome.

e) Multilingualism

One of the significant hallmarks of the framework is a provision of pursuing multilingualism while studying any other discipline as core subject(s), which has no bearing with any language and linguistics. I and II semesters of the programme provides an opportunity to the students to study languages which are enshrined under the eighth schedule of the Constitution of India, thereby allowing the students for their holistic development, including the ability to acquire proficiency in a language beyond their mother tongue.

f) Research and Innovation

The framework provides a mandatory programme on research methodologies as one of the discipline specific elective (DSE) courses at the VI & VII semester for students who opt for writing dissertation on major/ minor at VII and VIII semesters. Further, provision for internship/apprenticeship/project/community outreach right from the III semester up to VI semester provides ample opportunity to the students to explore areas of knowledge/activity beyond the four walls of the classroom and reach out to the world outside without any dilution of the academic feature of the course of study, he/she is pursuing. This also acts a precursor for the students to take up academic project or entrepreneurship at a later stage in VII & VIII semester. Such an initiative will help in skill development and laying a strong foundation for research and thus contribute towards overall national development through the development of skilled manpower and innovation.

g) Intra and Inter-University Mobility

Intra and inter University mobility of students is another element of critical importance which has been ingrained in the framework. A student, by virtue of such mobility, will be able to make lateral movement within the University as well as from the University to any other Institution and vice-versa. Such an attribute allows a student maximum flexibility in terms of pursuance of education with special reference to higher education and enables him/ her to achieve goal of life, the way he/she perceived it.

Based on the aforementioned features of UGCF-2022, the University expects maximum involvement of the student fraternity in utilizing the benefits of such a flexible yet rigorous curriculum framework at the undergraduate level and reaping the benefits of it through enrichment of their skills in their area of interest which will eventually help them in gaining employment, entrepreneurship, start-ups and various other ways of a dignified life and living as a global citizen with comparable skills and innovative ideas befitting to the contemporary global demands. The University expects the youthful nation to reap the maximum benefits out of the UGCF-2022 in developing skilled manpower to harness the youthful energy at one hand and expand the permeation of the skilled workforce globally, taking the demographic advantage on the other hand.

3. Introduction to Undergraduate Degree course in Industrial Chemistry

As per the recommendations of UGCF 2022, the undergraduate degree course in Industrial Chemistry is a six/ eight semester course spread over three/ four academic years. The teaching – learning process is student-centric and it involves both theory and practical components. It offers a flexibility of programme structure while ensuring that the student gets a strong foundation in the subject and in-depth knowledge, understanding of maximum aspects of the industrial processes. Besides the DSCs, a student can opt courses from the syllabus comprising of DSEs, GEs, SECs, AECs and VACs. Thereby, bringing out the multidisciplinary approach and adherence to innovative ways within the curriculum framework. Moreover, it allows a student maximum flexibility in pursuing his/ her studies at the undergraduate level to the extent of having the liberty to eventually design the degree with multiple exit options depending upon the needs and aspirations of the student in terms of his/ her goals of life, without compromising on the teaching learning, both in qualitative and quantitative terms. The syllabus is designed to inculcate the interest of students and provide them a detailed knowledge of the concepts, methods, principles and experimental techniques in industrial chemistry which facilitates in their path towards higher studies or employment.

4. Programme Duration and Exit Options

The minimum credit to be earned by a student per semester is 18 credits and the maximum is 26 credits. ***However, students are advised to earn 22 credits per semester***. This provision is meant to provide students the comfort of the flexibility of semester-wise academic load and to learn at his/her own pace. However, the mandatory number of credits which have to be secured for the purpose of award of *Undergraduate Certificate/ Undergraduate Diploma/*Appropriate *Bachelor's Degree in Industrial Chemistry are listed in* ***Table 1.***

Table 1: Qualification Type and Credit Requirements

S. No.	Type of Award	Stage of Exit	Mandatory Credits to be Secured for the Award
1	*Undergraduate Certificate in Industrial Chemistry*	After successful completion of Semester II	44
2	*Undergraduate Diploma in Industrial Chemistry*	After successful completion of Semester IV	88
3	*Bachelor of Science (Industrial Chemistry)*	After successful completion of Semester VI	132
4	*Bachelor of Science (Industrial Chemistry). with Research / Academic Projects/Entrepreneurship)*	After successful completion of Semester VIII	176
5	*Bachelor of Science (Industrial Chemistry) with Research in Industrial Chemistry (Major) & Discipline-2 (Minor)*	After successful completion of Semester VIII with minimum 28 GE credits in Discipline-2 (Minor)	176

Major Discipline (Industrial Chemistry)

A student pursuing four-year undergraduate programme in Physical Sciences shall be awarded B.Sc. Honours Industrial Chemistry degree with Major in Industrial Chemistry/Chemistry on completion of VIII Semester, if he/she secures at least 80 credits in Industrial Chemistry/Chemistry out of the total of 176 credits. He/she shall study 6 DSCs and at least 3 DSEs in the respective discipline (Industrial Chemistry/ Chemistry) in the first six semesters and 2 DSCs, 6 DSEs and write dissertation in respective discipline (Industrial Chemistry/Chemistry) in the VII and VIII semester.

Minor discipline

A student of B.Sc. (Hons.) Industrial Chemistry may be awarded Minor in a discipline (Industrial Chemistry/Chemistry), on completion of VIII Semester, if he/she earns minimum 28 credits from six DSCs and One DSE of that discipline.

5. Programme Objectives

The undergraduate degree course in Industrial, Chemistry aims to provide:

- Develop proficiency in application of current aspects of industrial chemistry with in-depth knowledge to use chemical techniques relevant to academia and industry, generic skills and global competencies including knowledge and skills that enable the students to undertake further studies in the field of industrial chemistry or a related field.
- Competence and skill in solving both theoretical and applied chemistry problems.
- A conducive learning environment that ensures holistic cognitive development of students.
- Exposure to the latest advances in chemistry, applied chemistry, allied disciplines and research.
- Development of critical and analytical thinking, scientific reasoning, problem-solving skills, communication skills and teamwork.
- Moral and ethical awareness, leadership qualities, innovation and life-long learning.
- Multicultural competence and multilinguism.
- Knowledge and skills to undertake higher studies/research in industrial chemistry and related interdisciplinary areas thereby enabling students' employment/entrepreneurship.
- Sufficient subject matter competence and also enable students to prepare for various competitive examinations such as IIT-JAM, GATE, GRE, UGC-CSIR NET/JRF and Civil Services Examinations.

6. Program Outcomes

The programme learning outcomes of the undergraduate degree course in Industrial Chemistry are as follows:

- **In-depth knowledge**: The student will acquire theoretical knowledge of basic and applied areas of Chemistry along with understanding of the fundamental concepts, principles and processes in the main and allied branches of chemistry. The core papers will provide in-depth understanding of the chemistry related to industry. A wide choice of elective courses offered to the student will provide specialized understanding rooted in the core and interdisciplinary areas.
- **Hands-on/ Laboratory Skills:** Comprehensive hands-on/ laboratory exercises will impart analytical, computational and instrumentation skills. The students will be able to demonstrate mature skills for the collating, evaluation, analysis and presentation of information, ideas, concepts and quantitative and/or qualitative data.
- **Lab Safety**: The students will develop skills for the use of safety data sheets, safe-handling of chemical materials, considering their physical and chemical properties including any specific hazards associated with their use through the various practical and SEC courses.
- **Research skills:** The course provides an opportunity to students to hone their research and innovation skills through internship/ apprenticeship/project/ community outreach/ dissertation/Academic Project/Entrepreneurship. It will enable the students to demonstrate mature skills in literature survey, information management skills, data analysis and research ethics.
- **Role of Industrial Chemistry**: The students will develop awareness and appreciation for the significant role played by industrial chemistry in current societal and global issues, including areas such as sustainable development and green chemistry. Advanced knowledge of fundamentals of industrial chemistry with enhanced command over modern scientific methods, techniques and chemical processes equipped with environment safety measures. They will be able to address and contribute to such issues through their skills and knowledge acquired during the programme.
- **Communication and IT Skills:** Various DSCs, DSEs, SECs, GEs and AECs have been designed to enhance student's ability to write methodical, logical and precise reports. The courses will, in addition, guide the student to communicate effectively through oral/poster presentations, writing laboratory/ project reports and dissertations. Several IT based papers in DSCs, DSEs, SECs and AECs will enable students to develop expertise in general and subject specific computational skills.
- **Lateral Thinking**: The programme will develop proficiency in application of current aspects of industrial chemistry. Students will be able to use chemical techniques relevant to academia and industry, generic skills and global competencies including knowledge and skills that enable the students to undertake further studies in the field of industrial chemistry or a related field.

- **Competence and Job Opportunities**: The skills acquired during the programme will provide varied opportunities for student's career progression. They will be able to join analytical, chemical, pharmaceutical, textile, cosmetic industries/ laboratories, innovation and research at different exit points.

7. Programme Structure

The detailed framework of undergraduate degree programme in Industrial Chemistry is provided **in Table -2.**

Table 2

Structure of Undergraduate Programme in Industrial Chemistry under UGCF-2022

Semester	Discipline Specific Core (DSC) (4)#	Discipline Elective (DSE) (4)	Generic Elective (GE) (4)	Ability Enhancement Course (AEC) (2)	Skill Enhancement Course (SEC) (2)	Internship/ Apprenticeship/ Project/Community Outreach (IAPC) (2)	Value Addition Course (VAC) (2)	Total Credits
I	DSC- IC 1 **(2T+2P)** DSC-C 1 **(2T+2P)** DSC-MP 1 **(2T+2P)**	N/A	Choose one from a pool of courses **GE-1 (2T+2P)**	Choose one **AEC** from a pool of courses	Choose one **SEC** from a pool of courses **(0T+2P)**	N/A	Choose from a pool of courses	**22**
II	DSC- IC 2 **(2T+2P)** DSC-C 2 **(2T+2P)** DSC-MP 2 **(2T+2P)**	N/A	Choose one from a pool of courses **GE-2 (2T+2P)**	Choose one **AEC** from a pool of courses	Choose one **SEC** from a pool of courses **(0T+2P)**	N/A	Choose from a pool of courses	**22**
Students on exit shall be awarded *Undergraduate Certificate in Industrial Chemistry* after securing the requisite 44 credits in Semester I & II								**Total = 44**
III	DSC- IC 3 **(2T+2P)** DSC-C 3 **(2T+2P)** DSC-MP 3 **(2T+2P)**	Choose from a pool of courses **DSE-1 (2T +2P)** OR **GE-3 (2T+2P)**		Choose one **AEC** from a pool of courses	Choose one **SEC (0T+2P)** OR **IAPC****		Choose from a pool of courses	**22**

IV	DSC- IC 4 **(2T+2P)** DSC-C 4 **(2T+2P)** DSC-MP 4 **(2T+2P)**	Choose from a pool of courses **DSE-2 (2T+2P)** OR **GE-4 (2T+2P)**		Choose one **AEC** from a pool of courses	Choose one **SEC (0T+2P)** OR **IAPC****	Choose from a pool of courses	**22**
Students on exit shall be awarded *Undergraduate Diploma in Industrial Chemistry* after securing the requisite 88 credits after completion of Semester IV							**Total = 88**
V	DSC- IC 5 **(2T+2P)** DSC-C 5 **(2T+2P)** DSC-MP 5 **(2T+2P)**	Choose one from a pool of courses **DSE-3 (2T+2P)**	Choose one form a pool of courses **GE-5 (2T+2P)**	N/A	Choose one **SEC (0T+2P)** OR **IAPC****	NA	**22**
VI	DSC- IC 6 **(2T+2P)** DSC-C 6 **(2T+2P)** DSC-MP 6 **(2T+2P)**	Choose one from a pool of courses **DSE-4** *** **(2T+2P)**	Choose one form a pool of courses **GE-6 (2T+2P)**	N/A	Choose one **SEC (0T+2P)** OR **IAPC****	NA	**22**
Students on exit shall be awarded *Bachelor of Industrial Chemistry* after securing the requisite 132 credits on completion of Semester VI							**Total = 132**
VII	DSC- 7 **(2T+2P)**	Choose three DSE (4) courses **OR** Choose two DSE (4) and one GE (4) courses **OR** Choose one DSE (4) course and two GE (4)		N/A	N/A	N/A	Dissertation on Major (6) **OR** Dissertation on Minor (6)	**22**

		courses **** or all three GE				**OR** Academic project/ Entrepreneurship (6)	
VIII	DSC-8 **(2T+2P)**	Choose three DSE (4) courses **OR** Choose two DSE (4) and one GE (4) courses **OR** Choose one DSE (4) course and two GE (4) courses **** or all three GE	N/A	N/A	N/A	Dissertation on Major (6) **OR** Dissertation on Minor (6) **OR** Academic project/ Entrepreneurship (6)	**22**
Students on exit shall be awarded *Bachelor of Industrial Chemistry (Hons. with Research /Academic Projects/Entrepreneurship)* after securing the requisite 176 credits on completion of Semester VIII							**Total = 176**

7.1 Semester-wise Distribution of Discipline Specific Core (DSC) Courses

A student will study three Discipline Specific Core Courses each; in Semesters I to VI and one core course each in semesters VII and VIII. The semester wise distribution of DSC courses over eight semesters is listed in **Table 3**.

Table 3

Semester-wise Distribution of Discipline Specific Core (DSC) Courses

DISCIPLINE CORE COURSES –18 (4 Credits each)			
SEMESTER	**COURSE CODE**	**NAME OF THE COURSE**	**CREDITS T=Theory Credits P=Practical Credits**
I	DSC-IC 1	Industrial chemicals and environment	T=2 P=2
I	DSC-C 1	Basic Concepts of Organic Chemistry	T=2 P=2
I	DSC-MP 1		T=2 P=2
II	DSC-IC 2	Fossil Fuels and Cleansing Agents	T=2 P=2
II	DSC-C 2	Periodic Properties and Chemical Bonding	T=2 P=2
II	DSC- MP 2		T=2 P=2
III	DSC-IC 3	Inorganic Materials	T=2 P=2
III	DSC-C 3	Chemical Energetics and Equilibria	T=2 P=2
III	DSC- MP 3		T=2 P=2
IV	DSC-IC 4	Pharmaceuticals, Cosmetics & Pesticides	T=2 P=2
IV	DSC-C 4	Functional Group Organic Chemistry-I	T=2 P=2
IV	DSC-MP 4		T=2 P=2

V	DSC- IC 5	Industrial Catalysis	T=2 P=2
V	DSC-C 5	Coordination Chemistry and Organometallics	T=2 P=2
V	DSC-MP 5		T=2 P=2
VI	DSC-IC 6	Food Additives, Contamination & Safety	T=2 P=2
VI	DSC- C 6	Quantum Chemistry and Spectroscopy	T=2 P=2
VI	DSC- MP 6		T=2 P=2
VII		**To be decided**	
VIII		**To be decided**	

7.2 Details of Discipline Specific Elective (DSE) Courses

The DSE courses will be offered to students from the three branches of chemistry, *viz*., inorganic, organic and physical chemistry in each of the III, IV, V, and VI semesters as listed below in **Table 4**.

Table 4

Details of Discipline Specific Elective (DSE) Courses

DSE COURSES –12 (4 Credits each-T+2P)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS T=Theory Credits P=Practical Credits**
Industrial Chemistry DSE-1	Green Chemistry	(2T +2P)
Industrial Chemistry DSE-2	Analytical Methods in Chemistry	(2T+2P)
Industrial Chemistry DSE-3	Polymer Chemistry	(2T+2P)

Industrial Chemistry DSE-4	Molecules of Life	(2T+2P)
Chemistry DSE-5	Main Group Chemistry	(2T+2P)
Chemistry DSE-6	Nanoscale Materials and Their Applications	(2T+2P)
Chemistry DSE-7	Chemistry of Polymers, Dyes and Drugs	(2T+2P)
Chemistry DSE-8	IT skills and Molecular Modelling	(2T+2P)
DSE-9	**To be decided**	
DSE-10	**To be decided**	
DSE-11	**To be decided**	
DSE-12	**To be decided**	
DSE-13	**To be decided**	
DSE-14	**To be decided**	
DSE-15	**To be decided**	
DSE-16	**To be decided**	
DSE-17	**To be decided**	
DSE-18	**To be decided**	
DSE-19	**To be decided**	
DSE-20	**To be decided**	
DSE-21	**To be decided**	
DSE-22	**To be decided**	
DSE-23	**To be decided**	
DSE-24	**To be decided**	

Pool A: Pool for Odd Semester: It consists of All the DSE Courses having an Odd number Course Code.

Pool B: Pool for Even Semesters: It consists of All the DSE Courses having an Even number Course Code

7.3 Details of Skill Enhancement Courses (SECs)

To enhance the skills required for advanced studies, research and employability of students various Skill Enhancement Courses will be offered to students as listed in **Table 5**.

Table 5

Details of Skill Enhancement Courses

SEC COURSES –16 (2 Credits each (0T+2P)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS** **T=Theory Credits** **P=Practical Credits**
Industrial Chemistry SEC-1	Basic Principles and Laboratory Operations	T=0 P=2
Industrial Chemistry SEC-2	Computational Chemistry in the Industry	T=0 P=2
Industrial Chemistry SEC-3	Pharmaceutical Chemistry	T=0 P=2
Industrial Chemistry SEC-4	Pesticide Chemistry	T=0 P=2
Industrial Chemistry SEC-5	Fuel Chemistry	T=0 P=2
Chemistry SEC-6	Instrumental Methods of Chemical Analysis	T=0 P=2
Chemistry SEC-7	IT Skills and Data Analysis	T=0 P=2
Chemistry SEC-8	Green Methods in Chemistry	T=0 P=2
Chemistry SEC-9	Chemical of Cosmetics & Toiletries	T=0 P=2
Chemistry SEC-10	Material Characterization Techniques	T=1 P=1
Chemistry SEC-11	Chemical Aspects of Forensic Science	T=1 P=1
SEC-12	**To be decided**	
SEC-13	**To be decided**	
SEC-14	**To be decided**	

SEC-15	**To be decided**	
SEC-16	**To be decided**	
SEC-17	**To be decided**	
SEC-18	**To be decided**	

Pool A: Pool for Odd Semester: It consists of All the SEC Courses having an Odd number Course Code.

Pool B: Pool for Even Semesters: It consists of All the SEC Courses having an Even number Course Code

Note: It is to be ensured that while choosing DSEs or SECs a student should not opt for a paper where the course content is similar to the paper previously studied by the student in any semester.

7.4 Details of Generic Elective (GE) Courses

Generic Elective courses provide multidisciplinary or interdisciplinary education to students. Various GE courses will be offered which may be opted by students with/ without the previous knowledge of chemistry as listed below in **Table 6**.

Table 6

Details of Generic Elective (GE) Courses

GE COURSES –18 (4 Credits each-3T+1P/2T+2P)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS** **T=Theory Credits** **P=Practical Credits**
GE-1	States of Matter	T=2 P=2
GE-2	Energy and the Environment	T=2 P=2
GE-3	Medicines in Daily Life	T=2 P=2
GE-4	Fragrances and Flavours: A chemists' Perspective	T=3 P=1
GE-5	Radio-chemistry in Energy, Medicine and Environment	T=2 P=2
GE-6	Molecular Modelling, Artificial Intelligence & Machine Learning in Chemistry	T=2 P=2

7.5 Details of Ability Enhancement Courses (AECs)

A student has to study one AEC course each in first four semesters of the programme. The AEC courses include environmental studies and language courses. The pool of courses is offered by the University.

7.6 Details of Value Addition Courses (VACs)

A pool of value-added courses will be provided by the University.

Note: The size of the group for practical papers is recommended to be a maximum of 12 to 15 students.

8. Teaching-Learning Process

The undergraduate programme in Industrial Chemistry is designed to provide students with a sound theoretical background, practical training in all aspects of Industrial chemistry and research. It will help them develop an appreciation of the importance of Industrial chemistry in different contexts. The programme includes foundational as well as in-depth courses that span the traditional sub-disciplines of Industrial chemistry and chemistry. Along with the DSCs there are DSEs, GEs, SECs and AECs which address the need of the hour.

These courses will be delivered through the conventional chalk and talk method, laboratory work, projects, case studies, field work, seminars, hands-on training/workshops in a challenging, engaging, and inclusive manner that accommodates a variety of learning styles and ICT enabled teaching-learning tools (PowerPoint presentations, audio visual resources, e-resources, models, software, simulations, virtual labs, etc.).

Students will be required to carry out short term projects and participate in industrial and institutional visits and outreach programmes. They will be introduced to scientific reasoning and discovery, innovative problem-solving methodologies, online quizzes, surveys, critical analysis etc. to develop divergent thinking abilities.

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

Different pedagogies such as experiential learning, participative learning, project-based learning, inquiry-based learning and ICT pedagogy integration instruction (blended and flipped learning) will be adopted wherever possible. Students will be encouraged to work in groups to develop their interpersonal skills like communication and team work.

Students' active participation/ engagement in industrial visits/ internships/ Academic Projects/ Dissertations will lay a strong foundation for a successful career in Industry, academics, research, entrepreneurship and community outreach.

9. Assessment Methods

The primary objective of assessment will be to assess the learning outcomes of the course in tune with the broad outcomes of strengthening core theoretical knowledge base, practical laboratory skills, and research. Assessment will be based on continuous evaluation (class test, presentation, quiz, assignment etc.) and end of semester examination of University of Delhi.

(i) Internal Assessment or Continuous Evaluation: During a semester, students' learning outcomes as described in the syllabus will be assessed through class tests, assignments, group assignments, laboratory record files, project reports, presentations etc. Each theory paper will have 25% marks for internal assessment. The component of internal assessment for each practical paper will be 50 % marks. The critical analysis of internal assessment/ continuous evaluation outcomes will provide opportunities to improve the teaching-learning process by focusing on the areas that need conceptual strengthening, laboratory exposure or design of new experiments, and research.

(ii) End of Semester University Examinations*:* The end-semester university examinations will be conducted for both theory and practical courses. Besides internal assessment, each theory paper will have 75% marks and each practical paper will be of 50% marks for end of semester examination of the university.

10. Scheme of Examination

The total marks for a four credit course is 100 and for a two credit course is 50. The distribution of 100 marks for each of DSC (2T+2P), DSE (2T+2P) and GE (2T+2P) courses having four credits is shown in **Table 7**. Further, the distribution of 50 marks for each of SEC course in (0T+2P) and VAC course in (2T+0P) format is given in **Table 7**.

Table 7
Distribution of total marks for each of DSC/ DSE/ SEC/ GE/ VAC courses in different credit formats.

Types of Paper	Credit Format of Papers	Theory Component	Practical Component
Discipline Specific Core (DSC)	**2 T + 2 P**	**Theory: 50 Marks** **Internal assessment:** 12 Marks: Class Test: 05 Marks Assignment/presentation/Quiz/ group discussion: 05 Marks Attendance: 02 Marks **End Semester Theory Examination:** 38 Marks	**Practical: 50 Marks** **Practical Examination:** 25 Marks: Experiment: 20 Marks Viva Voce: 05 Marks **Continuous Evaluation:** 25 Marks Performance Assessment: 15 Marks Record File: 10 Marks
Discipline Specific Elective (DSE)	**2 T + 2 P**	**Theory: 50 Marks** **Internal assessment:** 12 Marks: Class Test: 05 Marks Assignment/presentation/Quiz/ group discussion: 05 Marks Attendance: 02 Marks **End Semester Theory Examination:** 38 Marks	**Practical: 50 Marks** **Practical Examination:** 25 Marks: Experiment: 20 Marks Viva Voce: 05 Marks **Continuous Evaluation:** 25 Marks Performance Assessment: 15 Marks Record File: 10 Marks
Generic Elective (GE)	**2 T + 2 P**	**Theory: 50 Marks** **Internal assessment:** 12 Marks: Class Test: 05 Marks Assignment/presentation/Quiz/ group discussion: 05 Marks Attendance: 02 Marks **End Semester Theory Examination:** 38 Marks	**Practical: 50 Marks** **Practical Examination:** 25 Marks: Experiment: 20 Marks Viva Voce: 05 Marks **Continuous Evaluation:** 25 Marks Performance Assessment: 15 Marks Record File: 10 Marks
Skill Enhancement Course (SEC)	**0 T + 2 P**	NA	**Practical: 50 Marks** **Practical Examination:** 25 Marks: Experiment: 20 Marks Viva Voce: 05 Marks **Continuous Evaluation:** 25 Marks: Performance Assessment: 15 Marks Record File: 10 Marks
Value Addition Course (VAC)	**2 T + 0 P**	**Theory: 50 Marks** **Internal assessment:** 12 Marks: Class Test: 05 Marks Assignment/presentation/Quiz/ group discussion: 05 Marks Attendance: 02 Marks **End Semester Theory Examination:** 38 Marks	NA

* Performance Assessment: Performance throughout the semester

**Duration of end-semester theory and practical examinations of different credit courses will be as per University regulations/ordinances.

Minimum Acceptable Level of Academic Standards

The minimum acceptable level of achievement that a student must demonstrate to be eligible for the award of academic credit or a qualification is the minimum acceptable level of

academic standards. The Letter Grades and Grade Points which shall be used to reflect the outcome of assessment process of the student's performance is indicated in **Table 8**.

TABLE 8
Letter Grades and Grade Points

Letter Grade	Grade point
O (outstanding)	10
A+ (Excellent)	9
A (Very good)	8
B+ (Good)	7
B (Above average)	6
C (Average)	5
P (Pass)	4
F (Fail)	0
AB (Absent)	0

DISCIPLINE SPECIFIC CORE COURSES (DSC)

SEMESTER-I

Course Code: Industrial Chemistry DSC-IC1
Course Title: Industrial Chemicals & Environment
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The objective of this course is to teach the Chemistry of the general industrial separation and purification techniques. Production, uses and hazards associated with different industrial gases and chemicals. Air pollution, air pollutants, pollutants control procedures, greenhouse effect, global warming, water pollution, water pollutants, industrial effluents and their treatment, water quality parameters and water purification techniques.

Learning Outcomes:

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

- Know the various separation and purification techniques used in industries like distillation, solvent extraction, absorption, adsorption etc.
- Know the production, uses and hazards of important gases like oxygen, helium, argon, hydrogen, acetylene, ammonia etc.
- Know the production, uses and hazards of important inorganic chemicals like hydrochloric acid, sulphuric acid, nitric acid, sodium hydroxide, potassium hydroxide etc.
- Learn about air pollution, air pollutants, their control procedure, global warming, ozone depletion, water pollution, water pollutants, effluents from different industries, their treatment, water quality parameters and water purification techniques like reverse osmosis, electrodialysis and ion exchange.

Unit 1: General industrial processes — Lectures: 05

Basic principles of distillation, solvent extraction, solid-liquid leaching and liquid-liquid extraction, separation by absorption and adsorption

Unit 2: Industrial Gases and Inorganic Chemicals — Lectures: 12

(a) *Industrial Gases*: Production, uses and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, chlorine, fluorine and ammonia.
(b) *Inorganic Chemicals*: Production, uses and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, sodium hydroxide, potassium hydroxide,

bleaching powder, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.

Unit 3: Environment **Lectures: 13**

(a) *Air Pollution*: Pollutants and their sources, pollution by SO_2, CO, NOx. Methods of estimation of CO, NOx, SOx and their control procedures. Greenhouse effect and global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and halogens, Particulate matter and its types.

(b) *Water Quality Standards and Water pollution:* Water quality parameters like pH, alkalinity, DO, BOD, COD, chloride, sulphate, available chlorine etc. Water treatment and purification processes (reverse osmosis, electro dialysis, ion exchange). Pollutants and their sources. Effluent treatment (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: textile, tannery, dairy and petrochemicals and agrochemicals.

Practical

(Credits: 02, Laboratory periods: 60)

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD).
3. Determination of Biological Oxygen Demand (BOD).
4. Measurement of chloride and sulphate ions of water samples by simple titration method. (With $AgNO_3$ and potassium chromate).
5. Measurement of salinity of water samples by simple titration method. (With $AgNO_3$ and potassium chromate).
6. Estimation of total alkalinity of water samples (CO_3^{2-}, HCO_3^-) using double titration method.
7. Determination of Percentage of available chlorine in bleaching powder.
8. Isolation of compound using solvent extraction method.

References (Theory):

1. Stocchi, E. (1990), Industrial Chemistry, Vol-I, Ellis Horwood Ltd. UK.
2. Kent, J. A. (ed.) (1997), Riegel's Handbook of Industrial Chemistry, CBS Publishers, New Delhi.
3. Austin, G.T (2012), Shreve's Chemical Process Industries, Tata McGraw-Hill Education Private Limited.
4. Girard, J.E, (2011), Principles of Environmental Chemistry, Jones & Bartlett India Pvt. Limited.
5. Sodhi, G.S. ((2013), Fundamental Concepts of Environmental Chemistry, Narosa Publishing House.
6. Vermani, O.P; Narula, A.K. (2012), Industrial Chemistry, Galgotia Publishing Pvt. Limited.
7. Sharma, B.K. (2011), Industrial Chemistry, Goel Publishing House.
8. Pani, B. (2017), Textbook of Environmental Chemistry, I.K. International Publishing House.
9. De, A. K. (2015), Environmental Chemistry, New Age International Pvt, Ltd, New Delhi.

10. Khopkar, S.M. (2012), Environmental Pollution Analysis, New Age International Publisher.

References (Practical):

1. Bassett,J.; Denney, R.C.; Jeffery, G.H.; Mendham, J.(1996) Vogel Textbook of quantitative inorganic analysis, 7th edition, ELBS edition.Prentice Hall Publications.
2. Furniss, B. S; Hannaford, A. J.; Smith, Peter W. G.; Tatchell, A. R; Vogel's Text Book of Practical Organic Chemistry, 5th Edition, Longman Scientific and Technical, Longman Group Ltd.
3. Mittal, K.; Chandra, L.(2013) Experiments in organic chemistry, Anne Books Pvt. Limited.
4. Gulati, S.; Sharma, J.L.; Manocha, S. (2017)Practical Inorganic Chemistry. CBS, Publications.
5. Rogers, A. (2015) Laboratory Guide of Industrial chemistry, Palala Press.

Teaching Learning Process:

- The teaching learning process will involve the traditional chalk and black board method.
- Along with pedagogy of flipped classroom students are encouraged to participate actively in the classroom through regular presentations on curriculum based topics, peer assessment, designing games based on specific topics etc.
- As the best way to learn something is to do it yourself, practicals are planned in such a way so as to reinforce the topics covered in theory

Assessment Methods:

The effectiveness of learning can be judged by assessing the students. Assessment can be in the form of graded assignments, conventional class tests, class seminars by students on course topics and end semester university examination for theory and practical.

Keywords:

Industrial processes, Inorganic chemicals, acids and bases, oxidizing agents, Air pollution, particulate matters, Water pollution, Water quality parameters, Industrial effluents.

Course Code: Chemistry DSC-C1
Course Title: Basic Concepts of Organic Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The course is infused with the recapitulation of fundamentals of organic chemistry and the introduction of the concept of visualizing the organic molecules in a three-dimensional space. To establish the applications of these concepts, a study of diverse reactions through mechanisms is included. The constitution of the course strongly aids in the paramount learning of the basic concepts and their applications.

Learning Outcomes:

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

- Understand and explain the differential behaviour of organic compounds based on fundamental concepts learnt.
- Understand the fundamental concepts of stereochemistry.
- Formulate the mechanism of organic reactions by recalling and correlating the fundamental properties of the reactants involved.
- Learn and identify many organic reactions and their mechanisms including electrophilic addition, nucleophilic addition, nucleophilic substitution, electrophilic substitution and rearrangement reactions.

Unit 1: Fundamentals of organic chemistry — Lectures: 05

Types of Electronic displacements: Inductive effect, Resonance effect, Hyperconjugation, Electromeric Effect. Reactive intermediates and their stability: carbocations, free radicals, carbanions, benzyne, carbenes.

Acidity and basicity in organic compounds (comparison of carboxylic acids, alcohols, phenols, primary, secondary and tertiary aliphatic amines, aniline and its derivatives)

Unit 2: Stereochemistry — Lectures: 07

Types of projection formulae: Flying Wedge Formula, Newmann, Sawhorse and Fischer representations and their interconversion.
Stereoisomerism: Concept of chirality (upto two carbon atoms). Configurational isomerism: geometrical and optical isomerism; enantiomerism, diastereomerism and meso compounds). Threo and erythro; D and L; *Cis-trans* nomenclature; CIP Rules: R/ S (for upto 2 chiral carbon atoms) and *E*/*Z* nomenclature (for upto two C=C systems).
Conformational isomerism with respect to ethane, butane and cyclohexane.

Unit 3: Types of Organic Reactions (Including reactions of alkenes, alkyl and aryl halides, alcohols, aldehydes, ketones) — Lectures: 18

Electrophilic addition reactions
Electrophilic addition reaction (with respect to propene, propyne, 3,3-dimethyl-1-butene): Hydration, Addition of HX in the absence and presence of peroxide, Hydroboration oxidation, Addition of bromine (with stereochemistry).

Nucleophilic addition reactions

Nucleophilic addition reaction of carbonyl compounds: Addition of HCN, ammonia derivatives (Hydroxylamine, Hydrazine, Semicarbazide and 2,4-DNP), the addition of carbanion (Aldol condensation, Claisen Schmidt, Benzoin condensation, Perkin reaction, reactions involving Grignard reagent).

Elimination and Nucleophilic substitution reactions

Nucleophilic substitution reaction (S_N1 and S_N2) in alkyl halides (mechanisms with stereochemical aspect), alcohols (with nucleophiles like ammonia, halides, thiols, ambident nucleophiles (cyanide and nitrite ion)), ethers (Williamson ether synthesis), Elimination reaction (E1 & E2), elimination *vs* substitution (*w.r.t.* potassium t-butoxide and KOH); Nucleophilic aromatic substitution in aryl halides-elimination addition reaction *w.r.t.* chlorobenzene, including the effect of nitro group (on the ring) on the reaction. relative reactivity and strength of C-X bond in alkyl, allyl, benzyl, vinyl and aryl halides towards substitution reactions

Electrophilic substitution reactions

Electrophilic Aromatic substitution with mechanism (benzene)- sulphonation, nitration, halogenation, Friedel craft acylation :*o*-, *m*- and *p*- directive influence giving examples of toluene/nitrobenzene/ phenol/ aniline/ chlorobenzene.

Reactive intermediates and Rearrangement Reactions

Free radicals (Birch Reduction); *Carbocations* (Pinacol-Pinacolone, Wagner-Meerwein, Rearrangement, and Beckmann rearrangement); *Carbanions (*Michael Addition); *Carbenes* (Reimer-Tiemann).

Practical

(Credits: 02, Laboratory periods: 60)

1. Purification of an organic compound by crystallization (from water and alcohol) and distillation, Criteria of purity: Determination of M.P.
2. Determination of boiling point of liquid compounds. (Boiling point lower than and more than 100 °C by distillation and capillary method)
3. Detection of extra element
4. Preparations: (Mechanism of various reactions involved to be discussed).

    a. Bromination of phenol/aniline.
    b. 2,4-Dinitrophenylhydrazone of aldehydes and ketones
    c. Semicarbazone of aldehydes/ ketones
    d. Aldol condensation reaction using green method.
    e. Bromination of Stilbene.
    f. Acetanilide to p-Bromoacetanilide.

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

References (Theory):

1. Sykes, P.(2003), **A Guide Book to Mechanism in Organic Chemistry,** 6th Edition Pearson Education.
2. Eliel, E. L. (2001), **Stereochemistry of Carbon Compounds**, Tata McGraw Hill.
3. Morrison, R. N.; Boyd, R. N., Bhattacharjee, S.K. (2010), **Organic Chemistry**, 7th Edition, Pearson Education.
4. Bahl, A; Bahl, B. S. (2019), **Advanced Organic Chemistry**, 22nd Edition, S. Chand.

References (Practical):

1. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), **Vogel's Textbook of Practical Organic Chemistry**, Pearson.
2. Mann, F.G.; Saunders, B.C. (2009), **Practical Organic Chemistry**, Pearson Education.
3. Dhingra, S; Ahluwalia V.K., (2017), **Advanced Experimental Organic Chemistry**, Manakin Press.
4. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume I**, I K International Publishing House Pvt. Ltd., New Delhi.

Teaching Learning Process:

- Blend of conventional blackboard teaching, modern teaching learning tools.
- Computational infrastructure- based instructions and Practical training.
- Problem solving and quizzes for enhanced understanding of the concepts.
- Explaining the handling and usage of the hardware and softwares required for solution to the given set of problems.

Assessment Methods:

- Presentations by individual student/ group of students
- Class Tests at periodic intervals.
- Written assignment(s)
- End semester University theory examination presentations by individual student/ group of students

Keywords:

Chirality, Electrophilic addition, Nucleophilic addition, Nucleophilic substitution, Electrophilic substitution

SEMESTER-II

Course Code: Industrial Chemistry DSC-IC 2
Course Title: Industrial Chemistry-Fossil Fuels and Cleansing Agents
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

After studying this course, student shall be able to understand the different aspects of industrial processes of fossil fuels in detail. Optimised use of limited resources of non-renewable energy and technology investment in improving the production of renewable cleaner energy sources and biofuels. The analytical approach of this course is to enhance the reasoning and to understand the mechanical part of the industry.

Learning Outcomes:

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

- Know about fuels, composition, carbonization of coal, liquefaction, and coal tar based chemicals and layout for key processes in oil refining.
- Understand the role of petroleum and petrochemical industry, composition, applications, process-cracking. Increasing demand for non-petroleum fuels, synthetic fuels.
- Understand different fossil fuel products and processes
- Know types of oils, familiarized with rancidity, saponification value, iodine number, Superiority of synthetic detergents, gain knowledge about surfactants.

Unit 1: Fuel Chemistry and Introduction to Coal — Lectures: 11

Review of energy sources (renewable and non-renewable). Classification of fuels and their calorific value. Introduction of coal, uses of coal (fuel and non-fuel) in various industries (at least three examples), its types and composition, carbonization of coal. Coal gas, producer gas and water gas—composition and their uses, uses of coal-tar based chemicals, Requisites of a good metallurgical coke, Coal liquefaction and Solvent refining.

Unit 2: Petroleum and Petrochemical Industry — Lectures: 11

Composition of crude petroleum, Refining and different types of petroleum products and their applications. Fractional distillation (principle and process), Cracking (thermal and catalytic cracking), Reforming petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, biofuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels.

Unit 3: Oils and Fats Lectures: 8

Classification of oils, hydrogenation of oils, rancidity, saponification value, iodine number, acid value, soap and synthetic detergent, preparation of soap and detergent, different types of soap and their composition, surfactants (LAS, ABS, LABS).

Practical

(Credits: 02, Laboratory periods: 60)

1. Determination of alkali in water samples and soaps.
2. Determination of iodine value of the oils/ fats.
3. Determination of saponification value of the oils/ fats.
4. Determination of acid value of the oils/ fats.
5. To determine the moisture content of different fuels.
6. Estimation of hardness of water by titration with soap solution.
7. Preparation of soap.
8. Preparation of biodiesel from waste cooking oil and its characterization.
9. To compare the viscosity of biodiesel and vegetable oil.
10. To determine the density of the given fuel sample.
11. Characterization of different petroleum products using UV and IR.

References (Theory):

1. Vermani, O. P.; Narula, A. K. (2004), Industrial Chemistry, Galgotia Publications Pvt. Ltd., New Delhi.
2. Bhatia, S. C. (2004), Chemical Process Industries, Vol. I & II, CBS Publishers, New Delhi.
3. Jain, P. C.; Jain, M. (2013), Engineering Chemistry, Dhanpat Rai & Sons, Delhi.
4. Gopalan, R. Venkappayya, D.; Nagarajan, S. (2004), Engineering Chemistry, Vikas Publications.
5. Sharma, B. K. (1997), Engineering Chemistry, Goel Publishing House, Meerut.

References (Practical):

1. Verma ,S. and Goyal,R.K.(2021) Fuel Chemistry Theory and Practical,1st Edition Aaryush Publications, Muzaffarnagar (U.P.)
2. Ahluwalia,V.K. and Aggarwal,R. Comprehensive Practical Organic Chemistry, Preparation and Quantitative Analysis ,University Press, New Delhi.
3. Sharma, R.K., Sidhwani,I.T., Chaudhari,M.K. (2013),Green Chemistry Experiments: A monograph, I.K. International Publishing House Pvt Ltd. New Delhi.

Teaching Learning Process:

To accomplish a goal, it is very important to learn in a strategic manner. There are different components of learning and the capacity of each learner varies. ‘How’ to teach and ‘What’ to

teach in the defined curriculum not only depends on the content and the knowledge of the teacher but critically more so on designing, i.e. how to introduce the concept to the students in a very effective way. Different ways of teaching include classical board teaching method, visual conceptual method, powerpoint presentation, application based practical demonstration of the concept etc. In fact the pedagogy is to make a class interesting and thus learning becomes enjoyable.

Assessment Methods:

The effectiveness of learning can be judged by assessing the students.
Assessment can be in form of:

- Graded assignments
- Conventional class tests
- Class seminars and presentations by students on relevant topics from the course
- End semester university examination for theory and practical.

Keywords:

Renewable and non-renewable resources, Synthetic fuels, calorific value, Refining, Cracking, Biofuels, Uses of Coal-tar, Carbonization of Coal, Rancidity, Synthetic Detergents, Surfactants

Course Code: Chemistry DSC-C 2
Course Title: Periodic Properties and Chemical bonding
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The course discusses the periodicity in properties with reference to the s, p and d block, which is necessary in understanding their group chemistry. It provides basic knowledge about ionic, covalent and metallic bonding underlining the fact that chemical bonding is best regarded as a continuum between the three cases. It provides an overview of hydrogen bonding and van der Waal's forces which influence the melting points, boiling points, solubility and energetics of dissolution of compounds.

Learning Outcomes:

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

- Understand periodicity in ionization enthalpy, electron gain enthalpy, electronegativity and enthalpy of atomization.
- Understand variability in oxidation state, colour, metallic character, magnetic and catalytic properties and ability to form complexes
- Understand the concept of lattice energy using Born-Landé expression.
- Draw Born Haber Cycle and analyse reaction energies.
- Draw the plausible structures and geometries of molecules using VSEPR theory.
- Understand and draw MO diagrams (homo- & hetero-nuclear diatomic molecules).
- Understand the importance and applications of hydrogen and van der Wall bonding.

Unit 1: Periodic Properties — Lectures: 12

Electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy, inert pair effect.

General group trends of s, p and d block elements with special reference to Ionization Enthalpy, Electron Gain Enthalpy, Electronegativity, Enthalpy of Atomization, oxidation state, colour, metallic character, magnetic and catalytic properties, ability to form complexes

Unit 2: Chemical Bonding — Lectures: 18

Ionic Bonding: General characteristics of ionic bonding, Lattice Enthalpy and Solvation Enthalpy and their relation to stability and solubility of ionic compounds, Born-Lande equation for calculation of Lattice Enthalpy (no derivation), Born-Haber cycle and its applications, polarizing power and polarizability, Fajan's rules, ionic character in covalent compounds, bond moment, dipole moment and percentage ionic character.

Covalent Bonding: Valence Bond Approach, Hybridization and VSEPR Theory with suitable examples, Concept of resonance and resonating structures in various inorganic and organic compounds, Molecular Orbital Approach: Rules for the LCAO method, bonding, nonbonding and antibonding MOs and their characteristics for s-s, s-p and p-p combinations of atomic orbitals, MO treatment of homonuclear diatomic molecules of 1^{st} and 2^{nd} periods (including idea of s-p mixing) and heteronuclear diatomic molecules such as CO, NO and NO^{+}.

Brief introduction to Metallic Bonding, Hydrogen Bonding, van der Waal's Forces

Practical

(Credits: 02, Laboratory periods: 60)

1. Preparation of standard solutions.
2. Estimation of Sodium carbonate with HCl.
3. Estimation of oxalic acid by titrating it with $KMnO_4$.

4. Estimation of Mohr's salt by titrating it with $KMnO_4$.
5. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
6. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using internal and external indicators.
7. Estimation of Cu (II) ions iodometrically using $Na_2S_2O_3$.
8. Chromatographic separation of mixture of metal ions Cu^{2+}, Cd^{2+} or Ni^{2+}, Co^{2+}.
9. Estimation of Fe (II) ions by titrating it with $K_2Cr_2O_7$ using
    a. internal indicator
    b. external indicator
10. Estimation of Cu (II) ions iodometrically using $Na_2S_2O_3$.
11. Paper Chromatographic separation of mixture of metal ions
    a. Cu^{2+}, Cd^{2+}
    b. Ni^{2+} , Co^{2+}
12. Any suitable experiment (other than the listed ones) based upon neutralisation/redox reactions.

References (Theory):

1. Huheey, J.E.; Keiter, E.A., Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education
2. Shriver, D.D.; Atkins, P.; Langford, C.H. (1994), **Inorganic Chemistry** 2nd Ed., Oxford University Press.
3. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Inorganic Chemistry**, 5th Edition, W. H. Freeman and Company.
4. Lee, J.D.; (2010), **Concise Inorganic Chemistry**, Wiley India
5. Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), **Concepts and Models of Inorganic Chemistry**, John Wiley & Sons.
6. Wulfsberg, G (2002), **Inorganic Chemistry**, Viva Books Private Limited.
7. Miessler, G.L.; Fischer P.J.; Tarr, D. A. (2014), **Inorganic Chemistry**, 5th Edition, Pearson.

References (Practical):

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), **Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.

Teaching Learning Process:

- Conventional chalk and board teaching,
- Class interactions and discussions
- Power point presentation on important topics.

Assessment Methods:

- Presentations by Individual Student/ Group of Students
- Class Tests at Periodic Intervals.
- Written assignment(s)

- End semester University Theory Examination

Keywords:

Ionization Enthalpy, Electron Gain Enthalpy, Electronegativity, Ionic Bonding, Dipole Moment, VSEPR Theory, Covalent Bonding, Metallic Bonding, van der Waal's Forces

SEMESTER III

Course Code: Industrial Chemistry DSC-IC 3
Course Title: Inorganic Materials
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The paper imparts basic knowledge of chemistry of inorganic materials such as silicates, non-silicates, ceramics, cement. This paper is designed in such a way that it will enrich students with the knowledge of various types of batteries like Pb acid Battery, Li-ion Battery, Fuel Cells, Solar cell and Polymer cell. The paper has been drafted to impart the theoretical and practical knowledge of estimation and determination of various industrially important chemicals.

Learning Outcomes:

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

- Establish an appreciation of the role of inorganic chemistry in the chemical sciences.
- Gain sound knowledge of inorganic materials like silicates, ceramics and cement.
- Get skilled in the scientific method of planning, developing, conducting, reviewing and reporting experiments.
- Identify various concepts of industrial metallurgy which will help them to explore new innovative areas of research.
- Know scientific methods employed in inorganic chemistry.

Unit 1: Silicate Industries Lectures:14

(a) *Glass*: Glassy state and its properties, Classification (silicate and non-silicate glasses).

Manufacture and processing of glass. Composition and properties of the following: Soda lime glass, lead glass, armoured glass, safety glass, borosilicate glass, and photosensitive glass.
(b) *Ceramics*: Ceramic, their types and manufacture. High technology ceramics and their applications, super conducting and semiconducting oxides, fullerenes carbon nanotubes and carbon fiber, clays and feldspar.
(c) *Cement*: Classification of cement, ingredients and their role. Manufacture of cement and the setting process, quick setting cements.

Unit 2: Batteries **Lectures: 8**

Primary and secondary batteries, battery components and their role and characteristics of battery. Working of following batteries: Pb acid Battery, Li-ion Battery, Fuel Cells, Solar cell and Polymer cell

Unit 3: Fertilizers **Lectures: 8**

Different types of fertilizers (N, P and K). Importance of fertilizers, chemistry involved in the manufacture of the following fertilizers: urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates, superphosphate of lime, potassium chloride and potassium nitrate.

Practical

(Credits: 2, Laboratory periods: 60)

1. Detection of constituents of Dolomite (Calcium, Magnesium and carbonate ions) by qualitative analysis.
2. Determination of composition of Dolomite using complexometric titration.
3. Detection of constituents of Ammonium Sulphate fertilizer (Ammonium and Sulphate ions) by qualitative analysis.
4. Determine its free acidity in Ammonium Sulphate fertilizer.
5. Detection of constituents of CAN fertilizer (Calcium, Ammonium and Nitrate ions) by qualitative analysis.
6. Estimation of Calcium content in CAN fertilizer.
7. Detection of constituents of Superphosphate fertilizer (Calcium and Phosphate ions) by qualitative analysis.
8. Estimation of phosphoric acid content in Superphosphate fertilizer.
9. To determine the total insoluble residue in the cement sample.
10. To determine the amount of lime (CaO) in the given sample of cement.
11. To determine the total silica in the given sample of cement.
12. To determine the total Oxides (Sesquioxides Fe_2O_3 + Al_2O_3) in the given sample of cement.

References (Theory):

1. Felder, R. M.; Rousseau, R. W. (2015), **Elementary Principles of Chemical Processes**,
2. Wiley Publishers, New Delhi.
3. Stocchi, E.(1990), **Industrial Chemistry**, Vol -I, Ellis Horwood Ltd. UK.

4. Kingery, W. D.;Bowen, H. K.;Uhlmann, D. R. (1976), **Introduction to Ceramics**, Wiley
5. Publishers, New Delhi.
6. Kent, J. A. (ed**)** (1997), **Riegel's Handbook of Industrial Chemistry**, CBS Publishers, New Delhi.
7. Jain, P. C.; Jain, M. (2013), **Engineering Chemistry**, Dhanpat Rai & Sons, Delhi.
8. Sharma, B. K. (2014), **Engineering Chemistry**, Goel Publishing House, Meerut

References (Practical):

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), **Vogel's Textbook of Quantitative Chemical Analysis,** John Wiley and Sons.
2. Svehla, G.(1996),**Vogel's Qualitative Inorganic Analysis**, Prentice Hall.
3. Banewicz, J. J.; Kenner, C.T. **Determination of Calcium and Magnesium in Limestones and Dolomites**, Anal. Chem., 1952, 24 (7), 1186–1187.

Teaching Learning Process:

To accomplish a goal, it is very important to learn in a strategic manner. There are different components of learning and the capacity of each learner varies. 'How' to teach and 'What' to teach in the defined curriculum not only depends on the content and the knowledge of the teacher but critically more so on designing, i.e. how to introduce the concept to the students in a very effective way. Different ways of teaching include classical board teaching method, visual conceptual method, application based practical demonstration of the concept etc. Infact the pedagogy is to make a class interesting and thus learning becomes enjoyable.

Assessment Methods:

The effectiveness of learning can be judged by assessing the students. Assessment can be in the form of graded assignments, conventional class tests, class seminars by students on course topics with a view to strengthening the content through width and depth, end semester university examination for theory and practical.

Keywords:

Glass, Ceramics, Cements, Primary and Secondary batteries, Fertilizer

Course Code: Chemistry DSC-C 3
Course Title: Chemical Energetics and Equilibria
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The objective of this paper is to develop basic understanding of the chemical energetics, laws of thermodynamics and ionic equilibrium. It provides basic understanding of the behaviour of electrolytes and their solutions. The students will also learn about the properties of ideal and real gases and deviation from ideal behaviour.

Learning Outcomes:

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

- Understand the laws of thermodynamics, thermochemistry and equilibria.
- Understand concept of pH and its effect on the various physical and chemical properties of the compounds.
- Use the concepts learnt to predict feasibility of chemical reactions and to study the behaviour of reactions in equilibrium.

Unit 1: Chemical Energetics — Lectures: 16

Recapitulation of Intensive and extensive variables; state and path functions; isolated, closed and open systems, concept of heat, Q, work, W, internal energy, U, and enthalpy, H.

First law

Concept of heat, Q, work, W, internal energy, U, and statement of first law; enthalpy, H, relation between heat capacities for ideal gas, Joule's experiment, calculations of Q, W, ΔU and ΔH for reversible expansion of ideal gases under isothermal conditions.

Thermochemistry

Enthalpy of reactions: standard states; enthalpy of neutralization, enthalpy of ionization enthalpy of hydration, enthalpy of formation and enthalpy of combustion, Integral enthalpy of solution, bond dissociation energy and bond enthalpy; Hess's law, Born Haber's cycle (NaCl/ KCl).

Second Law

Concept of entropy; statements of the second law of thermodynamics (Kelvin and Clausius). Calculation of entropy change for reversible processes (for ideal gases). Free Energy

Functions: Gibbs and Helmholtz energy (Non-PV work and the work function); Free energy change and concept of spontaneity (for ideal gases).

Third Law

Statement of third law, qualitative treatment of absolute entropy of molecules (examples of NO, CO), concept of residual entropy

Unit 2: Chemical Equilibrium — Lectures: 4

Criteria of thermodynamic equilibrium. Free energy change in a chemical reaction and equilibrium constant, exergonic and endergonic reactions with examples such conversion of ATP to ADP or vice versa,, Le Chatelier's principle, relationship between Kp, Kc and Kx for reactions involving ideal gases.

Unit 3: Ionic Equilibria — Lectures: 10

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, Ostwald's dilution law, ionization constant and ionic product of water, ionization of weak acids and bases, Degree of ionization, pH scale, common ion effect, Buffer solutions, Henderson-Hasselbach equation. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle

Practical

(Credits: 02, Laboratory periods: 60)

Chemical Energetics:

1. Determination of heat capacity of calorimeter.
2. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
3. Determination of the enthalpy of ionization of acetic acid.
4. Determination of enthalpy of neutralization of acetic acid and ammonium hydroxide using Hess's law.
5. Determination of integral enthalpy of solution (both endothermic and exothermic) of salts.
6. Determination of enthalpy of hydration of Copper sulphate.

Ionic equilibria:

7. Preparation of buffer solutions: (i) Sodium acetate-acetic acid or (ii) Ammonium chloride-ammonium acetate. Measurement of the pH of buffer solutions and comparison of the values with theoretical values.
8. Study the effect of addition of HCl/NaOH on pH of the buffer solutions (acetic acid, and

sodium acetate).

9. pH metric titration of strong acid with strong base,
10. pH metric titration of weak acid with strong base

References (Theory) :

1. Castellan, G. W. (2004),**Physical Chemistry**, Narosa.
2. Kapoor, K. L. (2015),**A Textbook of Physical Chemistry**,Vol 1, 6th Edition, McGraw Hill Education.
3. Kapoor, K. L. (2015), **A Textbook of Physical Chemistry**, Vol 2, 6thEdition, McGraw Hill Education.
4. Puri, B. R., Sharma, L. R. and Pathania M. S. (2020), **Principles of Physical Chemistry**, Vishal Publishing Co.

References (Practical):

1. Khosla, B. D.; Garg, V. C.; Gulati, A.(2015), **Senior Practical Physical Chemistry**, R. Chand & Co.
2. Kapoor, K. L. (2019), **A Textbook of Physical Chemistry**, Vol 7, 1st Edition, McGraw Hill Education.
3. Batra, S. K., Kapoor, V and Gulati, S. (2017) 1st Edition, **Experiments in Physical Chemistry,** Book Age series.

Additional Resources:

1. Mahan, B. H.(2013), **University Chemistry**, Narosa.
2. Barrow, G. M. (2006), **Physical Chemistry**, 5th Edition, McGraw Hill.

Teaching Learning Process:

- Teaching Learning Process for the course is visualized as largely student-focused.
- Transaction through an intelligent mix of conventional and modern methods.
- Engaging students in cooperative learning.
- Learning through quiz design.
- Problem solving to enhance comprehension.

Assessment Methods:

Assessment will be done on the basis of regular class test, presentations and assignments as a part of internal assessment during the course as per the curriculum. End semester university examination will be held for both theory and practical. In

practical, assessment will be done based on continuous evaluation, performance in the experiment on the date of examination and viva voce.

Keywords:

Chemical thermodynamics, First law, Second law, Third law, Spontaneity of reaction, Equilibrium, buffers.

SEMESTER IV

Course Code: Industrial Chemistry DSC-IC 4
Course Title: Pharmaceuticals, Cosmetics and Pesticides
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The objectives of this paper are to provide basic knowledge of chemistry of pharmaceuticals, cosmetics, perfumes and pesticides considering their importance for human beings. This paper is designed in a manner that it forms a cardinal part of the learning of industrial chemistry for the students. The paper has been designed to impart theoretical and practical knowledge on the basic chemistry and uses of various pharmaceuticals, cosmetic products and pesticides.

Learning Outcomes:

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

- Have sound knowledge of pharmaceuticals, cosmetics, perfumes and pesticides.
- Become well equipped to design, carry out, record and analyze the industrial preparations.
- Understand the ethical, historic, philosophical, and environmental dimensions of problems and issues facing industrial chemists.
- Become skilled in problem solving, critical thinking and analytical reasoning.
- Identify and solve chemical problems and explore new innovative areas of research.
- Know the proper procedures and regulations for safe handling and use of chemicals and can follow the proper procedures.

Unit 1: Drugs and Pharmaceuticals — Lectures: 12

Drug discovery, design and development. Synthesis of the representative drugs of the following classes: analgesics, antipyretics, antiinflammatory agents (Aspirin, Paracetamol.), antibiotics (Penicillin, Cephalosporin, Chloromycetin, Streptomycin and Chloramphenicol), antibacterial and antifungal agents (Sulphonamides, Sulfamethoxazole), antiviral agents (Acyclovir), Central Nervous System agents (Phenobarbital, Diazepam), Cardiovascular drugs (Glyceryl trinitrate), antileprosy drug (Dapsone).

Unit 2: Cosmetics — Lectures: 08

Introduction to cosmetics and perfumes, preparation and uses of the following: Hair dye, hair spray. Shampoo. Sun-tan lotions, face powder, lipsticks. talcum powder, nail enamel, creams (cold, vanishing and shaving creams), antiperspirants.

Unit 3: Pesticides — Lectures: 10

Introduction to pesticides (natural and synthetic), benefits and adverse effects, changing concepts of pesticides. Synthesis and technical manufacture, uses of representative pesticides in the following classes: Organochlorines (DDT, Gammaxene), Organophosphates (Malathion, Parathion), Carbamates (Carbofuran and carbaryl), Quinones (Chloranil), Anilides (Alachlor and Butachlor).

Practical

(Credits: 2, Laboratory periods: 60)

1. Preparation of talcum powder.
2. Preparation of shampoo.
3. Preparation of nail enamel
4. Preparation of hair remover.
5. Preparation of face cream.
6. Preparation of Aspirin and its analysis.
7. Preparation of nail polish and nail polish remover.
8. To calculate acidity in a given sample of pesticide formulations as per BIS specifications.
9. To calculate alkalinity in a given sample of pesticide formulations as per BIS specifications.
10. Preparation of Antacid.
11. Preparation of paracetamol.

References (Theory and practical):

1. Vermani, O. P.; Narula, A. K. (2004), Industrial Chemistry, Galgotia Publications Pvt. Ltd., New Delhi.
2. Bhatia, S. C. (2004), Chemical Process Industries, Vol. I & II, CBS Publishers, New Delhi.

3. Barel, A.O.; Paye, M.; Maibach, H.I.(2014), Handbook of Cosmetic Science and Technology, CRC Press.
4. Gupta, P.K.; Gupta, S.K.(2011),Pharmaceutics and Cosmetics, Pragati Prakashan
5. Butler, H. (2000),Poucher's Perfumes, Cosmetic and Soap, Springer.
6. Kumari,R.(2018),Chemistry of Cosmetics,Prestige Publisher.

Teaching Learning Process:

To accomplish a goal, it is very important to learn in a strategic manner. There are different components of learning and the capacity of each learner varies. 'How' to teach and 'What' to teach in the defined curriculum not only depends on the content and the knowledge of the teacher but critically more so on designing, i.e. how to introduce the concept to the students in a very effective way. Different ways of teaching include classical board teaching method, visual conceptual method, application based practical demonstration of the concept etc.

Assessment Methods:

The effectiveness of learning can be judged by assessing the students. Assessment can be in the form of graded assignments, conventional class tests, class seminars by students on course topics with a view to strengthening the content through width and depth, end semester university examination for theory and practical.

Keywords:

Drugs, Pharmaceuticals, Pesticides, Cosmetic Products, Perfumes.

Course Code: Chemistry DSC-C 4
Course Title: Chemistry of Carboxylic acids & derivatives, Amines and Heterocycles
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The paper is infused with the details of the chemistry of carboxylic acids and their derivatives (aliphatic and aromatic), amines (aliphatic & aromatic), diazonium salts and heterocyclic systems.

Learning Outcomes:

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

- Understand reactions of carboxylic acids, esters, amides, amines and diazonium salts
- Understand the concept of protection and deprotection.
- Use the synthetic chemistry learnt in this course to do functional group transformations.
- Gain theoretical understanding of chemistry of heterocyclic compounds.

Unit 1: Carboxylic acids and their Derivatives (aliphatic and aromatic) Lectures:13

Preparation: Oxidation reactions of alcohols, aldehydes and ketones, Acidic and alkaline hydrolysis of esters; Reactions: Hell-Volhard Zelinsky reaction,

Carboxylic acid derivatives (aliphatic): Preparation: Acid chlorides, anhydrides, esters and amides from acids and their interconversion, Claisen condensation. Reactions: Relative reactivities of acid derivatives towards nucleophiles, Reformatsky reaction, Perkin condensation.

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

Unit 2: Amines (aliphatic & aromatic) and Diazonium Salts Lectures:10

Amines

Preparation: from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann Bromamide reaction. Reactions: Hofmann vs Saytzeff elimination, carbylamine test, Hinsberg test, reaction with HNO2, Schotten-Baumann reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation; basicity of amines.

Diazonium salt

Preparation: from aromatic amines; Reactions: conversion to benzene, phenol and dyes.

Unit 3: Heterocyclic Compounds Lectures:07

Introduction, classification, structure, nomenclature and uses. Preparation and properties of the following heterocyclic compounds with reference to electrophilic and nucleophilic substitution: furan, pyrrole, thiophene, and pyridine.

Practical

(Credits: 02, Laboratory periods: 60)

1. Systematic qualitative analysis and preparation of suitable crystalline derivative (carboxylic acids, carbonyl, alcohols, phenols, amines (1°, 2°,3°) and amides).
2. Preparation:

a. Acetylation of Aniline and Phenols.
b. Benzoylation of Aniline and phenols

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

References (Theory):

1. Morrison, R. N.; Boyd, R. N. **Organic Chemistry**, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Finar, I. L. **Organic Chemistry** (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Ahluwalia, V.K.; Bhagat, P.; Aggarwal, R.; Chandra, R. (2005), **Intermediate for Organic Synthesis**, I.K. International.
4. Solomons, T. W. G.; Fryhle, C. B. ; Snyder, S. A. (2016), Organic Chemistry, 12th Ed., Wiley.

References (Practical):

1. Ahluwalia, V.K.; Dhingra, S.; Gulati, A. (2005), **College Practical Chemistry**, University Press (India) Ltd.
2. Ahluwalia, V.K.; Dhingra, S. (2004), **Comprehensive Practical Organic Chemistry: Qualitative Analysis**, University Press.
3. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume I**, I K International Publishing House Pvt. Ltd., New Delhi.
5. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume II**, I K International Publishing House Pvt. Ltd., New Delhi.
6. Vogel, A.I. (1972), **Textbook of Practical Organic Chemistry**, Prentice-Hall.
7. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), Vogel's Textbook of Quantitative Chemical Analysis, John Wiley and Sons.

Teaching Learning Process:

- Teaching Learning Process for the course is visualized as largely student-focused.
- Transaction through an intelligent mix of conventional and modern methods.
- Engaging students in cooperative learning.
- Learning through quiz design.
- Problem solving to enhance comprehension**.**

Assessment Methods:

- Presentations by Individual Student/ Group of Students
- Class Tests at Periodic Intervals.
- Written assignment(s)
- End semester University Theory Examination Presentations by Individual Student/ Group of Students

Keywords:

Carboxylic acids and derivatives, amines and diazonium salts, heterocyclic compounds

SEMESTER V

Course Code: Industrial Chemistry DSC-IC 5
Course Title: Industrial Catalysts
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The paper imparts basic knowledge of catalysis, properties of catalysts and mode of action. This paper is designed in such a way that it will enrich students with the knowledge of various types of catalyst such as organometallic catalyst, biocatalyst, shape selective catalyst and photocatalyst. The paper has been drafted to impart the theoretical and practical knowledge of catalysts with the view of their industrial applications.

Learning Outcomes:

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

- Establish an appreciation of the role of catalyst in industrial applications.
- Gain sound knowledge of various types of catalyst.
- Get skilled in the scientific method of planning, developing, conducting, reviewing and reporting experiments.
- Get skilled concepts of industrial catalysis which will help them to explore new innovative areas of research.

Unit 1: Introduction of Catalyst — Lectures: 8

General principles of catalysis, properties of catalysts, Mode of action of catalyst, Types of catalyst (homogeneous and heterogeneous catalysis), Deactivation and regeneration of catalysts, catalytic poison, Promoter, Turnover frequency, Turnover number, Specificity and selectivity

Unit 2: Catalysis by Organometallic Compounds — Lectures: 6

Study of the following industrial processes, catalytic cycle and their mechanism:
Alkene hydrogenation (Wilkinson's Catalyst), Synthetic gasoline (Fischer Tropsch reaction), Polymerisation of ethene using Ziegler-Natta catalyst

Unit 3: Biocatalysis **Lectures: 5**

Introduction, Kinetics of enzyme–catalysed reactions, Industrial process with biocatalyst, Aspartame through enzymatic peptide synthesis, 4-Hydroxyphenoxypropionic acid as herbicide intermediate

Unit 4: Shape selective catalysis: Zeolites **Lectures: 6**

Composition and structure of Zeolites, Catalytic properties of Zeolites, Shape selectivity, Isomorphic substitution of Zeolites, Metal doped Zeolites, Applications of Zeolites

Unit 5: Photocatalysis **Lectures: 5**

Basic principle, Photoreduction and oxidation of water, Water reduction, Water oxidation, Photocleavage of water

Practical

(Credits: 2, Laboratory periods: 60)

1. Catalytic bromination of benzene. Catalyst: $FeCl_3/AlCl_3$
2. Catalytic chlorination of benzene. Catalyst: $FeCl_3/AlCl_3$
3. Catalytic Removal of Bromates from polluted Water: Synthesis of catalyst one lab, Removal of Bromates one lab.
4. Phase-Transfer Catalytic Reactions
5. Catalytic oxidation of ammonia using chromium(III) oxide as a catalyst. Catalytic Friedal-craft reaction using $AlCl_3$ and Lewis acid catalyst. Synthesis of toluene.
6. Synthesis of "Zeolite A" catalyst.
7. Zeolite Hydrogen-Y or dil.HCl/dil.H_2SO_4 as a Catalyst for the Preparation of an Ester.
8. Synthesis of biaryl using palladium catalyst.
9. Catalytic Transfer Hydrogenation of Castor Oil
10. Reduction of Nitrobenzene

References (Theory):

1. Huheey, J. E.; Keiter, E.A.; Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education.
2. Cotton, F.A.; Wilkinson, G. (1999), **Advanced Inorganic Chemistry,** Wiley-VCH.
3. Jens Hagen (2015) **Industrial Catalysis: A Practical Approach** Wiley-VCH Verlag GmbH & Co

References (Practical):

1. Cerrillo, J. L.; López-Hernández, I.; Palomares, A. E. **Catalytic Removal of Bromates from Water: A Hands-On Laboratory Experiment to Solve a Water Pollution Problem through Catalysis** J. Chem. Educ. 2021, 98, 1726−1731.

2. Shabestary, N.; Khazaeli, S.; Hickman, R.; **Phase-Transfer Catalytic Reactions Journal of Chemical Education**, 1998, 75, 1470-1472.
3. Volkovich, V. A.; Griffiths, T. R.; **Catalytic Oxidation of Ammonia: A Sparkling Experiment** J. Chem. Educ. 2000, 77, 2, 177.
4. Williams, D. J.; Huck, B. E.; Wilkinson, A. P. **First-Year Undergraduate Laboratory Experiments with Zeolites Chem. Educator** 2002, 7, 33–36.
5. Coker, E. N.; Davis, P. J.; **Experiments with Zeolites at the Secondary-School Level: Experience from The Netherlands** Journal of Chemical Education 1999, 76, 10, 1417.
6. Hanson RW. **Catalytic transfer hydogenation reactions for undergraduate practical programs.** J Chem Educ. 2009, 74, 430.
7. Alwaseem H, Donahue CJ, Marincean S. **Catalytic transfer hydrogenation of castor oil.** J Chem Educ. 2014; 91, 575–8.

Teaching Learning Process:

To accomplish a goal, it is very important to learn in a strategic manner. There are different components of learning and the capacity of each learner varies. 'How' to teach and 'What' to teach in the defined curriculum not only depends on the content and the knowledge of the teacher but critically more so on designing, i.e. how to introduce the concept to the students in a very effective way. Different ways of teaching include classical board teaching method, visual conceptual method, application based practical demonstration of the concept etc. Infact the pedagogy is to make a class interesting and thus learning becomes enjoyable.

Assessment Methods:

The effectiveness of learning can be judged by assessing the students. Assessment can be in the form of graded assignments, conventional class tests, class seminars by students on course topics with a view to strengthening the content through width and depth, end semester university examination for theory and practical.

Keywords:

Catalyst, Homogeneous and heterogeneous catalysis, Wilkinson's Catalyst, Fischer Tropsch reaction, Ziegler-Natta catalyst, Biocatalysis, Shape selective catalysis, Photocatalysis

Course Code: Chemistry DSC-C 5
Course Title: Coordination Chemistry and Organometallics
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The course introduces the students to basics of coordination chemistry and organometallics which are of immense importance to biological systems, qualitative and quantitative analysis, catalysis, medicines, paints and pigments etc. Nomenclature, isomerism, bonding in coordination compounds has been dealt with in sufficient detail along with special emphasis on important coordination compounds in the biological system. In organometallic chemistry, the students are introduced to classification of organometallic compounds, the concept of hapticity and the 18-electron rule governing the stability of a wide variety of organometallic species with special emphasis on metal carbonyls.

Learning Outcomes:

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

- Understand terms: ligand, denticity of ligands, chelate, coordination number.
- Systematically name coordination compounds.
- Discuss the various types of isomerism possible in Octahedral and Tetrahedral coordination compounds.
- Use Valence Bond Theory to predict the structure and magnetic behaviour of metal complexes and understand the terms inner and outer orbital complexes.
- Explain the meaning of the terms $\Delta o.$, Δt, pairing energy, CFSE, high spin and low spin and how CFSE affects thermodynamic properties like lattice enthalpy and hydration enthalpy.
- Explain magnetic properties and colour of complexes on basis of Crystal Field Theory
- Apply 18-electron rule to rationalize the stability of metal carbonyls and related species.
- Learn how IR data can be used to understand extent of back bonding in metal carbonyls

Unit 1: Introduction to Coordination compounds — Lectures: 06

Brief discussion with examples of types of ligands, denticity and concept of chelate. IUPAC system of nomenclature of coordination compounds (mononuclear and binuclear) involving simple monodentate and bidentate ligands. Structural and stereoisomerism in complexes with coordination numbers 4 and 6.

Unit 2: Bonding in coordination compounds — Lectures: 14

Valence Bond Theory (VBT): Salient features of theory, concept of inner and outer orbital complexes, Drawbacks of VBT.

Crystal Field Theory: Splitting of d orbitals in octahedral symmetry. Crystal field effects for weak and strong fields, Crystal field stabilization energy (CFSE), concept of pairing energy, Factors affecting the magnitude of Δ, Spectrochemical series, Splitting of d orbitals in tetrahedral symmetry, Comparison of CFSE for octahedral and tetrahedral fields, tetragonal distortion of octahedral geometry, Jahn-Teller distortion

Unit 3: Organometallic chemistry Lectures: 10

Definition and classification with appropriate examples based on nature of metal-carbon bond (ionic, sigma, pi and multicentre bonds), Structure and bonding of methyl lithium and Zeise's salt, Structure and bonding of ferrocene, mononuclear and polynuclear carbonyls of 3d metals, 18-electron rule as applied to carbonyls, π-acceptor behaviour of carbon monoxide (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding.

Practical

(Credits: 02, Laboratory periods: 60)

1. Estimation of Mg^{2+} by direct complexometric titrations using EDTA.
2. Estimation of Zn^{2+} by direct complexometric titrations using EDTA.
3. Estimation of Ca^{2+} by direct complexometric titrations using EDTA.
4. Estimation of total hardness of a given sample of water by complexometric titration.
5. Determination of the composition of the Fe^{3+} - salicylic acid complex / Fe^{2+}-1, 10- phenanthroline complex in solution by Job's method.
6. Determination of the composition of the Fe^{3+} - salicylic acid complex / Fe^{2+}-1,10-phenanthroline complex in solution by mole ratio method
7. Preparation of the following inorganic compounds:
    a. Tetraamminecopper(II) sulphate
    b. Potassium trioxalatoferrate(III) trihydrate
    c. Chrome alum
    d. *Cis*- and *trans*-Potassium diaquadioxalatochromate(III)
8. Any suitable experiment (other than the listed ones) based upon complexation reactions.

References (Theory):

1. Huheey, J.E.; Keiter, E.A., Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education
2. Shriver, D.D.; Atkins, P.; Langford, C.H. (1994), **Inorganic Chemistry 2nd Ed.**, Oxford University Press.
3. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Inorganic *Chemistry*, 5th Edition**, W. H. Freeman and Company.
4. Cotton, F.A.; Wilkinson, G.; Gaus, P.L. **Basic Inorganic Chemistry, 3rd Edition**, Wiley India.

5. Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), **Concepts and Models of Inorganic Chemistry**, John Wiley & Sons.
6. Greenwood, N.N.; Earnshaw, A. (1997), **Chemistry of the Elements**, 2nd Edition, Elsevier.

References (Practical):

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989),**Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.
2. Marr, G.; Rockett, B.W. (1972), **Practical Inorganic Chemistry**, Van Nostrand Reinhold.

Teaching Learning Process:

- Conventional chalk and board teaching,
- Class interactions and discussions
- Power point presentation on important topics.

Assessment Methods:

- Presentations by Individual Student/ Group of Students
- Class Tests at Periodic Intervals.
- Written assignment(s)
- End semester University Theory Examination

Keywords:

Crystal field theory, Dq, CFSE, Nomenclature, Valence bond theory, Crystal field theory, Magnetic properties, 18 electron rule, metal carbonyls, hapticity

SEMESTER VI

Course Code: Industrial Chemistry DSC-IC 6
Course Title: Food Additives, Contamination and Safety
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

To understand the chemistry of food additives and their applications This has been designed to impart theoretical and practical knowledge on common food additives, contaminants and adulterants. The analytical approach of this course is to enhance the understanding of safety measures of food and evaluation techniques to determine toxicity of additives. This course also enhances knowledge about regulations and monitoring agencies of food.

Learning Outcomes:

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

- Understand and describe applications of various food additives in food processing and preservation.
- Know the merits and demerits of synthetic and natural colouring, flavouring and sweetening agents as food additives.
- Identify and prevent potential sources of food contamination
- Know Safety measures of food additives, regulations and monitoring agencies and toxicological evaluation of additives.

Unit 1: Food Additives — Lectures: 12

Introduction, need of food additives in food processing and preservation. Characteristics and classification of food additives.
Antimicrobial agents. -Nitrites, sulphides, sulphur dioxide, sodium chloride, hydrogen peroxide.
Antioxidants - Introduction, mechanism of action, natural and synthetic antioxidants, technological aspect of antioxidants.
Sweeteners- Introduction, importance, classification- natural and artificial, chemistry, technology and toxicology, consideration for choosing sweetening agents.
Colors- Introduction, importance, classification- natural, artificial, and natural identical, FD&C Dyes and Lakes. polymeric colors.

Unit 2: Food Contamination & adulterants — Lectures: 12

Contamination in Food: Physical, chemical contaminants- heavy metals, pesticide residues, agrochemicals, Antibiotics and Veterinary Drug residues, environmental pollutants, radionuclides, solvent residues, NOTS (Naturally Occurring Toxic Substances)
Contaminants formed during processing & packaging – nitrosamines, acrylamide, alloys, benzene, dioxins, furans, persistent organic pollutants, polymers, PAH (Polycyclic Aromatic Hydrocarbons) in smoked foods, food. fumigants, autoxidation products.
Food adulteration - Common adulterants in foods and tests to detect common adulterants.

Unit 3: Food Safety, Risks and hazards — Lectures: 6

Food related hazards, regulations and monitoring agencies, interaction of additives with food ingredients and their toxicological aspects, quality evaluation of additives and contaminants, Acute and chronic studies, NOEL, ADI, LD50

Practical

Credits: 02, Laboratory periods: 60)

1. Determination of moisture content of foods by oven drying.
2. Determination of reducing and total sugar content in foods.
3. Chromatographic Separation and identification of sugars and amino acids.
4. Testing of turmeric powder, milk and mustard oil for adulterants.
5. Extraction of natural coloring and flavoring agent from flowers and fruits
6. Inspection of various food grains- cereals and coarse cereals
7. Determination of quality standards and inspection of spices and condiments.
8. Qualitative tests for hydrogenated fats, butter, and ghee.
9. Estimation of sulphur dioxide in beverages.
10. Qualitative estimation of benzoic acid in ketchup and sauces.
11. Chromatographic estimation of colour.
12. Study the effect of aerial oxidation of food.

References (Theory):

1. DeMan. (2007). Principles of Food Chemistry. Springer, 3rdedition
2. Emerton, V, (2008). Food Colours. Blackwell Publishing.
3. Wilson, R. (2007).Sweeteners. Blackwell Publishing.
4. Fennema OR.(1996). Food Chemistry. Marcel Dekker.
5. Pieternel A, Luning. & Willem, J. Marcelis. (2009). Food Quality Management Technological and Managerial principles and practices. Wageningen.

References (Practical):

1. Ranganna, S., & Ranganna, S. (2003). Handbook of analysis and quality control for fruit and vegetable products. New Delhi: Tata McGraw-Hill

2. Nielsen, S. S. (2017). Food analysis.
3. Vogel, Arthur I. (Arthur Israel). (1989). Vogel's textbook of quantitative chemical analysis. Harlow, Essex, England : New York :Longman Scientific & Technical ; Wiley,

Teaching Learning Process:

To accomplish a goal, it is very important to learn in a strategic manner. There are different components of learning and the capacity of each learner varies. Different ways of teaching include classical board teaching method, visual conceptual method, application based practical demonstration of the concept etc. Infact the pedagogy is to make a class interesting and thus learning becomes enjoyable.

Assessment Methods:

The effectiveness of learning can be judged by assessing the students. Assessment can be in the form of graded assignments, conventional class tests, class seminars by students on course topics with a view to strengthening the content through width and depth, end semester university examination for theory and practical.

Keywords:

Food colours. Flavours, Preservatives, sugars. Food contamination adulterants, Food safety.

Course Code: Chemistry DSC-C 6
Course Title: Quantum Chemistry and Spectroscopy
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The objective of this course is to introduce the students to the concepts and methodology of quantum mechanics, its applications to spectroscopy and establish the relation between structure determination and spectra.

Learning Outcomes:

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

- Understand basic principles of quantum mechanics: operators, eigen values, averages, probability distributions.

- Understand and use basic concepts of microwave, IR and UV-VIS spectroscopy for interpretation of spectra.

Unit 1: Quantum Chemistry — Lectures: 16

Postulates of quantum mechanics, quantum mechanical operators.
Schrodinger equation and its application to free particle and particle in a 1-D box (complete solution), quantization, normalization of wave functions, concept of zero-point energy.
Qualitative treatment of H and H like atoms. Setting up of Schrodinger equation for many electron atoms.
Rotational Motion: Schrödinger equation of a rigid rotator and brief discussion of its results (solution not required). Quantization of rotational energy levels.
Vibrational Motion: Schrödinger equation of a linear harmonic oscillator and brief discussion of its results (solution not required). Quantization of vibrational energy levels.
Qualitative treatment of H and H like atoms. Setting up of Schrodinger equation for many electron atoms.

Unit 2: Spectroscopy — Lectures: 14

Electromagnetic radiation and its interaction with matter. Difference between atomic and molecular spectra. Born- Oppenheimer approximation: Separation of molecular energies into translational, rotational, vibrational and electronic components.
Microwave (pure rotational) spectra of diatomic molecules. Selection rules. Structural information derived from rotational spectroscopy.
IR Spectroscopy: Selection rules, IR spectra of diatomic molecules. Structural information derived from vibrational spectra. Effect of hydrogen bonding (inter- and intramolecular) and substitution on vibrational frequencies.
Electronic Spectroscopy: Electronic excited states. Free electron model and its application to electronic spectra of polyenes. chromophores, auxochromes, bathochromic and hypsochromic shifts.

Practical

(Credits: 02, Laboratory periods: 60)

UV/Visible spectroscopy

1. Study the 200-500 nm absorbance spectra of $KMnO_4$ and K_2Cr2O_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).
2. Study the pH-dependence of the UV-Vis spectrum (200-500 nm) of K_2Cr2O_7
3. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.

Colorimetry

4. Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/ $KMnO_4$/ $K_2Cr_2O_7$/ $CoCl_2$ in a solution of unknown concentration
5. Determine the concentrations of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture.
6. Study the kinetics of iodination of propanone in acidic medium.
7. Determine the amount of iron present in a sample using 1, 10-phenanthroline.
8. Determine the dissociation constant of an indicator (phenolphthalein).
9. Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.

References (Theory):

1. Banwell, C.N.; McCash, E.M.(2006), **Fundamentals of Molecular Spectroscopy**, Tata McGraw- Hill.
2. Kapoor, K.L.(2015),**A Textbook of Physical Chemistry**, McGraw Hill Education, ,Vol 4, 5th Edition, McGraw Hill Education.
3. McQuarrie, D.A.(2016),**Quantum Chemistry**, Viva Books.
4. Chandra, A. K.(2001),**Introductory Quantum Chemistry**, Tata McGraw-Hill.
5. Dua A and Tyagi P, **Molecular Spectroscopy: Quantum to Spectrum**, (2022) Atlantic Publishers & Distributors Pvt Ltd.
6. Dua A, Singh C, **Quantum Chemistry: Classical to Computational** (2015) Manakin Press.

References (Practical):

1. Khosla, B.D.; Garg, V.C.; Gulati, A. (2015),**Senior Practical Physical Chemistry**, R. Chand & Co, New Delhi.
2. Kapoor, K.L. (2019),**A Textbook of Physical Chemistry**, Vol.7, 1st Edition, McGraw Hill Education.
3. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P.(2003),**Experiments in Physical Chemistry**, 8th Edition, McGraw-Hill, New York.

Additional Resources:

1. Castellan, G. W .(2004),**Physical Chemistry**, Narosa.
2. Petrucci, R. H.(1989),**General Chemistry: Principles and Applications**, Macmillan Publishing

Teaching Learning Process:

- Teaching Learning Process for the course is visualized as largely student-focused.
- Transaction through an intelligent mix of conventional and modern methods.
- Engaging students in cooperative learning.
- Learning through quiz design.
- Problem solving to enhance comprehension.

Assessment Methods:

Assessment will be done on the basis of regular class test, presentations and assignments as a part of internal assessment during the course as per the curriculum. End semester university examination will be held for both theory and practical. In practical, assessment will be done based on continuous evaluation, performance in the experiment on the date of examination and viva voce.

Keywords:

Quantisation, Selection rules, Schrodinger equation, Operator, Spectrum, Quantum efficiency, Fluorescence.

DISCIPLINE SPECIFIC ELECTIVE COURSES (DSE)

Course Code: Industrial Chemistry DSE-1
Course Title: Green Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

Huge rise in environmental pollution, depleting resources, climate change, ozone depletion, heaps and heaps of landfills piling up has forced the society to become more and more environmentally conscious. Future chemists and innovators are compelled to work towards sustainable practices. Green chemistry has arisen from these concerns. It is not a new branch of chemistry but helps to improve the creative and innovative thinking in undergraduate students. Green chemistry is a way to boost profits, increase productivity and ensure sustainability with absolute zero waste. Innovations and applications of green chemistry in education have helped companies to gain environmental benefits as well as to achieve economic and societal goals also. Undergraduate students are the ultimate scientific community of tomorrow. Training them to practice chemistry in the safest way possible is key towards safe working conditions in the laboratories as well as the chemical industry and extends to society in a sustainable future for the planet.

Learning Outcomes:

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

- Understand the twelve principles of green chemistry and also build the basic understanding of toxicity, hazard and risk related to chemical substances.
- Calculate atom economy, E-factor and relate them in all organic synthesis
- Appreciate the use of catalyst over stoichiometric reagents
- Learn to use green solvents, renewable feedstock and renewable energy sources for carrying out safer chemistry
- Appreciate the use of green chemistry in problem solving skills and critical thinking to innovate and find solutions to environmental problems.
- Learn to design safer processes, chemicals and products through understanding of inherently safer design (ISD)
- Appreciate the success stories and real-world cases as motivation for them to practice green chemistry

Unit 1: Introduction Lectures:08

Definition of green chemistry and how it is different from conventional chemistry and environmental chemistry.

• Need of green chemistry

• Importance of green chemistry in- daily life, Industries and solving human health problems (four examples each).

• A brief study of Green Chemistry Challenge Awards (Introduction, award categories and study about five last recent awards).

Unit 2: Twelve Principles of Green Chemistry Lectures: 12

The twelve principles of the Green Chemistry with their explanations, Special emphasis on the following:

• Prevention of waste / byproducts, pollution prevention hierarchy.

• Green metrics to assess greenness of a reaction: environmental impact factor, atom economy and calculation of atom economy.

• Green solvents-supercritical fluids, water as a solvent for organic reactions, ionic liquids, solvent less reactions, solvents obtained from renewable sources.

• Catalysis and green chemistry- comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis.

• Green energy and sustainability.

• Real-time analysis for pollution prevention.

• Prevention of chemical accidents, designing greener processes, inherent safer design, principle of ISD “What you don’t have cannot harm you”, greener alternative to Bhopal Gas Tragedy (safer route to carcarbaryl) and Flixiborough accident (safer route to cyclohexanol) subdivision of ISD, minimization, simplification, substitution, moderation and limitation

Unit 3: **Lectures: 10**

The following Real-world Cases in green chemistry should be discussed: Surfactants for carbon dioxide – replacing smog producing and ozone depleting solvents with CO_2 for precision cleaning and dry cleaning of garments. Designing of environmentally safe marine antifoulant. Rightfit pigment: Synthetic azo pigments to replace toxic organic and inorganic pigments. An efficient, green synthesis of a compostable and widely applicable plastic (polylactic acid) made from corn.

Practical

(Credits: 02, Laboratory periods: 60)

Characterization by melting point, UV-Visible spectroscopy, IR spectroscopy and any other specific method should be done (wherever applicable).

1. Preparation and characterization of nanoparticles of gold using tea leaves/silver nanoparticles using plant extracts.
2. Preparation of biodiesel from waste cooking oil and characterization (TLC, pH, solubility, combustion test, density, viscosity, gel formation at low temperature and IR can be provided).
4. Benzoin condensation using thiamine hydrochloride as a catalyst instead of cyanide.
5. Extraction of D-limonene from orange peel using liquid CO_2 prepared from dry ice.
6. Mechanochemical solvent free, solid-solid synthesis of azomethine using *p*-toluidine and *o*-vanillin/*p*-vanillin.
9. 6 Microwave-assisted Knoevenagel reaction using anisaldehyde, ethylcyanoacetate and ammonium formate.
7. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.
8. Photochemical conversion of dimethyl maleate to dimethyl fumarate (*cis-trans* isomerisation)
9. Benzil- Benzilic acid rearrangement: Preparation of benzilic acid in solid state under solvent-free condition.

References (Theory):

1. Anastas, P.T., Warner, J.C. (2014), **Green Chemistry, Theory and Practice**, Oxford University Press.
2. Lancaster, M. (2016), **Green Chemistry: An Introductory Text**, 3rd Edition, RSC Publishing.
3. Cann, M. C., Connely, M.E. (2000), **Real-World cases in Green Chemistry, American Chemical Society**, Washington.
4. Matlack, A.S. (2010), **Introduction to Green Chemistry**, 2nd Edition, Boca Raton: CRC Press/Taylor & Francis Group publisher.
5. Alhuwalia, V.K., Kidwai, M.R. (2005), **New Trends in Green chemistry**, Anamalaya Publishers.
6. Sidhwani, I.T, Sharma, R.K. (2020), **An Introductory Text on Green Chemistry**, Wiley India Pvt Ltd.

References (Practical):

1. Kirchoff, M.; Ryan, M.A. (2002), **Greener approaches to undergraduate chemistry experiment**, American Chemical Society, Washington DC.
2. Sharma, R.K.; Sidhwani, I.T.; Chaudhari, M.K. (2013), **Green Chemistry Experiments: A monograph**, I.K. International Publishing House Pvt Ltd. New Delhi.
3. Pavia, D.L.; Lamponam, G.H.; Kriz, G.S.W. B. (2012), **Introduction to organic Laboratory Technique- A Microscale approach**, 4th Edition, Brooks-Cole Laboratory Series for Organic chemistry.
4. Sidhwani I.T. (2015), Wealth from Waste: A green method to produce biodiesel from waste cooking oil and generation of useful products from waste further generated. **DU Journal of Undergraduate Research and Innovation**, 1(1),131-151. ISSN: 2395-2334.
5. Sidhwani, I.T; Sharma, R.K. (2020), **An Introductory Text on Green Chemistry**, Wiley India Pvt Ltd.
6. **Monograph on Green Chemistry Laboratory Experiments**, Green Chemistry Task Force Committee, Department of Science and Technology, Government of India.

Teaching Learning Process:

- Conventional chalk and board teaching
- Power point presentations
- Interactive sessions on recent green chemistry presidential awards
- Visit a chemical industry and ask the students to think critically for improving the conditions there.
- Screening of documentaries based on chemical accidents/ and then ask them to think about the solutions

Assessment Methods:

- Presentation/assignment by students
- Class Test at Periodic Intervals
- Written Assignment
- Continuous evaluation in practicals
- End Semester University Theory and Practical Exams

Keywords:

Green chemistry, Twelve principles of green chemistry, Atom economy, Waste minimization, green metric, green solvents, Solvent free, Catalyst, Bio-catalyst, Renewable energy sources, Hazardous, Renewable feedstock, Ionic liquids, Supercritical fluids, Inherent safer design, green synthesis, combinatorial, Sustainable development, Presidential green chemistry awards.

Course Code: Industrial Chemistry DSE-2
Course Title: Analytical Methods in Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The objective of this course is to make the students aware of the concept of sampling, accuracy, precision, statistical test data-F, Q and t test. The course exposes students to the laws of spectroscopy and selection rules governing the possible transitions in the different regions of the electromagnetic spectrum. Thermal and electroanalytical methods of analysis are also dealt with. Students are exposed to important separation methods like solvent extraction and chromatography. The practicals expose students to the latest instrumentation and they learn to detect analytes in a mixture.

Learning Outcomes:

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

- Perform experiments with accuracy and precision.
- Develop methods of analysis for different samples independently.
- Test contaminated water samples.
- Understand basic principles of instruments like Flame Photometer, UV-vis spectrophotometer.
- Learn separation of analytes by chromatography.
- Apply knowledge of geometrical isomers and keto-enol tautomers to analysis.
- Determine composition of soil.
- Estimate macronutrients using Flame photometry.

Unit 1: Qualitative and quantitative aspects of analysis Lectures:04

Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression. Normal law of distribution of indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals.

Unit 2: Optical methods of analysis Lectures:10

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules. UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument; Transmittance. Absorbance and Beer-Lambert law. Absorption and Emission Spectrometry: Basic principles

of instrumentation (choice of source, monochromator, detector, choice of flame and Burner designs).

Unit 3: Thermal methods of analysis Lectures:04

Theory of thermogravimetry (TG) and basic principle of instrumentation of thermal analyser. Techniques for quantitative estimation of Ca and Mg from their mixture.

Unit 4: Electroanalytical methods Lectures:04

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

Unit 5: Separation techniques Lectures:08

Solvent extraction: Classification, principle and efficiency of the technique. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media. Chromatography: Classification, principle and efficiency of the technique, Mechanism of separation: adsorption, partition &ion-exchange, Development of chromatograms: frontal, elution and displacement methods.

Practical

(Credits: 02, Laboratory periods: 60)

1. Separation of mixtures by paper chromatography and reporting the Rf values:
   (i) Co^{2+} and Ni^{2+}.
   (ii) Amino acids present in the given mixture.
2. Solvent Extractions

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

3. Analysis of soil:
   (i) Determination of pH of soil.
   (ii) Total soluble salt
   (iii) Estimation of calcium and magnesium
   (iv) Qualitative detection of nitrate and phosphate
4. Ion exchange:
   (i) Determination of exchange capacity of cation exchange resins and anion exchange resins.
   (ii) Separation of amino acids from organic acids by ion exchange chromatography.
5. Spectrophotometry
   (i) Verification of Lambert-Beer's law and determination of concentration of a coloured species ($CuSO_4$, $KMnO_4$, $CoCl_2$, $CoSO_4$)
   (ii) Determination of concentration of coloured species via following methods;

(a) Graphical method
(b) Epsilon method
(c) Ratio method
(d) Standard addition method

References (Theory):

1. Willard, H.H.(1988),Instrumental Methods of Analysis, 7th Edition, Wardsworth Publishing Company.
2. Christian, G.D.(2004),Analytical Chemistry, 7th Edition, John Wiley & Sons, New York.
3. Harris, D. C.(2007),Quantitative Chemical Analysis,7th Edition, Freeman.
4. Khopkar, S.M. (2008), Basic Concepts of Analytical Chemistry, New Age International Publisher.
5. Skoog, D.A.; Holler F.J.; Nieman, T.A. (2017), Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd.

References (Practical):

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C.(1989),Vogel's Textbook of Quantitative Chemical Analysis,John Wiley and Sons.

Teaching Learning Process:

- Teaching through audio-visual aids.
- Students are encouraged to participate actively in the classroom through regular presentations on curriculum-based topics.
- As the best way to learn something is to do it yourself, practicals are planned in such a way so as to reinforce the topics covered in theory.

Assessment Methods:

- Presentations by individual student/ small group of students
- Class tests at periodic intervals.
- Written assignment(s)
- Objective type chemical quizzes based on contents of the paper.
- End semester university theory and practical examination.

Keywords:

Separation techniques, Solvent extraction, Ion-exchange, Optical methods, Flame Atomic Absorption and Emission Spectrometry, indeterminate errors, statistical test of data; F, Q and t tests, TGA.

Course Code: Industrial Chemistry DSE-3
Course Title: Basics of Polymer Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The primary objective of this paper is to help the student to know about the synthesis, properties and applications of polymers. This paper will give glimpse of polymer industry to the student and help them to choose their career in the field of polymer chemistry.

Learning Outcomes:

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

- Know about history of polymeric materials and their classification
- Learn about different mechanisms of polymerization and polymerization techniques
- Learn about different methods of finding out average molecular weight of polymers
- Differentiate between glass transition temperature (Tg) and crystalline melting point (Tm)
- Determine Tg and Tm
- Learn properties and applications of various useful polymers in our daily life.

Unit 1: Introduction to Polymeric Materials — Lectures:10

History of polymeric materials, Different schemes of classification of polymers, Polymer nomenclature
Molecular forces and chemical bonding in polymers, Physical and chemical properties of polymers
Solubility and Criteria for polymer solubility, Texture of Polymers, modification of polymers, Structure and property relationships, Introduction to conducting and biodegradable polymers.

Unit 2: Characterization of Polymers: — Lectures:10

Thermal characterisation of polymer: Glass transition temperature (Tg), thermal stability and decomposition of polymers, Molecular weight of polymers (Mn, Mw, etc.) by end group analysis, viscometry, light scattering technique and osmotic pressure methods.
Structural characterisation of polymers by IR and NMR spectroscopy.

Unit 3: Preparation, Properties and Uses of Polymers: — Lectures:10

Brief introduction to polymerisation, mechanism, properties and application of the following polymers: polyolefins, polystyrene, poly(vinyl chloride), poly(vinyl acetate), polyurethanes,

acrylic polymers and polyamides. Phenol formaldehyde and urea formaldehyde, Silicone polymers, Conducting Polymers: polyacetylene, polyaniline, polypyrrole, polythiophene., Biopolymer: Cellulose and Chitosan.

Practical:

(Credits: 2, Laboratory periods: 60)

1. Preparation of nylon 6,6.
2. Redox polymerization of acrylamide.
3. polymerization of acrylonitrile.
4. Preparation of urea-formaldehyde resin.
5. Preparations of phenol-formaldehyde resin.
6. Determination of molecular weight of different polymers in water by viscometry.
7. Estimation of the amount of HCHO in the given solution by sodium sulphite method.
8. Demonstration for chemical structure and functional group in polymers using IR spectroscopy.
9. Purification of monomer and polymerisation of Styrene and Polymethylmethacrylate using BPO (Benzoyl Peroxide).
10. Polymerization of aniline and pyrrole by chemical polymerisation method.
11. Preparation of poly methylacrylate by emulsion and bulk polymerisation and compare the results.
12. Characterisation of polymers by IR spectroscopy.

References (Theory):

1. Ahluwalia V.K. & Mishra A**. Polymer Science :A Textbook**(2009) Anne Books.
2. Odian, G. (2004), **Principles of Polymerization**, John Wiley.
3. Billmeyer, F.W. (1984),**Text Book of Polymer Science**,3rd Ed., John Wiley.
4. Ghosh, P. (2001),**Polymer Science & Technology**, Tata Mcgraw-Hill.
5. Lenz, R.W. (1967),**Organic Chemistry of Synthetic High Polymers**, Interscience (Wiley).

References (Practical):

1. Hundiwale ,D.G.,Athawale V.D ,Kapadi, U.R.& Gite V.V, **Experiments in Polymer Science ,**New Age International Publishers .
2. Allcock, H.R.; Lampe, F. W.; Mark, J. E. (2003), **Contemporary Polymer Chemistry**, Prentice-Hall.
3. Fried, J.R. (2003), **Polymer Science and Technology**, 2nd Ed, Prentice-Hall.
4. Munk, P.; Aminabhavi , T. M. (2002), **Introduction to Macromolecular Science,** John Wiley & Sons.
6. Sperling, L.H. (2005), **Introduction to Physical Polymer Science**, John Wiley & Sons.

Teaching-Learning Process:

- Teaching learning process for the course is visualized as largely student-focused.
- Transaction through an intelligent mix of conventional and modern methods.
- Engaging students in cooperative learning.
- Learning through quiz design.
- Different ways of teaching include classical board teaching method, visual conceptual method, power point presentation, application based practical demonstration of the concept etc.

Assessment Methods:

Assessment can be in form of:

- Graded assignments
- Conventional class tests
- Class seminars and presentations by students on relevant topics from the course
- End semester university examination for both theory and practical.
- In practical, assessment will be done based on continuous evaluation, performance in the experiment and viva voce on the date of examination.

Keywords:

Bonding, Texture, Mechanism of Polymerization, Molecular Weight Determination, Properties, Applications.

Course Code: Industrial Chemistry DSE-4
Course Title: Molecules of Life
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

This course is designed to deliver information about the chemistry of carbohydrates, proteins & enzymes and its relevance in the biological system using suitable examples. Key emphasis is placed on understanding the structural principles that govern reactivity/physical /biological properties of biomolecules as opposed to learning structural details.

Learning Outcomes:

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

- Learn and demonstrate how the structure of biomolecules determines their chemical properties, reactivity and biological uses.

- Gain an insight into the mechanism of enzyme action and inhibition.
- Understand the basic principles of drug-receptor interaction and SAR.

Unit 1: Carbohydrates — Lectures: 12

Classification of carbohydrates, reducing and non-reducing sugars, biological functions, general properties and reactions of glucose and fructose, their open chain structure, epimers, mutarotation and anomers, reactions of monosaccharides, determination of configuration of glucose (Fischer proof), cyclic structure of glucose. Haworth projections. Cyclic structure of fructose. Linkage between monosaccharides: structure of disaccharides (sucrose, maltose, lactose) and polysaccharides (starch and cellulose) excluding their structure elucidation.

Unit 2: Amino Acids, Peptides and Proteins — Lectures: 10

Classification of amino acids and biological uses of amino Acids, peptides and proteins. Zwitterion structure, isoelectric point and correlation to acidity and basicity of amino acids. Determination of primary structure of peptides, determination of N-terminal amino acid (by Edman method) and C– terminal amino acid (with carboxypeptidase enzyme). Synthesis of simple peptides (up to dipeptides) by N-protection (t-butyloxycarbonyl) & C-activating groups (only DCC) and Merrifield solid phase synthesis, Overview of primary, secondary, tertiary and quaternary structure of proteins, denaturation of proteins.

Unit 3: Enzymes — Lectures: 04

Classification of enzymes and their uses (mention Ribozymes). Mechanism of enzyme action, factors affecting enzyme action, Coenzymes and cofactors and their role in enzyme action, specificity of enzyme action (including stereospecificity).

Unit 4: Nucleosides, Nucleotides and Nucleic acids — Lectures: 04

Components of Nucleic acids: Adenine, guanine, thymine, cytosine and uracil (structure only), other components of nucleic acids, nucleosides and nucleotides (nomenclature), structure of polynucleotides; structure of DNA (Watson-Crick model) and RNA (types of RNA), difference between DNA and RNA

Practical

(Credits: 02, Laboratory periods: 60)

1. Estimation of glucose by Fehling's solution.
2. Determination of total sugar content by ferricyanide method (volumetric/colorimetric method).
3. Study of the titration curve of glycine and determine the isoelectic point of glycine.
4. Estimation of proteins by Lowry's method.
5. Qualitative tests for amino acids, proteins and carbohydrates.
6. Separation and identification of mixture of sugars by paper chromatography.
7. Separation and identification of mixture of Amino acids by paper chromatography.
8. Study of the action of salivary amylase on starch under optimum conditions and find the enzyme activity.

9. Study the effect of temperature on activity of salivary amylase.
10. Extraction of DNA from onion/cauliflower.

References (Theory):

1. Finar, I. L. **Organic Chemistry** (Volume 1 & 2), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
2. Morrison, R. N.; Boyd, R. N., Bhattacharjee, S.K. (2010), **Organic Chemistry**, 7th Edition, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Berg, J. M.; Tymoczko, J. L.; Stryer, L. (2019), **Biochemistry**, 9th Ed., W. H. Freeman Co Ltd.

References (Practical):

1. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. (2012), **Vogel's Textbook of Practical Organic Chemistry**, Pearson.
2. **Manual of Biochemistry Workshop**, 2012, Department of Chemistry, University of Delhi.

Teaching Learning Process:

- Chalk and black board method. Along with pedagogy of flipped classroom
- Certain topics like mechanism of enzyme action and enzyme inhibition can be taught through audio-visual aids.
- Students should be encouraged to participate actively in the classroom through regular presentations on curriculum-based topics, peer assessment, designing games based on specific topics etc.
- As the best way to learn something is to do it yourself, practicals are planned in such a way so as to reinforce the topics covered in theory.

Assessment Methods:

- Graded assignments
- Class tests and Quizzes
- Class seminars by students on course topics with a view to strengthening the content through width and depth
- Continuous evaluation for the practicals
- End semester university theory and practical examination.

Keywords:

Carbohydrates, point, Amino acids, Enzymes, SAR, Drug Receptor Theory

Course Code: Chemistry DSE-5
Course Title: Main Group Chemistry
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The objective of this paper is to provide basic understanding of the fundamental principles of metallurgy through study of the different methods of extraction and refining of metals. The course illustrates the diversity and fascination of inorganic chemistry through the study of structure, properties and utilities of s- and p-block elements and their compounds

Learning Outcomes:

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

- Understand the basis of occurrence of metals in nature and the methods that can be applied on minerals to extract the metals from them.
- Explain the importance of free energy of formation of oxides with the choice of reducing agent for extracting the metals.
- Understand and explain the importance of refining of metals and the choice of a refining procedure
- Explain the group trends observed for different properties of s and p block elements
- Explain the structures and the bonding basis of compounds of s- and p- block elements
- Explain the uniqueness observed in alkali metals and some other main group elements
- Understand and explain the polymerization of inorganic ions to generate inorganic polymers and the difference between organic and inorganic polymers.

Unit 1: General Principles of Metallurgy — Lectures: 06

Chief modes of occurrence of metals based on standard electrode potentials. Ellingham diagrams for reduction of metal oxides using carbon and carbon monoxide as reducing agent. Electrolytic Reduction, Hydrometallurgy with reference to cyanide process for silver and gold. Methods of purification of metals: Electrolytic process, Van Arkel-De Boer process, Zone refining.

Unit 2: General Properties — Lectures: 05

General group trends of s- and p-block elements with special reference to melting and boiling points, flame colour, metallic character and complex formation tendency, diagonal relationship and anomalous behaviour of first member of each group, Alkali metal solutions in liquid ammonia

Unit 3: Structure, Bonding, Properties and Applications Lectures: 15

Structure, bonding, properties (Acidic/Basic nature, stability, ionic/covalent nature, oxidation/reduction, hydrolysis, thermal stability) and applications of the following:
Crown Ethers and cryptates of Alkali metals
Hydrides: hydrides of Group 13 (only diborane), Group 14, Group 15 (EH_3 where E = N, P, As, Sb, Bi), Group 16 and Group 17.
Oxides: Oxides of nitrogen, phosphorus and sulphur.
Oxoacids: oxoacids of phosphorus, sulphur and chlorine
Halides of phosphorus

Unit 4: Inorganic Polymers Lectures:04

Preparation, properties, structure and uses of the following:

Borazine, Silicates and Silicones

Practical

(Credits: 02, Laboratory periods: 60)

Qualitative semi-micro analysis of mixtures containing 2 anions and 2 cations (preferably 7-8 mixtures). Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested:

CO_3^{2-}, NO_2^- , S^{2-}, SO_3^{2-}, SO_4^{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+}

The mixtures may contain combination of anions/one interfering anion.

Spot tests should be preferred wherever applicable.

References (Theory):

1. Lee, J.D.; (2010), **Concise Inorganic Chemistry**, Wiley India.
2. Huheey, J.E.; Keiter, E.A.; Keiter; R. L.; Medhi, O.K. (2009), **Inorganic Chemistry-Principles of Structure and Reactivity**, Pearson Education.
3. Douglas, B.E.; McDaniel, D.H.; Alexander, J.J. (1994), **Concepts and Models of Inorganic Chemistry**, John Wiley & Sons.
4. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Shriver and Atkins Inorganic Chemistry**, 5th Edition, Oxford University Press.
5. Housecraft, E. H.; Sharpe, A.G. (2018), **Inorganic Chemistry**, 5th Edition, Pearson.
6. F.A. Cotton & G. Wilkinson (1999), **Advanced Inorganic Chemistry**, 6th Edition, John Wiley & Sons.

References (Practical):

1. Vogel, A.I. (1972), **Qualitative Inorganic Analysis**, Longman.

2. Svehla, G. (1996), **Vogel's Qualitative Inorganic Analysis**, Prentice Hall.

Teaching Learning Process:

- Conventional methods of teaching learning e.g. Lectures, use of chalk, blackboard and models.
- ICT enabled teaching learning
- Group discussions and quiz

Assessment Methods:

- Test / Examination
- Assignment
- Projects based on the real world application of important elements and their compounds
- End semester University theory and practical examination.

Keywords:

s-block elements, p-block elements, Borazine, Silicones, Silicates, solutions in ammonia, anomalous behaviour, inorganic polymers, oxides, oxyacids.

Course Code: Chemistry DSE-6
Course Title: Nanoscale Materials and Their Applications
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The general goal of the course is to provide an introduction to nanoscale materials and their applications. It provides an insight into bottom-up and top-down-approach, the methods of synthesis of nanoparticles, simple characterization techniques and applications of nanomaterials.

Learning Outcomes:

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

- Understand the concept of nano dimensions.
- Know the various methods of preparation of nanomaterials.
- Understand the principles of optical and electron microscopy techniques of characterizing nanomaterials.
- Understand the Appreciate the real life applications of nanomaterials.

Unit 1: Introduction to Nanodimensions Lectures: 12

0D, 1D, 2D nanomaterials, Quantum Dots, Nanoparticles, Nanostructures (nanowires, thin films, nanorods), carbon nanostructures (carbon nanotubes, carbon nanofibers, fullerenes), Size Effects in nano systems, Quantum confinement and its consequences, Semiconductors. Band structure and band gap. Optical Properties Surface plasmon resonance

Unit 2: Preparation of Nanomaterials Lectures: 10

Top down and Bottom up approach, Photolithography. Ball milling. Vacuum deposition. Physical vapor deposition (PVD), Chemical vapor deposition (CVD), Thermal decomposition, Chemical reduction, Sol-Gel synthesis, Hydrothermal synthesis, Spray pyrolysis, Electrochemical deposition, Pulsed Laser deposition. Characterization of nanomaterials: Basic principle of optical methods and electron microscopy.

Unit 3: Applications of Nanomaterials Lectures: 8

Nanomaterials as Catalysts, semiconductor nanomaterials as photocatalysts, Nanocomposites as catalysts. Carbon nanostructures as catalytic nanoreactors, metal and metal oxides confined inside carbon nanostructures, Nanowires and thin films for photonic devices (LEDs, solar cells, transistors).

Practical

(Credits: 02, Laboratory periods: 60)

1. Synthesis of silver nanoparticles by chemical methods and characterization using UV-visible spectrophotometer.
   a. Turkevich Method
   b. Burst Method
2. Synthesis of silver nanoparticles by green approach methods (using soluble starch, glucose or cinnamon bark) and characterization using UV-visible spectrophotometer.
3. Synthesis of metal sulphide nanoparticles and characterization using UV-visible spectrophotometer and determination of Band gap.
   a. MnS
   b. ZnS
   c. CuS
4. Intercalation of hydrogen in tungsten trioxide and its conductivity measurement using conductometer.

5. Synthesis of pure ZnO and Cu doped ZnO nanoparticles.
6. Phytochemicals mediated synthesis of gold nanoparticles (AuNPs) using tea leaves and to study the effect of size on color of gold/silver nanoparticles.
7. Preparation of magnetic nanoparticles (MNPs) of Fe_3O_4 using green tea leaf extract.
8. Any suitable experiment (other than the listed ones) based upon complexation reactions.

References (Theory):

1. West, A. R. (2014), **Solid State Chemistry and Its Application**, Wiley.
2. Smart, L. E.; Moore, E. A., (2012), **Solid State Chemistry: An Introduction**, CRC Press Taylor & Francis.
3. Rao, C. N. R.; Gopalakrishnan, J. (1997), **New Direction in Solid State Chemistry**, Cambridge University Press.
4. Poole Jr.; Charles P.; Owens, Frank J. (2003), **Introduction to Nanotechnology**, John Wiley and Sons. Harris, D. C. (2007), **Quantitative Chemical Analysis**,6th Edition, Freeman.
5. Chattopadhyay, K.K.; Banerjee, A. N. (2009), **Introduction to Nanoscience and Technology**, PHI.

References (Practicals):

1. Orbaek, W.; McHale, M.M.; Barron, A. R.; **Synthesis and Characterization of Silver Nanoparticles for An Undergraduate Laboratory**,J. Chem. Educ. 2015, 92, 339−344.
2. MacDiarmid, G.; Chiang, J.C.; Richter, A.F.; Somasiri, N.L.D.(1987), **Polyaniline: Synthesis and Characterization of the Emeraldine Oxidation State by Elemental Analysis**, L. Alcaeer (ed.), Conducting Polymers, 105-120, D. Reidel Publishing.
3. Cheng, K.H.; Jacobson, A.J.; Whittingham, M.S. (1981),**Hexagonal Tungsten Trioxide and Its Intercalation Chemistry, Solid State Ionics**, 5, 1981, 355-358.
4. Ghorbani H.R.; Mehr, F.P; Pazoki, H; Rahmani, B.M.; **Synthesis of ZnO Nanoparticles by Precipitation Method**, Orient J Chem 2015, 31(2).

Teaching Learning Process:

- Conventional chalk and board teaching,
- Class interactions and discussions
- Power point presentation on important topics.
- Using Excel and other software to plot graphs and analyse results

Assessment Methods:

- Presentations by Individual Student/ Group of Students
- Class Tests at Periodic Intervals.
- Written assignment(s)
- End semester University Theory and practical Examination

Keywords:

Nanomaterials, Quantum dots, Quantum confinement, Surface plasmon resonance, Applications of nanomaterials, electron microscopy.

Course Code: Chemistry DSE-7
Course Title: Chemistry of Polymers, Dyes and Natural Products
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

Chemistry is everywhere and everything, as a result, chemistry offers a variety of business opportunities for small and medium enterprises. Keeping in view the applications of chemistry in small industries, this course will be useful for introducing the students to the process of converting knowledge of chemistry into marketable products for commercial gain.

Learning Outcomes:

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

- Learn about the chemistry of natural and synthetic polymers including fabrics and rubbers.
- Understand the chemistry of biodegradable and conducting polymers and appreciate the need of biodegradable polymers with emphasis on basic principles.
- Comprehend the theory of colour and constitution as well as the chemistry of dyeing.
- Know applications of various types of dyes including those in foods and textiles.
- Understand the chemistry and applications of natural products like terpenoids and alkaloids.

Unit-1: Polymers Lectures:12

Introduction and classification based on origin, monomer units, thermal response, mode of formation, structure, application and tacticity; di-block, tri-block and amphiphilic polymers; Weight average molecular weight, number average molecular weight, glass transition temperature (Tg) of polymers; Polymerisation Reactions-Addition and condensation. Mechanism of cationic, anionic and free radical addition polymerization; Ziegler-Natta polymerisation of alkenes.

Preparation and applications of: Plastics -thermosetting (phenol-formaldehyde, polyurethanes) and thermosoftening (PVC, polythene); Fabrics -natural (cellulose and

synthetic derivatives of cellulose like rayon and viscose); synthetic (acrylic, polyamide, polyester); Rubbers-natural and synthetic: Buna-N, Buna-S, Neoprene, silicon rubber; Vulcanization; Polymer additives; Introduction to Specialty Polymers: electroluminescent (Organic light emitting diodes), conducting, biodegradable polymers and liquid crystals.

Unit-2: Dyes **Lectures: 08**

Classification, Colour and constitution; Mordant and Vat Dyes; Chemistry of dyeing. Synthesis and applications of Azo dyes – Methyl orange, Congo red; Triphenyl methane dyes- Crystal violet; Phthalein Dyes – Phenolphthalein; Natural dyes –Structure elucidation and synthesis of Alizarin and Indigotin; Edible Dyes with examples.

Unit 3: Natural Product Chemistry- An Introduction to Terpenoids and Alkaloids

Lectures: 10

Terpenes: Introduction, occurrence, classification, uses, isoprene and special isoprene rule; structure elucidation, synthesis and industrial application of citral.

Alkaloids: Introduction, occurrence, classification, uses, general structural features, general methods for structure elucidation including Hoffmann's exhaustive methylation and Emde's method. Structure elucidation, synthesis and physiological action of Nicotine.

Practical

(Credits: 02, Laboratory periods: 60)

1. Preparation of Methyl Orange.
2. Preparation of Malachite Green.
3. Recycling of Plastic: Moulding of plastic or Cracking of plastic.
4. Preparation of Urea-formaldehyde resin.
5. (a) Dyeing of different fabrics (cotton, wool, silk) using Alizarin or any other dye.

   (b) Preparation of azo dye on the surface of the fabric.
6. Qualitative test for identification of alkaloids (Dragendorff Reagent and Mayer's reagent test) and terpenoids (Salkowski test).
7. Preparation of perichromic dye using p-amino Phenol and p-nitro benzaldehyde.

References (Theory):

1. Finar, I.L. (2008), **Organic Chemistry**, Volume 2, 5th Edition, Pearson Education
2. Saunders, K. J. (1988), **Organic Polymer Chemistry**,2nd Edition Chapman & Hall, London
3. Campbell, Ian M., (2000), **Introduction to Synthetic Polymers**, 2nd Edition Oxford University Press, USA.
4. Bahadur, P. and Sastry, N.V. (2002) **Principles of Polymer Science** Narosa, New Delhi

5. Patrick, G. **An Introduction to Medicinal Chemistry** (2013), 4th Edition, Oxford University Press.
6. Priscilla Abarca, Patricia Silva, Iriux Almodovar and Marcos Caroli ezende*Quim. Nova, Vol. 37, No. 4, 745-747, 2014. http://dx.doi.org/10.5935/0100-4042.20140120

Teaching Learning Process:

- The teaching learning process will involve the traditional chalk and black board method. Along with pedagogy of flipped classroom.
- Certain topics like mechanism of enzyme action and enzyme inhibition, transcription and translation etc. where traditional chalk and talk method may not be able to convey the concept, are taught through audio-visual aids.
- Students are encouraged to participate actively in the classroom through regular presentations on curriculum-based topics, peer assessment, designing games based on specific topics etc.
- As the best way to learn something is to do it yourself, practicals are planned in such a way so as to reinforce the topics covered in theory.

Assessment Methods:

- Graded assignments
- Conventional class tests
- Class seminars by students on course topics with a view to strengthening the content through width and depth.
- Quizzes
- End semester university examination

Keywords:

Ziegler-Natta polymerisation, Thermosetting, Thermosoftening, Biodegradable and conducting polymers, Alkaloids, Terpenoids, Azo dyes.

Course Code: Chemistry DSE-8
Course Title: IT Skills and Molecular Modelling
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The objective of this course is to introduce the students to basic computer skills that are a must for a new age chemist. It acquaints the students with data tabulation, calculation, graph

plotting, data analysis and document. Preparation using various software (preferably open-source). The students will also learn about molecular modelling, its applications to various molecular systems, energy minimization techniques, analysis of Mulliken Charge and ESP Plots.

Learning Outcomes:

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

- Become familiar with the use of computers
- Use software for tabulating data, plotting graphs and charts, carry out statistical analysis of the data.
- Solve chemistry problems and simulate graphs.
- Prepare documents that will incorporate chemical structure, chemical equations, mathematical expressions from chemistry.
- Understand theoretical background of computational techniques and selective application to various molecular systems.
- Learn ESP Plots by suitable software, electron rich and electron deficient sites.
- Compare computational and experimental results and explain deviations.
- Perform Optimization of geometry parameters of a molecule (such as shape, bond length and bond angle) through use of software like Chem Sketch and Argus Lab in interesting hands-on exercises.

Unit 1: Introduction to important software in chemistry Lectures:10

Introduction to different software available for drawing chemical structures (Proprietary and Open-source) like ACD Chemsketch and 3-D viewer, ChemDraw.
Carrying out simple calculations on anyone of the following software: ArgusLab, Pymol, Avogadro, Molview, MarvinSketch.
Draw structures of various compounds (aliphatic, aromatic, heterocyclic with different functional groups) using software. Save the structures in various file formats. Incorporate the structures in word document and powerpoint presentation. SMILES notation for the chemical structures. PDB Files.

Unit 2: Handling of Numerical Data Lectures:10

Using a spreadsheet software: applying basic functions and formulae to the data, drawing charts, tables and graphs, displaying the equation of graph along with the R^2 value, incorporating tables and graphs in Word files, graphical solution of equations, plotting pressure-volume curves of van der Waals gases, Maxwell-Boltzmann distribution, concentration versus time graphs, spectral data, titration curves, etc.

Unit 3: Molecular Modelling Lectures: 10

Introduction to molecular modelling, overview of classical and quantum mechanical methods (semi empirical, ab initio and DFT) and molecular mechanics method

Intrinsic Reaction Coordinates, Stationary points, Equilibrium points – Local and Global minima, concept of transition state with examples.

Practical

(Credits: 02, Laboratory periods: 60)

Plotting graphs using a spreadsheet

1. van der Waals isotherms
2. Maxwell-Boltzmann distribution curves as function of temperature and molecular weight
3. Plot the conductometric titration curve for

   a) strong acid vs strong base and b) weak acid vs strong base

4. Plot the pH metric titration curve for

   a) strong acid vs strong base and b) weak acid vs strong base

5. Plot the graphs for the kinetics of first order reaction.

Molecular Modelling

6. Optimise and compare the geometry parameters of H_2O and H_2S using Argus Lab.
7. Compare the basicities of ammonia, methylamine, dimethylamine and trimethylamine using Argus Lab by comparing Mulliken charges and ESP maps.
8. Compare C-C bond lengths and bond order in ethane, ethene and ethyne using Argus Lab.
9. Determine enthalpy of isomerization of cis and trans-2-butene in Argus Lab.
10. Compare the HAH bond angles for the second row hydrides (BeH_2, CH_4, NH_3, H_2O) and compare with the results from qualitative MO theory.

References (Theory):

1. Levie, R. de. (2001), **How to use Excel in analytical chemistry and in general scientific data analysis**, Cambridge Univ. Press.
2. Lewars, E. (2003), **Computational Chemistry,** Kluwer academic Publisher.
3. Cramer, C.J.(2004), **Essentials of Computational Chemistry,** John Wiley & Sons.
4. Hinchcliffe, A. (1996), **Modelling Molecular Structures,** John Wiley & Sons.
5. Leach, A.R.(2001), **Molecular Modelling,** Prentice-Hall.

References (Practical):

1. Lewars, E. **(2003), Computational Chemistry,** Kluwer academic Publisher.

2. Cramer, C.J. **(2004), Essentials of Computational Chemistry,** John Wiley & Sons.
3. Hinchcliffe, A. **(1996), Modelling Molecular Structures,** John Wiley & Sons.

SKILL-ENHANCEMENT COURSES (SEC)

Course Code: Industrial Chemistry SEC-1
Course Title: Basic Principles and Laboratory Operations
Total Credits: 02 (Credits: Theory-00, Practical-02)
Total Lectures Theory-00, Practical-60

Objectives:

The course is aimed at introducing students to General Chemistry Laboratory safety measures and exposure them to the basic laboratory operations. Experiments are designed in such a way so that students can enjoy learning some of the basic chemistry exercises.

Learning Outcomes:

By the end of the course, the students will be:

- Familiar with the safe working practices in chemistry laboratory.
- Able to handle the apparatus, chemicals and equipment safely.
- Familiar with basic laboratory apparatus/equipments like burette, pipettes, conical flask, weighing bottle etc.
- Able to understand working protocols related to various methods like titration, determination of melting/boiling point, pH determination, etc.

Practical

(Credits: 02, Laboratory periods: 60)

Part A: Safety Measures

1. Design a detailed chart exhibiting Do's and Don't instructions for working in a chemistry laboratory.
2. Prepare the indicative MSDS (Material Safety Data Sheet) of any two chemicals as per Standard MSDS format.
3. Design a chart exhibiting Common Safety Symbols along with its description.
4. Write the common pathways by which Chemicals can enter the body.
5. Write the protocols for safe Disposal of any five Chemicals.
6. Write the guidelines in the Event of a Chemical Accident or Spill.
7. Write the guidelines on Fire Safety in the laboratory.

A student is required to do any three exercises from Part A.

Part-B

1. To do the calibration of thermometer
2. To determine the melting point of given solid
3. To determine the boiling point of given liquid.
4. Preparation of standard solutions of acid and base.
5. Estimation of sodium carbonate solution by titration with hydrochloric acid
6. To determine the concentration of Mg^{+2} ions by titration with standard EDTA solution.
7. To observe the variation in the pH of acid/base with dilution.
8. To determine the pH of various shampoo and soap solutions.
9. To determine the surface tension of 3% aqueous solution of NaCl by drop number/drop weight method.
10. To determine the coefficient of viscosity of dilute ethylene glycol solution.

References:

1. Skoog, D.A.; West, D.M. (2003), Fundamentals of Analytical Chemistry, Brooks/Cole.
2. Mendham, J.; Denney, R.C.; Barnes, J.D.; Thomas, M.J.K. (2007), Vogel's Quantitative Chemical Analysis, 6th Edition, Prentice Hall.
3. Furniss, B. S; Hannaford, A. J.; Smith, Peter W. G.; Tatchell, A. R; Vogel's Text Book of Practical Organic Chemistry, 5th Edition, Longman Scientific and Technical, Longman Group Ltd.
4. Alhuwalia, V.K.; Dhingra, S.; Gulati, A. (2005) College Practical Chemistry, University of Delhi Press.
5. https://edu.rsc.org/resources/practical/experiments

Teaching Learning Process:

- Hands-on laboratory exercises.
- Conventional teaching learning method.
- Engaging students in collaborative learning.

Assessment Methods:

- Continuous evaluation of laboratory work and record file.
- Oral assessment, quizzes.
- Presentation on good lab practices.
- Semester end University examination.

Keywords:

Safety measures, MSDS, Calibration, Standard solution.

Course Code: Industrial Chemistry SEC-2
Course Title: Computational Chemistry in the Industry
Total Credits: 02 (Credits: Theory-00, Practical-02)
Total Lectures: Theory-00, Practical-60

Objectives:

The objectives of this paper are to familiarize the student with software useful for chemistry-related problems and apply the software for understanding the chemistry of various molecules and materials. The theory behind these calculations is explained here to make the student familiar with computational techniques.

Learning Outcomes:

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

- Draw molecular geometries and record their geometrical parameters.
- Run energy minimization calculations for different types of molecules.
- Understand the bonding and structure of simple chemical compounds.
- Interpret the results of theoretical calculations, including visualization of different kinds of plots like HOMO-LUMO and electrostatic potential.
- Know about structure of various materials like carbon nanotubes, run calculations to study different interactions with other molecules/atoms/ions.
- Draw geometries of different unit cells and calculate their physical parameters.
- Predict IR, Raman & NMR spectra
- Apply computational chemistry to design drugs and materials.

Practical

(Credits: 02, Laboratory periods: 60)

1. Perform geometry optimization runs (Molecular Mechanics methods) on the following compounds and report their energies and physical parameters (bond lengths, bond angles, dihedral angles.
    a. Ethane
    b. Ethene
    c. Ethyne
2. Arrange the following compounds in order of their energies obtained after geometry optimization in Avogadro software. interpret the results.
    a. (i) Propan-1-ol (ii) Propan-2-ol
    b. (i) Butan-1-ol (ii) Butan-2-ol (iii) Butan-3-ol

3. Perform energy minimization of different sized nanotubes, record their geometrical parameters and interpret the impact of size of nanotubes on their energy and stability.
4. Study the interaction of carbon nanotubes with small organic molecules (e.g. ethanol, methanol, formaldehyde, acetone, etc.). Report necessary observations and interpret your results.
5. Draw structures of various Solid State Unit cells (simple cubic, FCC, BCC), minimize their geometries. Find out their Miller indices. Compare the results with the experimental values.
6. Draw Van der Waals surfaces, HOMO-LUMO and electrostatic potential maps for the following molecules and discuss the favourable sites for nucleophilic and electrophilic attacks on the basis of their electron density.

    a. Phenol
    b. Chlorobenzene
    c. Toluene
    d. Aniline
    e. Pyridine

7. Predict molecular spectra, such as IR, Raman and NMR spectra for the above organic compounds.
8. Predict the ADME (Absorption, Distribution, Metabolism, Excretion) properties of a series of compounds (Particular series of compounds eg. Alcohols, carbonyls, Phenols etc…).
9. Apply SAR (structure-activity relationships) for design of drugs and materials.
10. Compare the shapes of the molecules: 1-butanol, 2-butanol, 2-methyl-1-propanol, and 2-methyl-2-propanol. Show how the shapes affect the trend in boiling points:(118 ºC, 100 ºC, 108 ºC, 82 ºC, respectively) and note the dipole moment of each molecule.
11. Compute the resonance energy of benzene by comparison of its enthalpy of hydrogenation with that of cyclohexene.
12. Plot the electrostatic potential mapped on electron density for benzene and use it to predict the type of stacking in the crystal structure of benzene dimer.

Recommended Software:

Avogadro, Chemsketch, SwissADME, ARGUS Lab, other freeware, open-source software and online platforms.

References:

1. Lewars, E.G. (2016). An Outline of What Computational Chemistry Is All About. In: Computational Chemistry. Springer,Chem.
2. Cramer, C.J. (2013) Essentials of Computational Chemistry: Theories and Models, 2nd edition. Wiley.

Teaching Learning Process:

This course has major components of hands-on exercises. The teaching learning process will require conventional teaching along with hands on exercise on computers.

Assessment Methods:

Assignment on any relevant topics related to exercises. Semester end practical examination.

Keywords:

Geometry optimization, Materials, Structure, Bonding, Spectra

Course Code: Industrial Chemistry SEC-3
Course Title: Pharmaceutical Chemistry
Total Credits: 02 (Credits: Theory-00, Practical-02)
Total Lectures: Theory-00, Practical-60

Objectives:

The objective of this paper is to develop skills of drug synthesis of major drug classes including-analgesics, antipyretics, anti- inflammatory agents, antibacterial and antiseptic agents. This paper also focuses on Analytical techniques to determine the content of vitamin C, alcohol in drugs and supplements and analysis of organic drugs.

Learning Outcomes:

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

- Learn synthetic pathways of major drug classes.
- Understand the analytical techniques for determination of ethanol and some classes of vitamins.
- Know qualitative analysis of drugs

Practical:

1. Preparation of Ammonical silver nitrate, Brady's reagent, Benedict's solution,Biuret reagent, dimethylglyoxime, Fehling's solution, Jones reagent and Molisch's reagent.
2. Synthesis of ibuprofen and its characterizations.
3. Synthesis of hippuric acid (Benzoylation of glycine).
4. Preparation of magnesium bisilicate (Antacid).
5. Synthesis of 7 hydroxy 4 methyl coumarin (Blood thinner).
6. Preparation of chlorobutanol, a sedative drug.
7. Synthesis of Phenytoin, Antiepileptic drug.
8. Preparation of Boric acid, antiseptic powder.
9. Determination of alcohol contents in liquid drugs/galenical.
10. Determination of ascorbic acid in vitamin C tablets by iodometric.
11. Determination of content of Iron in supplement tablets.

References:

1. Kjonaas, R.A.; Williams, P.E.; Counce, D.A.; Crawley, L.R. Synthesis of Ibuprofen. J. Chem. Educ., 2011, 88 (6), pp 825–828 DOI: 10.1021/ed100892p.
2. Marsh, D.G.; Jacobs, D.L.; Veening, H. Analysis of commercial vitamin C tablets by iodometric and coulometric titrimetry. J. Chem. Educ., 1973, 50 (9), p 626. DOI: 10.1021/ed050p626
3. Dickson C.; Experiments in Pharmaceutical Chemistry 2nd Edition, ISBN 978113845714, June, 2017, CRC Press.

Teaching Learning Process:

The teaching learning process will involve the traditional chalk and black board method. Students are encouraged to participate actively in the laboratory through regular presentations on curriculum-based topics.

Assessment Methods:

Assessment will be done on the basis of regular viva and presentations as a part of internal assessment during the course as per the curriculum. End semester university examination will be held for practical. In practical, assessment will be done based on continuous evaluation, performance in the experiment on the date of examination and viva voce.

Keywords:

Drug synthesis, Alcohol analysis, Vitamin analysis, analysis of Organic drugs.

Course Code: Industrial Chemistry SEC-4
Course Title: Pesticide Chemistry
Total Credits: 02 (Credits: Theory-00, Practical-02)
Total Lectures: Theory-00, Practical-60

Objectives:

Pesticide plays an important role in controlling quantity as well quality of the economic crops by protecting them from the various pests. They are used for prevention of much spoilage of stored foods and also used for prevention of certain diseases, which conserves health and has saved the lives of millions of people and domestic animals. Keeping the importance of pesticides in mind this course is aimed to introduce synthesis and application of pesticides.

Learning Outcomes:

- Students will be able to learn about the basic role of pesticide in everyday life, various ingredients and their role in controlling the pest.
- Students can also educate the farmers/gardeners to choose the appropriate pesticides for their crop production.

Practical

(Credits: 02, Laboratory periods: 60)

1. To carry out market survey of potent pesticides with details as follows:
   a. Name of pesticide
   b. Chemical name, class and structure of pesticide
   c. Type of formulation available and Manufacturer's name
   d. Useful information on label of packaging regarding: Toxicity, LD50 ("Lethal Dose, 50%"), Side effects and Antidotes.
2. To carry out market survey of potent botanical pesticides with details as follows:
   a. Botanical name and family
   b. Chemical name (active ingredient) and structure of active ingredient
   c. Type of formulation available and Manufacturer's name
   d. Useful information on label of packaging regarding: Toxicity, LD50 ("Lethal Dose, 50%"), Side effects and Antidotes.
3. Preparation of simple Organochlorine pesticides (DDT).
4. To calculate acidity in a given sample of pesticide formulations as per BIS specifications.
5. To calculate active ingredients in a given sample of pesticide formulations as per BIS specifications.
6. Preparation of Neem based botanical pesticides.
7. To calculate alkalinity in a given sample of pesticide formulations as per BIS specifications.
8. Preparation of 2,4-D-(2,4-dichlorophenoxyacetic acid).

References:

1. Perry, A.S.; Yamamoto, I.; Ishaaya, I.; Perry, R. Y. (1998), Insecticides in Agriculture and Environment, Springer-Verlag Berlin Heidelberg.
2. Kuhr, R. J. Derough, H.W. (1976), Carbamate Insecticides: Chemistry, Biochemistry and Toxicology, CRC Press, USA.

Teaching Learning Process:

- Conventional chalk and board teaching with power point presentation, you tube videos.
- Presentations from students on relevant topics.

Assessment Methods:

End semester practical examination.

Keywords:

Pesticide formulations, Antifeedants, Controlled release pesticide formulation

Course Code: Industrial Chemistry SEC-5
Course Title: Fuel Chemistry
Total Credits: 02 (Credits: Theory-00, Practical-02)
Total Lectures: Theory-00, Practical-60

Objectives:

The course aims to provide students with a basic scientific and technical understanding of various parameters and properties of hydrocarbon fuels. It also includes synthesis of emerging alternative & renewable fuels in laboratory. This will enable them to be industry ready to contribute effectively in the field of fuel industry especially coal and petroleum.

Learning Outcomes:

- The course covers both conventional petroleum-based fuels and alternative & renewable fuels.
- The students will learn the chemistry that underpins petroleum fuel technology and will know how differences in chemical composition affect properties of fuels and their usage in different applications.
- The course will also cover fuel product specifications, various test methods used to qualify different types of fuels. Students will also gain knowledge about the characterization methods of different petroleum products by simple spectroscopic methods.

Practical

(Credits: 02, Laboratory periods: 60)

1. To determine the moisture content of different fuels.
2. To prepare biodiesel from vegetable oil.
3. To determine the aniline point of different oils.
4. Characterization of different petroleum products using UV and IR.
5. To determine the iodine value of a mineral oil.
6. To compare the viscosity of biodiesel and cooking oil.
7. To determine acid value in the given oil sample.
8. To determine the density of the given fuel sample.

9. To determine the carbon content and sulphur content in the fuel sample.
10. To determine the nitrogen content in the fuel sample.

References:

1. Verma ,S. and Goyal ,R.K.(2021) Fuel Chemistry Theory and Practical,1st Edition Aaryush Publications, Muzaffarnagar (U.P.)
2. Stocchi, E.(1990),**Industrial Chemistry**, Vol -I, Ellis Horwood Ltd. UK.
3. Sharma, R.K.; Sidhwani,I.T.; Chaudhari ,M.K.(2013),Green Chemistry Experiments: A monograph, I.K. International Publishing House Pvt Ltd. New Delhi.

Teaching Learning Process:

The teaching learning process will require conventional explanation of theory of practical and Demonstration of few practical exercises.

Assessment Methods:

- Continuous evaluation
- Performance in the experiment and viva voce during examination.

Keywords:

Biodiesel, fuels

Course Code: Chemistry SEC-6
Course Title: Instrumental Methods of Analysis
Total Credits: 02 (Credits: Theory-00, Practical-02)
Total Lectures: Theory-00, Practical-60

Objective:

The Objective of this course is to make students aware about the following concepts:

- Spectroscopic methods of analysis
- Principles of UV and Visible spectrophotometry and its applications
- Various components of UV and Visible spectrophotometry
- Single and double beam instruments
- ^{1}H NMR instrumentation and its applications

Learning Outcomes:

By the end of this course, students should be able to understand about:

- The different types of spectroscopic methods of analysis.
- The instrumentation and the applications of the UV- Visible, Atomic, IR, ^{1}H NMR spectrometry and Thermogravimetric analysis

Practical

(Credits: 02, Laboratory periods: 60)

1. Basic principle of Lambert-Beer's law and verification of Lambert-Beer's law using UV-vis spectrophotometer for $CuSO_4$ solution.
2. Determination of the pKa of an indicator (phenolphthalein) using spectrophotometer.
3. To determine isoelectric pH of a protein.
4. Isolation of DNA from onion and its characterization using UV spectroscopy.
5. Basic principle of IR-spectroscopy and identification of functional group of simple organic compounds using IR-spectroscopy (IR spectra should be provided).
6. Basic principle of ^{1}H NMR spectroscopy and identification of structure of simple organic compounds using ^{1}H NMR spectroscopy (NMR spectra should be provided).
7. Synthesis of acetanilide and report the yield.
8. Characterization of acetanilide by melting point and discussion of its ^{1}H NMR and IR spectra. (spectra should be provided).
9. Synthesis of *m*-dinitro benzene and report the yield.
10. Characterization of *m*-dinitro benzene by melting point and discussion of its ^{1}H NMR and IR spectroscopy (spectra should be provided).
11. Importance and uses of Thermogravimetric analysis and calculation of weight loss of Zinc acetate and dolomite. (TGA pattern of Zinc acetate and dolomite should be provided).
12. Basic principles of MASS Spectroscopy and identification of structure of simple organic compounds using MASS spectroscopy (MASS spectra should be provided).

References:

1. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C.(1989),**Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.
2. Kemp, W. (1991), **Organic Spectroscopy**, PalgraveMacmillan.
3. Banwell, C.N. (2006), **Fundamentals of Molecular Spectroscopy**, Tata McGraw-Hill Education.
4. Smith, B.C. (1998), **Infrared Spectral Interpretations: A Systematic Approach**, CRC Press.
5. Joseph D. Menczel, R. Bruce Prime (2008), **Thermal Analysis of Polymers: Fundamentals and Applications,** John Wiley & Sons, Inc

Teaching Learning Process

- Conventional chalk and board teaching,
- Group discussions
- Lab demonstrations and experiments after completion of theory part
- Powerpoint presentation

Assessment Methods

- Presentations by individual student
- Class tests
- Laboratory tests
- Written assignment(s)
- End semester University practical examination

Keywords:

UV-Visible Spectroscopic Methods, IR-Spectrophotometry, ^{1}H NMR Spectroscopy, TGA

Course Code: Chemistry SEC-7
Course Title: IT Skills &Data Analysis
Total Credits: 04 (Credits: Theory-00, Practical-02)
Total Lectures: Theory- 00, Practical-60

Objectives:

The objective of this course is to introduce the basic computer skills to the students that will help them in solving chemistry problems. The students are introduced to recording of the experimental data, errors and data reduction. The paper also acquaints the students with different software for data tabulation, calculation, graph plotting, data analysis, drawing of structures and document preparation.

Learning Outcomes:

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

- Become familiar with the use of computers
- Become familiar with handling data
- Use software for tabulating data, plotting graphs and charts, carry out statistical analysis of the data.
- Solve chemistry problems and simulate graphs.

- Prepare documents that will incorporate chemical structure, chemical equations, and mathematical expressions from chemistry.
- Become familiar with software for drawing and visualizing chemical structures.

Practical

(Credits: 02, Laboratory periods: 60)

1. **Introductory writing activities**:
   (i) Introduction to word processor
   (ii) Incorporating chemical structures, chemical equations, expressions from chemistry (e.g. Maxwell-Boltzmann distribution law, Bragg's law, van der Waals equation, etc.) into word processing documents.
   (iii) Preparing a word processing document having tables, chemical structures and chemical equations

2. **Measurements in chemistry:**
   (i) Decimal places, significant figures, combining quantities.
   (ii) Recording laboratory data and data treatment.
   (iii) Uncertainty in experimental techniques: Displaying uncertainties
   (iv) Experimental errors. Types of errors, accuracy and precision

3. **Statistical treatment:**
   (i) Calculations of mean, variance, standard deviation, relative error.
   (ii) Student t distribution, rejection of discordant data, Q-test
   (iii) Data reduction- Numerical data reduction, graphical data reduction.
   (iv) Propagation of errors: Combination of errors, combination of random and systematic errors
   (v) Curve fitting: the method of least squares (regression).

4. **Handling numeric data**: Spreadsheet software (Excel/Libre Office Calc), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs.

5. **Simple calculations using a spreadsheet**
   (i) linear regression rate constants from concentration- time data
   (ii) molar extinction coefficients from absorbance data
   (iii) numerical differentiation (e.g. handling data from potentiometric and pH metric titrations, pKa of weak acid)
   (iv) integration (e.g. entropy/enthalpy change from heat capacity data).
   (v) Statistical analysis using Excel functions LINEST and Least Squares.
   (vi) Statistical significance testing: The t test. The Ftest.

6. **Plotting graphs using a spreadsheet**
   (i) Planck's distribution law

(ii) Radial distribution curves for hydrogenic orbitals
(iii) Maxwell-Boltzmann distribution curves as function of temperature and molecular weight)
(iv) Ideal gas isotherms
(v) Pressure-volume curves of van der Waals gas (van der Waals isotherms)
(vi) Data from phase equilibria studies.
(vii) Graphical solution of equations.
(viii) Simulation of pH metric titration curves.

7. **Presentation**: Preparing a presentation on a chemistry topic that includes text, tables, graphs and equations.
8. **Chemistry software**:

(i) Introduction to any one of the different software available for drawing chemical structures (Proprietary and Open-source) like ACD Chemsketch and 3-D viewer, ChemDraw.
(ii) Carrying out simple calculations on anyone of the following software: ArgusLab, Pymol, Avogadro, Molview, MarvinSketch
(iii) Draw structures of various compounds (aliphatic, aromatic, heterocyclic with different functional groups) using software. Save the structures in various file formats. Incorporate the structures in word document.
(iv) Use the software to find IUPAC name and SMILES notation for the structures.

Additional exercise

Use of Origin, MATLAB and GNUPLOTS for plotting simple graphs

References:

1. Steiner, E.(2008),The Chemical Maths Book Oxford University Press.
2. Yates, P.(2007),Chemical calculations, CRC Press.
3. Harris,D.C.(2007),Quantitative Chemical Analysis. Freeman, Chapters 3-5.
4. Levie, R. de., How to use Excel in analytical chemistry and in general scientific data analysis, Cambridge Univ. Press.
5. E. Joseph Billo, Excel for chemists, A comprehensive guide, 3rd Ed., Wiley

Teaching Learning Process:

- Hands on exercise on computers
- Handling of experimental data and data reduction using different available software.

Assessment Methods:

- Continuous evaluation of laboratory work and record file.
- Oral assessment, quizzes.
- Presentation
- Semester end University examination.

Keywords:

Uncertainty in measurements, least square, spreadsheet, curve fitting method, Spreadsheet, charts, tables, graphs, LINEST, t-test, F-test, chemistry software

Course Code: Chemistry SEC-8
Course Title: Green Methods in Chemistry
Total Credits: 04 (Credits: Theory-00, Practical-02)
Total Lectures: Theory- 00, Practical-60

Objectives:

This course is designed to make the students aware of chemistry that is good for human health and the environment. By gaining thorough knowledge of the green chemistry principles, students would be able to think of suitable remediation technologies for the cleaning up of hazardous substances. Also, students would be able to design, develop and run chemical processes in a sustainable way.

Learning Outcomes:

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

- Think to design and develop materials/ processes that reduce the use and generation of hazardous substances in industry.
- Know how injudicious use of chemicals can have an adverse/potentially damaging effect on humans and the environment.
- Get ideas of innovative approaches to environmental and societal challenges.
- Critically analyse the existing traditional chemical pathways/processes and creatively think about bringing environmentally benign reformations in these protocols.
- Convert biomass into valuable chemicals through green technologies.

Practical

(Credits: 02, Laboratory periods: 60)

1. Definition and Importance of green chemistry. Introduction to the prevention of Waste/ by products and waste/ pollution prevention hierarchy. Provide the scheme for the

traditional as well as green method for the synthesis of ibuprofen and ask them to calculate and compare the amount of waste generated in both the processes.

2. Principle and calculation of atom economy. Use of molecular model kit to simulate the reaction to investigate how the atom economy can illustrate Green Chemistry.
3. Preparation of propene by two methods can be studied
   a. Hoffman elimination
   b. Dehydration of propanol

The other types of reactions, like addition, elimination, substitution and rearrangement should also be studied for the calculation of atom economy

4. Prevention/ minimization of hazardous/ toxic products reducing toxicity. Risk = (function) hazard x exposure.
   a. Nitration of salicylic acid using green method $Ca(NO_3)_2$
   b. Preparation and characterization of nanoparticles of gold using tea leaves/silver nanoparticles using plant extracts.
   c. Preparation of dibenzalacetone by cross aldol condensation reaction using base catalysed green method
   d. Acetylation of primary aromatic amine using the green method.

5. Use of Green solvents and comparison of greenness of solvents:
   a. Explain about supercritical fluids with special reference to carbon dioxide. Extraction of D-limonene from orange peel using liquid CO_2 prepared from dry ice
   b. Introduction to water as a solvent for chemical reactions. preparation of Manganese (III) acetylacetonate using green method
   c. Advantages and application of solventless processes in organic reactions.
      i. Benzil- Benzilic acid rearrangement in solid State under solvent-free Condition.
      ii. Mechanochemical solvent free, solid–solid synthesis of azomethine using p-toluidine and o-vanillin/p-vanillin
6. Energy requirements for reactions – alternative sources of energy: use of microwaves and photochemical energy.
   a. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.
   b. Microwave assisted ammonium Formate-mediated Knoevenagel reaction: p-anisaldehyde, ethyl cyanoacetate, ammonium formate.
7. Selection of renewable starting material rather than depleting, Illustrate with few examples such as biodiesel and polymers from renewable resources (such as green plastic).

   Preparation of biodiesel from waste cooking oil and characterization.

8. Importance of using catalytic reagents in preference to stoichiometric reagents; catalysis and green chemistry, comparison of heterogeneous and homogeneous catalysis, biocatalysis, asymmetric catalysis and photocatalysis.
   a. Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide
   b. Rearrangement of diazoaminobenzene to *p*-aminoazobenzene using K10 montmorillonite clay
9. Students should be asked to prepare a presentation/project based on any of the following topics:

- Bhopal Gas Tragedy and safer route to carbaryl synthesis
- Flixiborough accident and safer route to cyclohexanol
- Use of Surfactants for SC-CO_2 for precision cleaning and dry cleaning of garments replacing PERC.
- A brief study of Green Chemistry Challenge Awards (Introduction, award categories and study about five last recent awards
- Healthier Fats and oils by Green Chemistry: Enzymatic Interesterification for production of No Trans-Fats and Oils.
- Synthesis of anti-tuberculosis drug Paramycin from waste water stream
- Synthesis of vitamin D_3 using photochemical energy
- Greener Manufacturing of Sitagliptin Enabled by an Evolved Transaminase
- Microwave assisted solvent free synthesis of aspirin
- Synthesis of 6-Aminopenicillanic Acid (6-APA) from penicillin G using biocatalyst.

References (Theory):

1. Anastas, P.T., Warner, J.C. (2014), **Green Chemistry, Theory and Practice**, Oxford University Press.
2. Lancaster, M. (2016), **Green Chemistry: An Introductory Text**, 3rd Edn., RSC Publishing.
3. Cann, M.C., Connely, M. E. (2000), **Real-World cases in Green Chemistry**, American Chemical Society, Washington.
2. Matlack, A.S. (2010), **Introduction to Green Chemistry**, 2nd Edn., CRC Press.
3. Alhuwalia, V.K.; Kidwai, M.R. (2012), **New Trends in Green chemistry**, Kluwer Academic Publishers, Springer.
4. Sidhwani, I.T; Sharma, R.K. (2020), **An Introductory Text on Green Chemistry**, Wiley India Pvt Ltd.
5. Etzkorn, F. A . (2019), **Green Chemistry: Principles and Case Studies**, Royal Society of Chemistry.

References (Practical):

1. Kirchoff, M., Ryan, M.A. (2002), **Greener approaches to undergraduate chemistry experiment**, American Chemical Society, Washington DC.
2. Sharma, R.K., Sidhwani, I.T., Chaudhari, M.K. (2013), **Green Chemistry Experiments: A monograph**, I.K. International Publishing House Pvt Ltd. New Delhi.
3. Pavia, D.L., Lamponam, G.H., Kriz, G.S.W. (2006), **Introduction to organic Laboratory Technique- A Microscale approach**, 4th Edition, Brooks-Cole Laboratory Series for Organic chemistry.
4. Sidhwani, I.T. ; Saini, G.; Chowdhury, S. **Wealth from Waste: A green method to produce biodiesel from waste cooking oil and generation of useful products from waste further generated**. University of Delhi, Journal of Undergraduate Research and Innovation, Volume 1, Issue 1, February 2015, ISSN: 2395-2334.

5. Sharma, R. K., Gulati, S., Mehta, S. (2012), **Preparation of Gold Nanoparticles Using Tea: A Green Chemistry Experiment,** Journal of Chemical Education, 89 (10), 1316-1318.

Teaching Learning Process:

- Interactive Classes
- Experiential Learning
- Powerpoint presentations
- Visit to pharmaceutical industries and green chemistry laboratories
- Interesting and inspiring short videos and movies in green chemistry
- Activities related to green chemistry would be conducted in classrooms that would enhance the critical thinking of students and help them redesign experiments in a greener way

Assessment Methods:

- Conventional Class tests
- Open Book tests
- Graded Assignments
- Online tests -objective or subjective
- Quizzes
- Presentation on a topic in front of the classmates
- Performing a new experiment based on the concepts learned in the course.

Keywords:

Waste production, Problem and prevention; Emerging green technologies, Green Catalysts, Green Solvents, Green Energy, Photo-oxidation technologies, Industry-academia collaboration, Circular economy.

Course Code: Chemistry SEC-9
Course Title: Chemistry of Cosmetics and Toiletries
Total Credits: 04 (Credits: Theory-00, Practical-02)
Total Lectures: Theory- 00, Practical-60

Objectives:

This course is designed for introducing chemistry students to the world of cosmetics and toiletries. Cosmetics play an important role in our everyday lives as they make an individual's appearance more attractive & boost one's self-esteem and confidence. Keeping in view the

tremendous potential which the cosmetic industry has today around the globe, this has been designed to impart the theoretical and practical knowledge on basic principles of cosmetic chemistry, manufacture, formulation of various cosmetic products.

Learning outcomes:

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

- understand the basic principles of various cosmetic formulations
- know different ingredients and their roles in cosmetic products.
- appreciate the role of herbal ingredients in various cosmetic products
- learn the use of safe, economic and body-friendly cosmetics
- prepare new innovative formulations to achieve the aimed efficacies and effects

Practical

(Credits: 02, Laboratory periods: 60)

1. Definition, History and Classification of cosmetic & cosmeceutical products.
2. **Skin Care Products**: Basic structure and function of skin. Principles of formulation of skin care products. Role of herbs in Skin Care: Aloe and turmeric. General Ingredients and preparation of
    a Preparation of Talcum powder (chemical based and herbal)
    b Face cream/ vanishing cream/ cold cream/ suntan cream/lather shaving cream (any two)
    c Body lotion
3. **Hair Care Products**: Basic structure of hair and classification of hair. Principles of formulation of Hair care products. Types of shampoo and conditioners. Role of herbs in Hair care: Henna and amla. Role of primary and secondary surfactants in shampoo. General Ingredients and preparation of
    a. Shampoo (chemical based and herbal)
    b. Conditioners
4. **Hand Care and hygiene Products**: Principles of formulation of hand sanitizers and hand wash. General Ingredients and preparation of:
    a. Hand wash
    b. Hand sanitizer
5. **Nail preparation**: Structure of nail, Nail lacquers, Nail polish remover. General Ingredients and preparation of:
    Nail polish and nail polish remover
6. **Personal hygiene products**: Total fatty matter, alkali content and pH of soaps. Bathing soap and toilet soap. Antiperspirants and deodorants. General Ingredients and preparation of
    a. Soaps
    b. Cream Soaps

7. **Oral hygiene products**: **Common problem associated with teeth and gums. Role of herbs in oral care: Neem and clove.** Principles of formulation of Oral hygiene products. Flavours and essential oils. General Ingredients and preparation of
    a. Tooth powder (chemical based and herbal)
    b. Tooth paste

References:

1. Barel, A.O.; Paye, M.; Maibach, H.I.(2014), **Handbook of Cosmetic Science and Technology,** CRC Press.
2. Garud, A.; Sharma, P.K.; Garud, N. (2012), **Text Book of Cosmetics**, Pragati Prakashan.
3. Gupta, P.K.; Gupta, S.K. (2011), **Pharmaceutics and Cosmetics**, Pragati Prakashan
4. Butler, H. (2000), **Poucher's Perfumes, Cosmetic and Soap**, Springer

Additional Resources:

i. Flick, E.W. (1990), **Cosmetic and toiletry formulations,** Noyes Publications / William Andrew Publishing.
ii. Natural Ingredients for Cosmetics; EU Survey 2005
iii. Formulation Guide for cosmetics; The Nisshin OilliO Group, Ltd.
iv. Functional Ingredients & Formulated Products for Cosmetics & Pharmaceuticals; NOF Corporation

Teaching Learning Process:

- Conventional chalk and board teaching with powerpoint presentation, youtube videos etc.
- paper/powerpoint presentations from students on relevant topics.
- Hand-on practice on various formulations of cosmetic products
- Theory coupled with preparation of cosmetic products in the lab.

Assessment Methods:

- Internal assessment through continuous evaluation.
- paper/presentations from students on relevant topics.
- End semester practical examination coupled with written viva.

Keywords:

Cosmetics, Ingredients, Formulations, soap, cream, shampoo, wash, sanitizer etc.

Course Code: Chemistry SEC-10
Course Title: Materials Characterization Techniques
Total Credits: 04 (Credits: Theory-01, Practical-01)
Total Lectures: Theory- 15, Practical-30

Objectives:

This course is aimed at providing and understanding on (a) the fundamental principles of some important instrumental measurements, (b) applications of these principles to specific chemical measurements/investigations with exercises on the analysis of results of measurements on these modern instrumentation techniques solve real analytical problems.

Learning Outcomes:

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

- Achieve sufficient knowledge and understanding of discussed material characterization techniques and the applications of these techniques for analysis of real analytical problems.
- Achieve understanding on carrying out the analysis of results or outcome of the measurements discussed modern instrumentation techniques based on the provided set of data and results of investigations.

Unit 1: Compositional and Structural Characterization — Lectures: 04

General properties of electromagnetic radiation, qualitative and quantitative aspects of spectrochemical measurements. Fundamental theory, basic operations, and applications of X-ray photoelectron spectroscopy (XPS) to examine the elemental composition and Energy dispersive X-ray analysis (EDAX)

Unit 2: Advanced Microscopy Techniques — Lectures:04

Fundamental and application of Atomic force microscopy (AFM) and determination of surface roughness and thickness, Overview of Scanning tunneling microscopy (STM) and its three-dimensional image formation, Principle, instrumentation, and applications of Transmission electron microscopy (TEM) and Scanning electron microscopy (SEM).

Unit 3: Thermal Characterization — Lectures: 03

Introduction to Differential scanning calorimetry (DSC) and evaluation of the percentage of crystallinity with a focus on different transition states, Principle, instrumentation, and applications of Differential thermal analysis (DTA) and Thermogravimetric analysis (TGA).

Unit 4: Optical and Electrochemical Characterization Lectures: 04

Principle, instrumentation, and applications of Photo-luminescence spectroscopy and Electrochemical Impedance Spectroscopy (Charge-discharge cyclic voltammetry-Nyquist and Bode plot)

Practical

(Credits: 01, Laboratory periods: 30)

1. Synthesis of ZnO nanoparticles, investigation particle size and surface investigations through following techniques (image formation of the plane and fractured surfaces):
   a. Identification of elemental composition using EDAX/EDS curves.
   b. surface morphology through SEM micrographs (image formation of the plane and fractured surfaces)
   c. Specimen preparation, imaging modes, evaluation of particle size from TEM analysis, and discussion on SAED pattern.
2. Preparation of Ag nanoparticles using sodium borohydride and performing following investigations:
   a. Quantitative analysis and interpretation of surface examination using STM curves.
   b. To analyze absorbance and emission spectrum by Photoluminescence spectra to identify the variety of material parameters.
   c. Diffraction and image formation using AFM technique. Interpretation of topographical 2D and 3D curves and evaluation of average size and thickness.

3. Preparation of TiO_2 nanoparticles and evaluation of thermal analysis curves.
   a. Interpretation of TGA thermogram, its different stages, and evaluation of residual content.
   b. Detection of phase transition, evaluation, and interpretation of DSC curves.
   c. Investigations of the reduction and oxidation processes of molecular species using cyclic voltametry (CV) curves.
4. Preparation of Iron oxide nanoparticles and evaluation of the following parameters:
   a. Quantitative analysis and interpretation of surface examination using STM curves.
   b. Understanding and interpretation of results: The intensity, position of peaks, oxidation state, and evaluation of binding energy using XPS spectra.
   c. To understand impedance spectra, Nyquist's plot using Electrochemical measurements.

References (Theory):

1. Skoog, D. A.; Holler, F. J.; Nieman, T. A. **Principles of Instrumental Analysis**, 5th Ed., Thomson Brooks/Cole, 1998.
2. Strobel, H. A.; Heineman, W. R. **Chemical Instrumentation: A Systematic Approach**, 3rd Ed., John Wiley and Sons, 1989.
3. Willard, H. H.; Merritt, Jr., L. L.; Dean, J. A.; Settle, Jr., F. A. **Instrumental Methods of Analysis**, 7 th Ed., Wadsworth, 1988.

4. Rubinson, K. A.; Rubinson, J. F**. Contemporary Instrumental Analysis**, 1st Ed., Prentice Hall, 2000.
5. Rouessac, F.; Rouessac, A. **Chemical Analysis: Modern Instrumentation Methods and Techniques**, 4th Ed., John Wiley and Sons, 1998.
6. Kaur, H. **Instrumental Methods of Chemical Analysis**, 1st Ed., Pragati Prakashan, 2001. Ewing, G. W. Instrumental Methods of Chemical Analysis, 5th Ed., Mcgraw-Hill, 1985.

References (Practical):

1. Settle, F. A. **Handbook of Instrumental Techniques for Analytical Chemistry,** 1st Ed., Prentice Hall, 1997.

Teaching Learning Process:

- Teaching-Learning process is largely student-focused
- Blend of conventional blackboard teaching and modern teaching-learning tools
- Focus on real-life applications of concepts
- Problem solving and quizzes for enhanced understanding of the concepts
- Engaging students in collaborative learning.
- Pre-lab learning of the theoretical concept of the experiment.
- Performing the experiment, recording the data, and calculating the result.
- Interpreting the result.
- Discussing the sources of error.

Assessment Methods:

- Presentations by Individual Student/ Group of Students
- Class Tests at Periodic Intervals.
- Written assignment(s)
- Continuous evaluation of laboratory work and records
- End semester University Theory and practical Examination

Keywords:

Spectroscopic Techniques, Thermal Analysis, Structural Characterization, Electrochemical Analysis

Course Code: Chemistry SEC-11
Course Title: Chemical Aspects of Forensic Science
Total Credits: 04 (Credits: Theory-01, Practical-01)
Total Lectures: Theory- 15, Practical-30

Objectives:

Forensic science is the branch of science which has been drawn from chemistry, physics, biology to apply in criminal investigations governed by the legal standards of admissible evidence and criminal procedure. Forensic science is important because it helps to establish the guilt or innocence of potential suspects. The objective of this course is to introduce students to this fascinating branch of science and familiarize them with important concepts like fingerprints, explosives/arson, drugs and their detection

Learning Outcomes:

- After the completion of this course the student will be familiar with
- The concepts of latent fingerprints
- Various methods of detection of latent fingerprints
- Explosive analysis in forensic science
- Collection and preservation of evidence from crime scene etc

Unit 1: History of Development of Forensic Science in India Lectures: 02

Definitions, Scope and Need of forensic science, Ethics in forensic science, History of forensic science, Basic principles of forensic science, Organizational structure of forensic science laboratories, Different branches in forensic science

Unit 2: Fingerprints Lectures: 05

Definition, History of fingerprint identification, Fingerprint as forensic evidence, Visible Finger marks, Latent Finger marks, ten-digit classification, Methods of Development of latent fingerprints using conventional methods–Powdering (Black and grey, fluorescent and magnetic), Methods of development of latent fingerprint using chemical method (iodine fuming, silver nitrate, Ninhydrin, Vacuum metal deposition), Automated Fingerprint identification system (AFIS), Poroscopy and Edgescopy.

Unit 3: Forensic Chemistry Lectures: 08

Scope & significance of Forensic Chemistry, Types of cases/exhibits received for analysis. Trap Cases: Collection, and Preliminary analysis of evidence in trap cases.

Alcoholic Beverages: Types of alcohols, country made liquor, illicit liquor, denatured spirits, Indian made foreign alcoholic and non-alcoholic beverages.

Dyes: Scope & Significance of dyes in crime investigation, analysis of ink by TLC and UV visible spectrophotometry. Petroleum products and their adulterations: Chemical composition of various fractions of Petroleum Products, Analysis of petrol, kerosene, diesel.

Fire/Arson and Explosives Fire: Introduction to Fire & Arson, origin of fire, Chemistry of Fire, Fire tetrahedron, Firefighting operations, preservation of fire scene, collection of evidences, Seat of fire, cause of fire, motives, Analysis of fire debris, Case studies related to fire and Arson. Explosive and Explosion: Scope & significance of explosive analysis in forensic science, Types of explosives, deflagration and detonation, explosive trains, collection, preservation and forwarding of exhibits, preliminary analysis of explosives. Dos and Don'ts. Case studies related to explosives.

Drugs of abuse: Classification, including designer drugs. Ill effects of drugs of abuse, Preliminary and confirmatory tests.

Practical

(Credits: 01, Laboratory periods: 30)

1. Development of fingerprint through conventional powder method.
2. Development of fingerprint through chemical methods.
3. To check the alcohol presence in different liquor.
4. Phenolphatelin test for trap cases.
5. Identification of Handwriting Individual Characteristics.
6. Study of Disguise in handwriting.
7. TLC of amino acids

References:

1. Saferstein, R. (1990) Criminalistics, Prentice Hall, New York.
2. Basic Principles of Forensic Chemistry by JaVed I. Khan • Thomas J. Kennedy Donnell R. Christian, Jr.
3. Fundamentals of FINGERPRINT ANALYSIS Hillary Moses Daluz
4. Clarke's Analysis of Drugs and Poisons 3rd Ed.

Teaching Learning Process:

- Conventional chalk and board teaching,
- Class interactions and discussions
- Power point presentation on important topics.

Assessment Methods:

- Presentations by Individual Student/ Group of Students
- Class Tests at Periodic Intervals.
- Written assignment(s)
- End semester University Theory and practical Examination

Keywords:

Latent fingerprints, Arson, explosives, Fire tetrahedron

GENERIC ELECTIVES COURSES (GE)

Note: These are suggested GE courses. A student may however choose any GE from the central pool

Course Code: Chemistry GE-1
Course Title: States of Matter
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-30

Objectives:

The students will learn about the properties of ideal and real gases deviation from ideal behaviour, properties of liquid, types of solids with details about crystal structure. The student will also learn about the reaction rate, order, activation energy and theories of reaction rates.

Learning Outcomes:

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

- Derive ideal gas law from kinetic theory of gases and explain why the real gases deviate from ideal
- behaviour.
- Explain Maxwell-Boltzmann distribution, critical constants and viscosity of gases.
- Explain the properties of liquids especially surface tension and viscosity.
- Explain symmetry elements, crystal structure specially NaCl, KCl and CsCl
- Define rate of reactions and the factors that affect the rates of reaction.
- Understand the concept of rate laws e.g., order, molecularity, half-life and their determination
- Learn about various theories of reaction rates and how these account for experimental observations.

Unit 1: Kinetic Theory of Gases — Lectures: 13

Postulates of kinetic theory of gases and derivation of the kinetic gas equation, deviation of real gases from ideal behaviour, compressibility factor, causes of deviation, van der Waals equation of state for real gases. Boyle temperature (derivation not required), critical phenomena, critical constants and their calculation from van der Waals equation, Andrews

isotherms of CO_2, Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance. Temperature dependence of these distributions, most probable, average and root mean square velocities (no derivation), collision cross section, collision number, collision frequency, collision diameter and mean free path of molecules, viscosity of gases and effect of temperature and pressure on coefficient of viscosity (qualitative treatment only).

Unit 2: Liquids State — Lectures: 5

Surface tension and its determination using stalagmometer, Viscosity of a liquid and determination of coefficient of viscosity using Ostwald viscometer, effect of temperature on surface tension and coefficient of viscosity of a liquid (qualitative treatment only). Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents.

Unit 3: Solid State — Lectures: 12

Forms of solids, symmetry elements, unit cells, crystal systems, Bravais lattice types and identification of lattice planes. Laws of crystallography - law of constancy of interfacial angles. Law of rational indices, Miller indices. X–ray diffraction by crystals, Bragg's law and powder XRD. Powder diffraction patterns of NaCl, CsCl and KCl (qualitative treatment only), defects in crystals. Glasses and liquid crystals.

Practical

(Credits: 02, Laboratory periods: 60)

1. Surface tension measurement (use of organic solvents excluded): Determination of the surface tension of a liquid or a dilute solution using a stalagmometer.

2. Viscosity measurement (use of organic solvents excluded):
   a. Determination of the relative and absolute viscosity of a liquid or dilute solution using an Ostwald viscometer.
   b. Study of the variation of viscosity of an aqueous solution with concentration of solute.

3. Solid State: Powder XRD
   a. Differentiate and classify the given set of the diffraction pattern as crystalline materials or amorphous (Glass) substance.
   b. Carry out analysis of a given set of powder XRD and determine the type of the cubic crystal structure
   c. Determination of approximate crystal size from a given set of powder XRD

References (Theory):

3. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Shriver and Atkin's Inorganic Chemistry**, Oxford.
4. Miessler, G. L.; Tarr, D.A. (2014), **Inorganic Chemistry**, Pearson.
5. Castellan, G. W. (2004), **Physical Chemistry**, Narosa.

6. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol.1, 6th Edition, McGraw Hill Education.
5. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol.5, 3rd Edition, McGraw Hill Education.

References (Practical):

1. Khosla, B.D.; Garg, V.C., Gulati, A. (2015), **Senior Practical Physical Chemistry**, R. Chand & Co.

Teaching Learning Process:

- Teaching Learning Process for the course is visualized as largely student-focused.
- Transaction through an intelligent mix of conventional and modern methods.
- Engaging students in cooperative learning.
- Learning through quiz design.
- Problem solving to enhance comprehension.

Assessment Methods:

- Regular class test, presentations and assignments as a part of internal assessment
- End semester university examination for both theory and practical.
- Practical assessment based on continuous evaluation, performance in the experiment during examination and viva voce.

Keywords:

Ideal/real gases, Surface tension, Viscosity, Crystal systems, Powder-XRD.

Course Code: Chemistry GE-2
Course Title: Energy and the Environment
Total Credits: 04 (Credits: Theory-03, Practical-01)
Total Lectures: Theory- 45, Practical-30

Objectives:

The objective of this paper is to develop basic understanding of energy, issues related to energy, importance of energy in terms of economy, health and the environment. To understand different sources of energies, renewable and non-renewable sources of energy. To understand the importance of green fuels. This course will help the students to understand the adverse effect of pollution, and possible remediations.

Learning Outcomes:

By the end of this course student will be able to learn:

- Describe basic energy concepts
- Account for conventional and renewable energy technologies and their application
- Reflect and evaluate the environmental impact of energy production and the relationship between energy production, consumption and climate change
- Reflect on energy costs, analyse the consequences of today's energy consumption
- Efficient use of energy, water and other resources, Use of renewable energy, such as solar energy
- Pollution and waste reduction measures, and the enabling of re-use and recycling
- Good indoor environmental air quality, Use of materials that are non-toxic, ethical and sustainable
- Consideration of the environment in design, construction and operation

Unit 1: Introduction — Lectures: 13

Introduction, chemistry and energy, conversion of chemical energy to electrical energy, Carbon cycle, Greenhouse gases, Global warming and climate change, Carbon footprint, zero-carbon or low-carbon energy. Electrical energy and steam energy, Energy Alternatives, Hidden Costs of Energy.

Unit 2: Non-Renewable (conventional) sources of energy — Lectures: 10

Production methods for electric power: Non-Renewable (conventional) sources of energy: Fossil fuels: Coal, petroleum and Natural gas. Energy transformation. Renewable energy sources: solar, hydropower, wind, geothermal, wave, ocean thermal, tidal, ocean currents, nuclear energy, biomass.

Unit 3: Renewable energy — Lectures: 12

Production methods for electric power: Renewable (green) energy, conversion and storage systems. Nuclear fusion, Hydrogen fuels, photovoltaic solar cells, hydroelectric. Sustainable energy, biomass, Biofuels, production of biofuels, advantages, blending of biofuels with conventional fuels, Carbon Capture and Reuse, Waste to Energy Technologies.

Unit 4: Pollution — Lectures: 10

Air Pollution, Urban and Indoor Air Pollution, Pollution and waste reduction measures, chemical remediation of air pollution. Effect of pollution on health and economy.

Practical

(Credits: 01, Laboratory periods: 30)

Tutorials

1. Conversion of biomass to biofuels (2-3 different biofuels)
2. Working on solar cell model.
3. Working on wind turbine model.
4. Working on geothermal energy model.
5. Working on hydroelectric plant model.
6. Presentations by students

References (Theory):

1. Rao, C S., **Environment pollution control Engineering**, New Age International reprint 2015, 2nd edition
2. Bharucha, E., **Textbook of Environmental Studies**, Universities Press (2005)
3. Wright, R.T., **Environmental Science-Towards a sustainable Future**, Prentice Hall (2008) 9th edition.
4. Ahluwalia, V. K., **Energy and Environment**, The Energy and Resources Institute (TERI) (2019).

References (Practicals):

1. Challapalli Narayan Rao, **Practical approach to implementation of Renewable Energy Systems,** Evincepub Publishing, 2022

Teaching Learning Process:

To accomplish a goal, it is very important to learn in a strategic manner. There are different components of learning and the capacity of each learner varies. It is expected to have a student centric teaching. Questions and answers, both should come from students. 'How' to teach and 'What' to teach in the defined curriculum not only depends on the content and the knowledge of the teacher but critically more so on designing, i.e. how to introduce the concept to the students in a very effective way. Different ways of teaching include classical board teaching method, visual conceptual method, application based practical demonstration of the concept etc. are required in this course. In fact, the pedagogy is to make a class interesting and thus learning becomes enjoyable.

Assessment Methods:

- Graded assignments, conventional class tests.
- Class seminars and presentations by students on course topics with a view to strengthening the content through width and depth.
- End semester university examination for theory and practical.

Keywords:

Energy, Renewable and non-renewable energy resources, Synthetic fuels, Biofuels, Carbon footprint, air pollution, remediation, pollution related health and economy.

Course Code: Chemistry GE-3
Course Title: Medicines in Daily Life
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The course is designed to study the basic details about various medicines of general uses, which are crucial for the various diseases. This course also gives the knowledge of active pharmaceutical ingredient in some medicines, their synthesis; therapeutic effect and side effects on human physiology. Medicines are essential for a healthy day-to-day life and therefore this course will aware the students about its positive and negative effects.

Learning Outcomes:

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

- Understand the role of different medicines on human physiology.
- Gain the knowledge of active pharmaceutical ingredient and their roles in different disease.
- Learn the proper use of different medicines and their effect and side effects.
- Learn the techniques of administering blood group, pulse rate, blood pressure and may other general diagnostic applications.

Unit 1: General Introduction — Lectures: 8

Introduction-Health, disease, drugs, chemotherapy, approaches in drug designing, classification of drugs and their origin. Structure of active ingredients, uses, dosage, side effects and their natural remedies

Unit 2: Different class of medicines — Lectures: 22

Analgesics and antipyretics- Aspirin, paracetamol, ibuprofen, morphine, codeine

Antibiotics- Amoxicillin, norfloxacin, ciprofloxacin

Antihistamines or antiallergics- Cetrizine and Levocetrizine (role of stereoisomers)

Antiparasitic- Albendazole

Antidiabetics- Insulin, Glipizide and metformin

Antihypertensive – Amlodipine and its natural remedies- Rauwolfia.

Diuretic- Lasix

Antidepressant-Zoloft and its natural treatment

Antifungal – Luconazole, Itraconazole

Antacids- Ideal properties of antacids, combinations of antacids, Sodium 40 Bicarbonate, rantidine, milk of magnesia, aluminium hydroxide gel

Anticoagulants/antiplatelet drugs- Warfarin, heparin and Ecosprin

Anesthetics- Introduction and its type with examples

Poison and Antidote: Sodium thiosulphate*, Activated charcoal, Sodium nitrite

Astringents: Zinc Sulphate, Potash Alum

Supplements- zinc and calcium, vitamins

Synthesis of small molecule drugs like aspirin and paracetamol

Practical

(Credits: 02, Laboratory periods: 60)

1. Determination of heart rate and pulse rate, blood pressure and discussion on medicines affecting them.
2. Identification test- Magnesium hydroxide, Sodium bicarbonate, Calcium gluconate.
3. Preparation of inorganic pharmaceuticals- Boric acid Potash alum
4. Determination of blood sugar.
5. Estimation of zinc and calcium
6. Qualitative analysis of carbohydrates (Glucose, Fructose, Lactose, Maltose, Sucrose and starch).
7. Identification tests for Proteins
8. Qualitative analysis of vitamin C.
9. Isolation of paracetamol (API) from tablet
10. Isolation of aspirin (API) from Tablet and recording of melting point (synthesis needs discussion)
    i. Paracetamol
    ii. Aspirin

References (Theory):

1. Patrick, G. L. (2001) **Introduction to Medicinal Chemistry**, Oxford University Press.
2. Lemke, T. L. & William, D. A. (2002), **Foye's Principles of Medicinal Chemistry**, 5th Ed., USA,
3. Singh H.; Kapoor V.K. (1996), **Medicinal and Pharmaceutical Chemistry**, Vallabh Prakashan.

4. Chatwal, G.R. (2010), **Pharmaceutical chemistry**, inorganic (vol. 1), Himalayan publishing house
5. https://go.drugbank.com./

References (Practicals):

1. Jeffery, G.H., Bassett, J., Mendham, J., Denney, R.C. (1989), **Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.
2. Ahluwalia, V.K., Dhingra, S. (2004), **Comprehensive Practical Organic Chemistry: Qualitative Analysis**, University Press.
3. Munwar, S., Ammaji, S.(2019), **Comprehensive Practical Manual of Pharmaceutical Chemistry,** Educreation Publishing.
4. Mondal, P., Mondal, S.(2019), **Handbook of Practical Pharmaceutical Organic, Inorganic and Medicinal chemistry**, Educreation Publishing.

Teaching Learning Process:

- Lecture in class rooms
- Peer learning
- Technology driven learning
- Learning through experiment in the practical classes

Assessment Methods:

- Presentations by Individual Student/ Group of Students
- Class Tests at Periodic Intervals.
- Written assignment(s)
- End semester University Theory and practical Examination

Keywords:

Medicines, Active pharmaceutical ingredient, drug

Course Code: Chemistry GE-4
Course Title: Fragrances and Flavours: An Industry's Perspective
Total Credits: 04 (Credits: Theory-03, Practical-01)
Total Lectures: Theory- 45, Practical-30

Objectives:

The use of fragrance is ubiquitous and is a global human phenomenon. Over the course of time, countless numbers of flavors and fragrances have found their way into everyday life, notably into foods, beverages and confectionery items; into personal care products (soaps, toothpastes, mouthwashes, deodorants, bath lotions and shampoos), perfumes, and other cosmetics as well as pharmaceutical formulations. Indeed, flavors and aromas are added to make such products more attractive or to mask the taste or smell of less pleasant ones. There is need to understand the applications of chemistry in the world of flavours and fragrances.

Learning Outcomes:

By the end of this course student will be able to learn:

- Synthesis of various fragrance and flavour ingredients
- Formulation methods, how different factors affects the formulation process in Fragrance and Flavour industry
- Uphold safety regulation and execute quality processes
- Quality control in manufacturing process, legal aspects, classification of odour and odorants.
- Different methods used for separation, purification and isolation of perfumes and flavours like distillation, extraction, crystallization, etc.

Unit 1: Fragrances — Lectures: 18

- Introduction to fragrances, types of fragrances (Fragrance families and classification)
- History of perfumes, Perfumery raw materials, classification of odour, odour type and odorants
- India in the context of Fragrance Industry
- ABCs of perfumery, odour aspects of perfumes, fragrance pyramid, fragrance families
- Some basic chemical knowledge to provide a better understanding of the structure of molecules possessing a sensory power, The volatility and solubility of sensory molecules
- Chemistry of aromatic compounds in perfume making, Composition of fragrances
- Current trends in fragrances, sensory analysis of different products
- Study of the raw materials used in perfumery (origin, extraction method, and olfaction)
- Key chemical reactions for conversion of raw materials to fragrances
- Extraction of essential oils used in perfumery
- Difference between alcohol and oil-based perfumes

- Outline of health, safety and sustainability parameters in perfumer

Unit 2: Sustainable Fragrance by Design **Lectures: 4**

- The challenges of sustainability and how it impacts the industry
- Sustainability charter
- Green chemistry principles
- Commitment to Biodiversity

Unit 3: Flavours **Lectures: 18**

- Introduction to flavours, types of flavours, flavour raw materials
- Understanding of terms like, Flavour and Flavouring agents. Attributes of flavour, taste, odour, odour stimulation, basic tastes and the human olfactory system.
- Stability of flavour in food, sensory evaluation of flavours in foods, Various flavour formulation
- Systematic approach to understanding flavour formation during food processing, food matrix, interaction of added flavours
- Flavour enhancers, modifiers, precursors, suppressors, solvents.
- Key chemical reactions for conversion of raw materials to flavours
- Forms of flavour and the manufacturing processes involving all types of flavours. Aroma recovery during processing.
- Biogenesis of flavours in fruits and vegetables, reaction flavours, off flavours.
- Stability of flavor in food, sensory evaluation of flavours in foods
- Selection and application of flavours in foods and beverages
- Legal aspects (natural flavours and natural flavouring substances, nature identical flavouring substances, artificial flavouring substances), and the FSSA act.

Unit 4: Extraction, Isolation and Purification of Perfumes and Flavour Compounds Lectures: 5

Extraction techniques for the separation of volatile oils from natural source- including. Distillation, Evaporation, Crystallization and Adsorption, supercritical fluid extraction methods of isolation of important ingredients

Practical

(Credits: 01, Laboratory periods: 30)

1. Extraction of D-limonene from orange peel using liquid CO_2.
2. Extraction of caffeine from coffee beans using liquid CO_2.
3. Extraction of essential oils from lemon using steam distillation
4. Extraction of essential oils from lemon using liquid CO_2.
5. Extraction of essential oils from fragrant flowers.
6. Determination of esters by Thin Layer Chromatography

7. Memorisation of different raw materials used in perfumery, perfume language, Memorisation of perfumes
8. Testing up of different flavours
9. Analysis of spectra of perfume formulations.

References (Theory):

1. Arctander, S. (2008), **Perfume and flavour materials of Natural origin,** Allured Publishing Corporation, USA
2. Arctander, S. (2017), Volume I and II, **Perfume and Flavour Chemicals**, (Aroma Chemicals), Allured Publishing Corporation, USA
3. Curtis,T.; Williams, D. C.(2001) 2nd Edition, **An Introduction to Perfumery**, Micelle Press, USA.
4. Sell,C. (2008), **Understanding Fragrance Chemistry,** Allured Publishing Corporation, USA
5. Calkin,R.R., Jellinek, J.S., **Perfumery: Practice and Principles,** John Wiley & Sons Inc.
6. Gimelli, S.P. (2001), **Aroma Science,** Micelle Press, USA
7. Arctander, S. (2019), **Perfume and Flavour Materials of Natural Origin,** Orchard Innovations
8. https://www.beyondbenign.org/lessons/essential-oil-extraction-using-liquid-co2/

Teaching Learning Process:

- Blackboard teaching along with Power point presentations.
- Assignments
- Field Trips to Flavour and perfumery Industry
- Different working models
- ICT enabled classes
- Interactive sessions
- recent literature using internet and research articles.

Assessment Methods:

- Evaluation on the basis of regular class test, presentations and assignments
- End semester university examination will be held for both theory and practical.
- Practical assessment based on continuous evaluation
- Performance in the experiment during examination and viva voce.

Keywords:

Fragrances, Flavours, pharmaceutical formulation, distillation, extraction techniques

Course Code: Chemistry GE-5
Course Title: Radio-chemistry in Energy, Medicine and Environment
Total Credits: 04 (Credits: Theory-03, Practical-01)
Total Lectures: Theory- 45, Practical-30

Objectives:

The objective of this course is to give an introduction to nuclear and radiochemical concepts. It will also help the student to gain fundamental knowledge about the radioisotopes and their real-world applications in medicine, diagnostic techniques, energy, research and environment.

Learning Outcomes:

By the end of the course, the students will:

- Learn about radioisotopes, radioactive decay
- Use of radiochemistry in various fields
- Effect of radiations on health
- Learn about nuclear energy and nuclear pollution

Unit 1: Introduction — Lectures: 10

Atoms, composition of nucleus, mass number, isotopes, nuclear stability, radioactive decay, radioactivity in nature: natural and artificial radioisotopes, elementary particles, radioactive decay (α, β and γ decay), half-life period, types of nuclear reactions: nuclear fission and nuclear fusion.

Unit 2: Nuclear power generation — Lectures: 5

Nuclear Power generation from uranium ore (energy production and nuclear waste), introduction to nuclear reactors for energy and nuclear weapons

Unit 3: Applications of radiochemistry — Lectures: 15

C 14 decay and radioactive dating, irradiation of food, radiotracers for studying chemical reactions (photosynthesis, metabolic studies of drugs, metabolism of organisms, fundamental properties of genetic material), medicinal application of radio chemicals in radiotherapy (use in cancer, hyperthyroidism, blood disorders), radio-pharmaceuticals, diagnostic procedures: CT, PET

Unit 4: Environment radioactivity — Lectures: 7

Natural radioactivity, natural process that release radioactive material in environment, man-made events like Chernobyl disaster, bomb test, use of radiotracers in environmental studies.

Unit 5: Nuclear pollution and safety management **Lecture: 8**

Radiation protection standards, basics of radiation hazards, international guidelines on radiation protection, disposal of nuclear waste, nuclear disaster and it's managements, Effect of radiation on health: Biological effects of radiation, radiation monitors, dose limits for workers and public,

Practical

(Credits: 01, Laboratory periods: 30)

1. Study the background radiation in different places and identify the probable source. (Data to be provided).
2. Survey the diagnostic procedures involving radio-chemistry in different diagnostic laboratories.
3. Write a report on the radio isotopes used in various diagnostic procedures.
4. Write a report on safety measures taken in diagnostic labs.
5. Write a report on any two nuclear and radiation accidents focusing on their impact on human life, environment and economy.

References (Theory):

1. Nuclear and radiochemistry, Konya J., Nagy N. 2nd Edition, Elsevier
2. Radiochemistry and Nuclear Chemistry, 4th Edition, Choppin G., Lilijenzin J-O, Rydberg J., Ekberg C. Elsevier.

Teaching Learning Process:

- Student centered teaching Learning process.
- Blend of conventional blackboard teaching and modern teaching learning tools
- Focus on real life applications of concepts
- Problem solving and quizzes
- Engaging students in collaborative learning.

Assessment Methods:

- Class Tests at Periodic Intervals.
- Written assignment(s)
- Oral assessment, quizzes.
- Semester end University examination.

Keywords:

Radioisotopes, radio-analysis, radiopharmaceuticals, nuclear reactor, nuclear pollution.

Course Code: Chemistry GE-6
Course Title: Molecular Modelling and Artificial Intelligence & Machine Learning
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives:

The course is aimed at familiarization of students to modern scientific machine (programming) language, i.e., artificial intelligence (AI) & machine learning (ML) and their potential applications in chemistry. Further the aim of the course is to provide elementary ideas of the techniques prevailing in the field of artificial intelligence (AI) and machine learning (ML) and their applications to research problems especially related to research and development of new materials and pharmaceutical compounds with desired properties.

Learning Outcomes:

By the end of the course, the students will be:

- Familiar with Elementary techniques of Artificial intelligence (AI) & Machine learning (ML)
- Able to apply techniques of AI & ML in basic problems of research in some important areas of research in Chemistry.

Unit 1: Molecular Modelling- Introduction to computational chemistry: Lectures: 7

Overview of Computational Methods in Chemistry (Ab initio, DFT, Semi- empirical, Molecular Mechanics

Unit 2: Potential Energy Surfaces Lectures: 4

The concept of Potential energy surface, Intrinsic Reaction Coordinates, Stationary points, Equilibrium points – Local and Global minima, Geometry optimization and energy minimization.

Unit 3: Molecular Mechanics Lectures: 4

Force Fields (A brief idea of a basic force field), Elementary idea of MM1, MM2, MM3, MM4, MM+, AMBER etc. A brief Idea of Molecular Docking

Unit 5: Artificial Intelligence & Machine learning in Chemistry Lectures: 15

An overview of computationally readable and processible representation of molecules, e.g., SMILES, mol files. Chemical space and access to chemical databases. Statistical treatment of data: regression analysis and types of regression. Elementary Idea of Quantitative structure-activity relationship (QSAR).
An insight into Artificial Intelligence & Machine learning and potential areas of applications in chemistry. Dimensional reduction; Principal Component Analysis (PCA) and the

importance and necessity of nonlinearity in Artificial Intelligence.
Genetic algorithm, basics of random mutation hill climbing (RMHC) and simulated annealing.

Practical/ Hands-on Training:

(Credits: 02, Laboratory periods: 60)

Molecular Modelling based Exercise

1. Write the Z-Matrix of a given set of molecules.
2. Carry out geometry optimisation on H_2O, H_2S, H_2Se molecules and compare the optimized bond angles and dipole moments from the results obtained. Obtain the ESP-mapped density surfaces and interpret the results obtained with reference to bonding in these molecules.

Suggested: A comparative analysis of results of the above exercise may be carried out using different quantum mechanicalmethods.

3. Calculate the energy of the following chemical species andarrange them in order of increasing stability.
   1-hexene, 2-methyl-2-pentene, (E)-3-methyl-2-pentene, (Z)-3- methyl-2-pentene, and 2,3-dimethyl-2-butene in order of increasing stability.
4. Carry out the geometry optimisation on the following chemical species and compare the shapes and dipole moments of the molecules.
   1-butanol, 2-butanol, 2-methyl-1-propanol, and 2-methyl-2- propanol.
   Correlate the computationally obtained values of the dipole moments with the experimental values of the boiling points: (118ºC, 100 ºC, 108 ºC, 82 ºC, of 1-butanol, 2-butanol, 2-methyl-1- propanol, and 2-methyl-2- propanol respectively).
5. Based on the implicit electronic structure calculations, determinethe heat of hydrogenation of Ethene.
6. Based on the calculations of enthalpies of the participatingchemical species on optimized geometry of the molecules, calculate the reaction enthalpy at 298 K for the following, industrially important reactions:
   $CH_4 + H_2O \rightarrow CO + 3H_2$ (steam reforming of methane)
   $N_2 + 3\,H_2 \rightarrow 2NH_3$ (Haber-Bosch process)
7. Carry out geometry optimisation and determine the energy of the participating chemical species in the following reactions Using these results calculate the resonance energy of thiophene.
8. Carry out geometry optimization & energy calculations on the following species and obtain Frontier Molecular Orbitals. Visualize the Molecular Orbitals of these species and interpret the results for bonding in these molecules.
   Benzene, Naphthalene, and Anthracene.
9. Compare the gas phase basicities of the methylamines by comparing the enthalpies of the following reactions:
10. On the basis of results of geometry optimization and energy calculations, determine the enthalpy of isomerization of cis andtrans 2-butene.

11. QSAR based exercise on problems of interest to chemist.
12. Perform a conformational analysis of butane. Plot the graph between the angle of rotation and the energy of the conformers using spreadsheet software.
13. Compute the resonance energy of benzene by comparison of its enthalpy of hydrogenation with that of cyclohexene.
14. Perform a geometry optimization followed by a frequency assessment (opt+freq keyword) using the B3LYP method and 6-31G(d) basis set on a given set of small molecules, i.e., BH_3, CH_4.

    Suggested: A greater number of molecules may be studied as per instructions received from the concerned teacher.
15. Based on the fundamentals of conceptual DFT calculate the ionization potential (IP), electron affinity (EA), electronegativity and electron chemical potential of a given set of molecules.
16. Perform molecular docking of Sulfonamide-type D-Glu inhibitor into MurD active site using Argus lab.

Artificial Intelligence (AI) and Machine Learning (ML) based exercise on problems of interest to chemist

17. Travelling salesman problem and electrical circuit design (minimization of path-length).
18. Genetic algorithm, in solving matrix form of linear equations
19. Non-linear least-square fitting problem.
20. Particle Swarm Optimization on the sphere function.

Important Instruction Note on working approach:

- A student is required to perform/investigate a minimum of 10 exercises.
- The exercises mentioned above will be performed by the student strictly in accordance with the instructions received and only under the supervision of the teacher concerned.
- Any other exercise may be carried out with prior permission, input, discussion and instructions received from the teacher concerned.

References (Theory):

1. Lewars, E. (2003), **Computational Chemistry**, Kluwer academicPublisher.
2. Cramer, C.J. (2004), **Essentials of Computational Chemistry**, John Wiley & Sons.
3. Cartwright C.; Kharma N., (2008), **Using artificial intelligence in chemistry and biology**, First Edition, CRC Press Taylor & Francis Group
4. Hippe; Z., **Artificial Intelligence in Chemistry: Structure Elucidation and Simulation of Organic Reactions**, (1991) Academic Press, Elsevier
5. Soft Computing in Chemical and Physical Sciences A Shift in Computing Paradigm (Kanchan Sarkar, Sankar Prasad Bhattacharyya) (z-lib.org)
6. Understanding Properties of Atoms, Molecules and Materials (PRANAB. SARKAR, Sankar Prasad Bhattacharyya) (z-lib.org)

Web Resources:

1. https://www.afs.enea.it/software/orca/orca_manual_4_2_1.pdf
2. https://dasher.wustl.edu/chem430/software/avogadro/learning-avogadro.pdf
3. http://www.arguslab.com/arguslab.com/ArgusLab.html
4. https://barrett- group.mcgill.ca/tutorials/Gaussian%20tutorial.pdf
5. https://gaussian.com/techsupport/
6. https://gaussian.com/man/
7. https://gaussian.com/wp-content/uploads/dl/gv6.pdf
8. https://dasher.wustl.edu/chem478/software/spartan-manual.pdf
9. http://www.mdtutorials.com/gmx/
10. https://vina.scripps.edu/manual/

Teaching Learning Process:

- Hands-on laboratory exercises
- Conventional teaching learning method.
- Engaging students in collaborative learning

Assessment Methods:

- Continuous evaluation of laboratory work and record file.
- Oral assessment, quizzes.
- Presentation on lab practices.Semester end examination.

Keywords:

Molecular Modelling, Potential Energy Surface (PES), Geometry Optimization, Frequency calculation, Artificial Intelligence, Machine Learning, Nural Networks, Genetic Algorithm.