दिल्ली विश्वविद्यालय
UNIVERSITY OF DELHI

Bachelor of Science-in Physical Sciences
or
Bachelor of Science (Hons.) in Physical Sciences with Dissertation/Academic Projects/ Entrepreneurship
or
Bachelor of Science (Hons.) in Physical Sciences with Dissertation/ Academic Projects/ Entrepreneurship (Discipline-1 Major)
or
Bachelor of Science (Hons.) in Physical Sciences with Dissertation/ Academic Projects/ Entrepreneurship (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

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Undergraduate Curriculum Framework – 2022

Preamble

The Preamble of the Undergraduate Curriculum Framework-2022 underlines the historical perspective, philosophical basis, and contemporary realities of higher education as enshrined in the National Education Policy (NEP) 2020 and endeavors to synchronize these cornerstones while charting the road ahead for the state of higher education.

The University of Delhi, a premier Institution for teaching, learning, and research in higher education, acclaimed nationally and internationally, has nurtured the quest for reaching the peak in every sphere of education, in its true sense, in the process of its contribution to the nation-building. Being a Central University, mandated to act as the torchbearer in expanding the horizons of human resource development through the expansion of higher education, it has always paid adequate premium towards constructive and meaningful innovation as a regular feature in its undergraduate curriculum development over the years.

A reflection of such sustained and continued endeavor is amply exemplified in the successive revision of undergraduate curricular framework over the decades and especially in the last two decades, keeping pace with the emerging trends in higher education in the new millennium globally and its critical importance in enriching the youth of our nation, well equipped with the prevailing priorities of skill development through innovative and practical oriented teaching-learning more than anything else.

To actualize the noble objective, as succinctly brought out in the National Education Policy 2020, the university has endeavored to explore the possibility of further restructuring and refinement of its undergraduate curriculum framework in line with the objective and underlying philosophy of the NEP 2020 to capture the imagination of the youth of our nation which depicts the contemporary realities of our demographic advantage globally.

The resultant outcome of this comprehensive exercise undertaken by the university is the Undergraduate Curriculum Framework-2022 (UGCF-2022) which not only underlines the heart and soul of the NEP 2020 in letter and spirit but also goes on to create a teaching-learning framework at the undergraduate level to attract the young minds towards research, innovation, apprenticeship, social outreach, entrepreneurship and similar such areas of human knowledge and endeavor while imbibing the truly charged academic environ of the university and its constituent colleges.

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 B.Sc. (Hons) Physical Sciences programme, DSCs are the core credit courses of Chemistry, Physics and Mathematics (See Table-2) 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 DSC Courses each, in Semesters I to VI (Table -3). In semesters VII and VIII the student has to study two DSC courses from any one of the disciplines; Chemistry or Physics or Mathematics, and not a combination of these.

(ii) Discipline Specific Elective (DSE): The Discipline Specific Electives (DSEs) are a pool of credit courses of Chemistry, Physics and Mathematics. Upto semester VI there are 12 DSE courses from chemistry discipline and 6 (six) each from Physics and Mathematics discipline (Table-4). A student gets an option of choosing one DSE course in each of the semesters III to VI from a pool of DSE courses as specified for Odd and Even Semesters (Table-4). In semesters VII and VIII the student has an option of choosing a maximum of three DSE courses from any one of the disciplines; Chemistry or Physics or Mathematics, and not a combination of Chemistry/ Physics/ Mathematics.

(iii) Generic Elective (GE): Generic Electives is a pool of courses offered by various disciplines of study 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 either a DSE course in chemistry/Physics/Mathematics or a GE course of any discipline offered by the institution. Similarly, in semesters VII and VII, I a student can exercise an option of choosing a maximum of two Generic elective courses out of a combination of 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 (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*** 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 in all the three discipline of study i.e. Chemistry, Physics and Mathematics.

  A student will study one Skill Enhancement Course of 2 credits each (following 0T+2P credit system) in all the semesters, from semester 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 (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 providing an opportunity to study multidisciplinary courses. In BSc (Hons.) Physical Sciences a student can study DSC, DSE and SEC courses of Chemistry or Physics or Mathematics. More importantly a student can choose to study Generic Elective (GE) Courses in all the disciplines offered by the college. Further a student pursuing multidisciplinary course of study may obtain a Major and a Minor in two different disciplines if she/he completes the credit requirements.

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 or minor or interdisciplinary at VII and VIII semesters.

Dissertation/Academic Project/Entrepreneurship in the 4 year shall commence from VII semester and conclude in VIII semester. Detailed outcomes of each track chosen out of these three options shall be notified and assessment at the end of VII and VIII semesters shall be done accordingly.

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 in 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 Physical Sciences

As per the recommendations of UGCF 2022, the undergraduate degree course in Physical Sciences 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 gains in-depth knowledge. Besides the DSCs of three different disciplines i.e. Chemistry or Physics or Mathematics, 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. This will suit the present day needs of students in terms of securing their paths 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 have to be secured for the purpose of award of *Undergraduate Certificate/ Undergraduate Diploma/*Appropriate *Bachelor of Science degree in Physical Science as 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 Physical Sciences*	After successful completion of Semester II	44
2	*Undergraduate Diploma in Physical Sciences*	After successful completion of Semester IV	88
3	*Bachelor of Science in Physical Sciences*	After successful completion of Semester VI	132
4	*Bachelor of Science (Hons.) in Physical Sciences with Dissertation/Academic Projects/Entrepreneurship*	After successful completion of Semester VIII	176
5	*Bachelor of Science (Hons.) in Physical Sciences with Dissertation/Academic Projects/Entrepreneurship (Discipline-1Major)*	After successful completion of Semester VIII	176
6	*Bachelor of Science (Hons.) in Physical Sciences with Dissertation/Academic Projects/Entrepreneurship (Discipline-1Major) & (Discipline-2 Minor)*	After successful completion of Semester VIII and credit requirements for Major and Minor	176

Major discipline

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

Minor discipline

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

For instance, a student who pursues 4 years B.Sc. (Hons.) Physical Sciences, if he/she earns minimum 80 credits in Chemistry from 8 DSCs and at least 9 DSEs from Chemistry and writes dissertation on a topic of chemistry discipline, then he/she will earn Major in Chemistry. Such a student shall get a minor in Physics/Mathematics, if he/she earns minimum 28 credits from 6 DSCs and 1 DSE of Physics/Mathematics.

5. Programme Objectives

The undergraduate degree course in Physical Sciences aims to provide:

(i) In-depth knowledge in chemistry, physics and mathematics through understanding of key concepts, principles, theories and manifestations of the three disciplines.
(ii) Competence and skill in solving both theoretical and applied problems in different disciplines.
(iii) A conducive learning environment that ensures holistic cognitive development of students.
(iv) Exposure to the latest advances in chemistry, physics, mathematics and research.
(v) Development of critical and analytical thinking, scientific reasoning, problem-solving skills, communication skills and teamwork.
(vi) Moral and ethical awareness, leadership qualities and innovation.
(vii) Multicultural competence and multilinguism.
(viii) Knowledge and skill to undertake higher studies in chemistry, physics, mathematics and related areas thereby enabling students' employment/entrepreneurship.
(ix) Sufficient subject matter competence and enable students to prepare for various competitive exams, 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 Physical Sciences are as follows:

- **In-depth knowledge**: The student will acquire theoretical knowledge and understanding of the fundamental concepts, principles and processes in the three different disciplines chemistry, physics and mathematics. The core papers will provide in-depth understanding

of the subject. 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.
- **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, and data analysis and research ethics.
- **Role of Physical Sciences**: The students will develop awareness and appreciation for the significant role played by chemistry, physics and mathematics in current societal and global issues, including areas such as sustainable development. They will be able to address and contribute to such issues through the 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 DSEs and SECs will enable students to develop expertise in general and subject specific computational skills.
- **Lateral Thinking**: The programme will develop the ability to apply the underlying concepts and principles of chemistry, physics and mathematics, and allied fields beyond the classrooms to real life applications, innovation and creativity.
- **Competence and Job Opportunities**: The skills acquired during the programme will provide varied opportunities for students' career progression. They will be able to join analytical, chemical, pharmaceutical, biochemical, material testing, fast moving consumer goods (FMCG) and other industries/laboratories, academics, innovation and research at different exit points.

7. Programme Structure

The detailed framework of undergraduate degree programme in Physical Sciences is provided **in Table -2.**

Table 2

Structure of Undergraduate Programme in Physical Sciences 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-1 CHEMISTRY-I **(2T+2P)** DSC-2 Physics-I **(2T+2P)** DSC-3 MATHEMATICS-I **(2T+2P)**	N/A	Choose one from a pool of courses **GE-1** **(2T+2P)/ (3T+1P)/**	Choose one **AEC** from a pool of courses	Choose one **SEC** from a pool of courses **(0T+2P) or (1T+1P)**	N/A	Choose one **VAC** from a pool of courses	**22**
II	DSC-4 CHEMISTRY-II **(2T+2P)** DSC-5 Physics-II **(2T+2P)** DSC-6 MATHEMATICS-II **(2T+2P)**	N/A	Choose one from a pool of courses **GE-2** **(2T+2P)/ (3T+1P)/**	Choose one **AEC** from a pool of courses	Choose one **SEC** from a pool of courses **(0T+2P) or (1T+1P)**	N/A	Choose one **VAC** from a pool of courses	**22**
Students on exit shall be awarded *Undergraduate Certificate in Physical Sciences* after securing the requisite 44 credits in Semester I & II								**Total = 44**
III	DSC-7 CHEMISTRY-III **(2T+2P)** DSC-8 Physics-III **(2T+2P)** DSC-9 MATHEMATICS-III **(2T+2P)**	Choose one from a pool of courses **DSE-1** **(2T+2P)** Chemistry/Physics/Mathematics OR **GE-3** **(2T+2P)/ (3T+1P)**		Choose one **AEC** from a pool of courses	Choose one **SEC** **(0T+2P) or (1T+1P)** OR **IAPC****		Choose one **VAC** from a pool of courses	**22**
IV	DSC-10 CHEMISTRY-IV **(2T+2P)** DSC-11 Physics-IV **(2T+2P)**	Choose one from a pool of courses **DSE-2** **(2T+2P)** Chemistry/Physics/Mathematics		Choose one **AEC** from a pool of courses	Choose one **SEC** **(0T+2P) or (1T+1P)** OR **IAPC****		Choose one **VAC** from a pool of courses	**22**

	DSC-12 MATHEMATICS-IV **(2T+2P)**	OR **GE-4 (2T+2P)/ (3T+1P)**					
Students on exit shall be awarded *Undergraduate Diploma in Physical Sciences* after securing the requisite 88 credits after completion of Semester IV							**Total = 88**
V	DSC-13 CHEMISTRY-V **(2T+2P)** DSC-14 Physics-V **(2T+2P)** DSC-15 MATHEMATICS-V **(2T+2P)**	Choose one from a pool of courses **DSE-3 (2T+2P)** Chemistry/Physics/Mathematics	Choose one form a pool of courses **GE-5 (2T+2P)/ (3T+1P)**	N/A	Choose one **SEC (0T+2P) or (1T+1P)** OR **IAPC****	NA	**22**
VI	DSC-16 CHEMISTRY-VI **(2T+2P)** DSC-17 Physics-VI **(2T+2P)** DSC-18 MATHEMATICS-VI **(2T+2P)**	Choose one from a pool of courses **DSE-4 *** (2T+2P)** Chemistry/Physics/Mathematics	Choose one form a pool of courses **GE-6 (2T+2P)/ (3T+1P)**	N/A	Choose one **SEC (0T+2P) or (1T+1P)** OR **IAPC****	NA	**22**
Students on exit shall be awarded *Bachelor of Science in Physical Sciences* after securing the requisite 132 credits on completion of Semester VI							**Total = 132**
VII	DSC-19 CHEMISTRY-VII OR PHYSICS-VII OR MATHEMATICS-VII	Choose three DSE courses # **OR** Choose two DSE# and one GE course **OR** Choose one DSE# and two GE courses	N/A	N/A	N/A	Dissertation on Major (6) **OR** Dissertation on Minor (6) **OR** Academic project/ Entrepreneurship (6)	**22**
VIII	DSC-20 CHEMISTRY-VIII OR PHYSICS-VIII OR MATHEMATICS-VIII	Choose three DSE# courses **OR** Choose two DSE# and one GE course **OR**	N/A	N/A	N/A	Dissertation on Major (6) **OR** Dissertation on Minor (6) **OR** Academic project/ Entrepreneurship	**22**

		Choose one DSE[#] and two GE courses				(6)	
Students on exit shall be awarded *Bachelor of Science (Hons.) with Research/Academic Projects/Entrepreneurship* or *Appropriate Bachelor of Science (Hons.) with Research/Academic Projects/Entrepreneurship (Discipline-1 Major) & (Discipline-2 Minor)* after securing the requisite 176 credits on completion of Semester VIII							**Total = 176**

* There shall be choice in Semesters III and IV to either choose a DSE course from a pool of DSE courses offered by Chemistry, Physics and Mathematics disciplines OR a GE course from a pool of GE courses offered by all the disciplines in the college. A DSE course if chosen from other discipline except Chemistry, Physics and Mathematics, such a course will be considered as a GE course.

** There shall be choice in Semesters III and IV to choose either one 'SEC' or in the alternative 'Internship/Apprenticeship/Project/Community Outreach (IAPC)' in each Semester of two credits each.

*** '**Research Methodology'** shall be offered as one of the DSE courses in VI and VII. If a student wishes to pursue four years B.Sc. (Hons.) Physical Science with Academic Project/Entrepreneurship, he/she shall compulsorily opt for a Research Methodology course in either Semester VI or VII.

In semesters VII and VIII a student will have the option to choose DSE courses from any one of the discipline Chemistry/Physics/Mathematics, and not a combination of these disciplines. The following choices will be available in VII and VIII semesters:

(i) to choose three DSEs of 4 credits each either from Chemistry or Physics or Mathematics (not a combination of these disciplines)
OR
(ii) to choose two DSEs of 4 credits each either from Chemistry or Physics or Mathematics (not a combination of these disciplines) and one GE of 4 credits
OR
(iii) to choose one DSE of 4 credits either from Chemistry or Physics or Mathematics and two GEs of 4 credits each.

Note: Wherever there is a practical there will be no tutorial and vice-versa. The size of the group for chemistry practical papers is recommended to be 12-15 students.

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**.

A student will study three DSC Courses each, in Semesters I to VI (Table -2 &3). In semesters VII and VIII the student has to study two DSC courses from any one of the disciplines; Chemistry or Physics or Mathematics, and not a combination of these.

Table 3

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

DISCIPLINE CORE COURSES (4 Credits each)			
SEMESTER	**COURSE CODE**	**NAME OF THE COURSE**	**CREDITS T=Theory Credits P=Practical Credits**
I	DSC-1 Chemistry -I	Basic Concepts of Organic Chemistry	T=2 P=2
	DSC-2 Physics-I		T=2 P=2
	DSC-3 Mathematics-I		T=2 P=2
II	DSC-4 Chemistry -II	Periodic Properties and Chemical Bonding	T=2 P=2
	DSC-5 Physics-II		T=2 P=2
	DSC-6 Mathematics-II		T=2 P=2
III	DSC-7 Chemistry -III	Chemical Energetics and Equilibria	T=2 P=2
	DSC-8 Physics-III		T=2 P=2
	DSC-9 Mathematics-III		T=2 P=2
IV	DSC-10 Chemistry -IV	Chemistry of Carboxylic acids & derivatives, Amines and Heterocycles	T=2 P=2

	DSC-11 Physics-IV		T=2 P=2
	DSC-12 Mathematics-IV		T=2 P=2
V	DSC-13 Chemistry -V	Coordination Chemistry and Organometallics	T=2 P=2
	DSC-14 Physics-V		T=2 P=2
	DSC-15 Mathematics-V		T=2 P=2
VI	DSC-16 Chemistry -VI	Quantum Chemistry and Spectroscopy	T=2 P=2
	DSC-17 Physics-VI		T=2 P=2
	DSC-18 Mathematics-VI		T=2 P=2
VII	DSC-19		T=2 P=2
VIII	DSC-20		T=2 P=2

7.2 Details of Discipline Specific Elective (DSE) Courses

The DSE courses will be offered to students from all the three disciplines *viz.*, Chemistry, Physics and Mathematics in each of the semesters; III, IV, V, and VI as listed below in Table 4. The DSE courses are distributed in Pool A (Pool for Odd Semesters) and Pool B (Pool for Even Semesters), to be offered to students in odd and even semesters, respectively as specified in the Table 4. A student studying in semester III and V will have an option of choosing any DSE course of his/her choice as floated by the respective college from Pool A. Similarly, a student studying in semester IV and VI will have an option of choosing any DSE course of his/her choice as floated by the college from Pool B. It is to be noted that the college will offer at least one DSE course from each of the three disciplines i.e., Chemistry, Physics and Mathematics. There shall be choice in Semesters III and IV to either choose a DSE course from a pool of DSE courses offered by Chemistry, Physics and Mathematics disciplines OR a GE course from a pool of GE courses offered by all the disciplines in the college. A DSE course if chosen from other discipline except Chemistry, Physics and Mathematics, such a course will be considered as a GE course. In semesters VII and VIII a student will have the option to choose DSE courses from any one of the discipline Chemistry/Physics/Mathematics, and not a combination of these disciplines.

Table 4

Details of Discipline Specific Elective (DSE) Courses

DSE COURSES (4 Credits each-2T+2P)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS T=Theory Credits P=Practical Credits**
Pool for ODD Semesters		
DSE-1 Chemistry	Main Group Chemistry	T=2 P=2
DSE-3 Chemistry	Inorganic Materials of Industrial Importance	T=2 P=2
DSE-5 Chemistry	Green Chemistry	T=2 P=2
DSE-7 Chemistry	Polynuclear Hydrocarbons, Pharmaceutical Compounds, UV- Visible & IR Spectroscopy	T=2 P=2
DSE-9 Chemistry	Chemistry of Colloids and Adsorption	T=2 P=2
DSE-11 Chemistry	Phase Equilibria and Photochemistry	T=2 P=2
DSE-13 Physics		T=2 P=2
DSE-15 Physics		T=2 P=2
DSE-17 Physics		T=2 P=2
DSE-19 Mathematics		T=2 P=2
DSE-21 Mathematics		T=2 P=2
DSE-23 Mathematics		T=2 P=2
DSE 26	Computer Applications in Chemistry	T=2 P=2
Pool for Even Semesters		
DSE-2 Chemistry	Nano-scale Materials and their applications	T=2 P=2
DSE-4 Chemistry	Analytical Methods in Chemistry	T=2 P=2
DSE-6 Chemistry	Molecules of Life	T=2 P=2

DSE-8 Chemistry	Chemistry of Polymers, Dyes and Natural Products	T=2 P=2
DSE-10 Chemistry	Conductance, Electrochemistry and Chemical Kinetics	T=2 P=2
DSE-12 Chemistry	Biophysical Chemistry	T=2 P=2
DSE-14 Physics		T=2 P=2
DSE-16 Physics		T=2 P=2
DSE-18 Physics		T=2 P=2
DSE-20 Mathematics		T=2 P=2
DSE-22 Mathematics		T=2 P=2
DSE-24 Mathematics		T=2 P=2
DSE-25	Research Methodology for Chemists	T=2 P=2

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**.

The SEC courses will be offered to students from all the three disciplines *viz*., Chemistry, Physics and Mathematics in each of the semesters; I, II, III, IV, V, and VI as listed below in Table 5. The SEC courses are distributed in Pool A (Pool for Odd Semesters) and Pool B (Pool for Even Semesters), to be offered to students in odd and even semesters, respectively as specified in the Table 5. A student studying in semester I, III and V will have an option of choosing any SEC course of his/her choice as floated by the respective college from Pool A. Similarly, a student studying in semester II, IV and VI will have an option of choosing any SEC course of his/her choice as floated by the college from Pool B. It is to be noted that the college will offer at least one SEC course from each of the three disciplines i.e. Chemistry, Physics and Mathematics in each semester. Any other SEC course may also be floated by a college from the central pool of each discipline.

There shall be a choice in Semesters III, IV, V and VI to either choose an SEC course from a pool of SEC courses offered by Chemistry, Physics and Mathematics disciplines OR to choose Internship/Apprenticeship/Project/Community Outreach (IAPC).

Table 5

Details of Skill Enhancement Courses

SEC COURSES 2 Credits each- (0T+2P)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS T=Theory Credits P=Practical Credits**
Pool for Odd Semester		
SEC-1 Chemistry	Chemistry Lab Operations and Safety Measures	T=0 P=2
SEC-3 Chemistry	Chemistry of Cosmetics and Toiletries	T=0 P=2
SEC-5 Chemistry	Chemical Aspect of Forensic Science	T=0 P=2
SEC-7 Physics		T=0 P=2
SEC-9 Physics		T=0 P=2
SEC-11 Physics		T=0 P=2
SEC-13 Mathematics		T=0 P=2
SEC-15 Mathematics		T=0 P=2
SEC-17 Mathematics		T=0 P=2
Pool for Even Semester		
SEC-2 Chemistry	IT Skills and Data Analysis	T=0 P=2
SEC-4 Chemistry	Material Characterization Techniques	T=0 P=2
SEC-6 Chemistry	Green Methods in Chemistry	T=0 P=2
SEC-8 Physics		T=0 P=2
SEC-10 Physics		T=0 P=2
SEC-12 Physics		T=0 P=2
SEC-14 Mathematics		T=0 P=2
SEC-16 Mathematics		T=0 P=2
SEC-18 Mathematics		T=0 P=2

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 as listed below in **Table 6**.

Table 6

Details of Generic Elective (GE) Courses

GE COURSES (4 Credits each- 2T+2P)		
COURSE CODE	**NAME OF THE COURSE**	**CREDITS** **T=Theory Credits** **P=Practical Credits**
GE-01	Chemistry: Statistical Methods and Data Analysis	T=2 P=2
GE-02	Medicines in Daily Life	T=2 P=2
GE-03	Chemistry: Molecular Modeling, Artificial Intelligence and Machine Learning	T=2 P=2
GE-04	Chemistry and Society	T=2 P=2
GE-05	Role of Metals in Medicine	T=2 P=2
GE-06	Energy and the Environment	T=3 P=1
GE-07	Fragrances and Flavors: An Industry's Perspective	T=3 P=1
GE-08	Radio-chemistry in Energy, Medicine and Environment	T=3 P=1
GE-09	States of Matter	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.

8. Teaching-Learning Process

The undergraduate programme in Physical Sciences is designed to provide students with a sound theoretical background, practical training in all aspects of Physical Sciences and research. It will help them develop an appreciation of the importance of Physical Sciences in different contexts. The programme includes foundational as well as in-depth courses that span the interdisciplinary approach in Physical Sciences. Along with the above Core Courses there are DSEs, GEs, SECs, AECs and VACs 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, softwares, simulations, virtual labs etc).

Students will be encouraged 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 convergent and 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, peer-led instruction 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 diligent and active participation/ engagement in industrial visits/ internships/ Academic Projects/ Dissertations will lay a strong foundation for a successful career in academics, industry, 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, group discussion, quiz, assignment etc.) and end of semester examination of University of Delhi.

(i) Internal Assessment or Continuous Evaluation: During a semester, students' mastery of the various learning outcomes as described in the syllabus will be assessed through class tests, assignments, group assignments, laboratory record files, project reports, quizzes, MCQs, 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 summative end-semester Delhi University examinations will be conducted for both theory and practical courses. 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-

A four credit course has a total of 100 marks and a two credit course is of 50 marks. The distribution of 100 marks for each of DSC (2T+2P) /DSE (2T+2P) /GE (2T+2P) course having four credits along with 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)	**2T + 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/ Written Test: 05 Marks **Continuous Evaluation:** 25 Marks Performance Assessment: 15 Marks Record File: 10 Marks
Discipline Specific Elective (DSE)	**2T + 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/ Written Test: 05 Marks **Continuous Evaluation:** 25 Marks Performance Assessment: 15 Marks Record File: 10 Marks

Skill Enhancement Course (SEC)	**0T + 2 P**	NA	**Practical: 50 Marks** **Practical Examination:** 25 Marks: Experiment: 20 Marks Viva Voce/ Written Test : 5 Marks **Continuous Evaluation:** 25 Marks: Performance Assessment: 15 Marks Record File: 10 Marks
GE	**2T + 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/ Written Test: 05 Marks **Continuous Evaluation:** 25 Marks Performance Assessment: 15 Marks Record File: 10 Marks
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

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

Computation of the grade cut offs on a 10-point grading system

Letter Grade	Numerical Grade	Formula	Computation of **Grade** Cut **off**
0 (Outsanding)	10	$m \geq \bar{X} + 2.5\ \sigma$	the value of $\bar{X}$ + 2.5 σ a to be taken into account for grade computation will be Actual $\bar{X}$ + 2.5 σ or90% whichever is lower
A+ (Excellent)	9	$\bar{X} + 2.0\ \sigma \leq m < \bar{X} + 2.5\ \sigma$	the value of $\bar{X}$ + 2.0 σ a to be taken into account for grade computation will be Actual $\bar{X}$ + 2.0 σ or80% whichever is lower
A (Very Good)	8	$\bar{X} + 1.5\ \sigma \leq m < \bar{X} + 2.0\ \sigma$	the value of $\bar{X}$ + 1.5 σ a to be taken into account for grade computation will be Actual $\bar{X}$ + 1.5 σ 70% whichever is lower
B+ (Goods	7	$\bar{X} + 1.0\ \sigma \leq m < \bar{X} + 1.5\ \sigma$	the value of $\bar{X}$ + 1.0 σ a to be taken into account for grade computation will be Actual $\bar{X}$ + 1.0 σ or 60% whichever is lower
B (Above average)	6	$\bar{X} \leq m < \bar{X} + 1.0\ \sigma$	the value of $\bar{X}$ a to be taken into account for grade computation will be Actual $\bar{X}$ or 50% whichever is lower
C (Average)	5	$\bar{X} - 0.5\ \sigma \leq m < \bar{X}$	the value of $\bar{X}$ - 0.5 σ a to be taken into account for grade computation will be Actual $\bar{X}$ - 0.5 σ or 40% whichever is lower
P (Pass)	4	$\bar{X} - \sigma \leq m < \bar{X} - 0.5\ \sigma$	the value of $\bar{X}$ - 1.0 σ a to be taken into account for grade computation will be Actual $\bar{X}$ - 1.0 σ or 30% whichever is lower

The results for the all the Undergraduate courses under the UGCF-2022 shall be based on a 10 point grading system with Letter Grades as per the formula prescribed by the University Grants Commission in the computation of the grade cut offs as shown in **Table 9**.

Table 9: The computation of the grade cut offs on a 10 point grading system with Letter Grades

m is the marks obtained by a student in a particular paper in that semester.

$\bar{X}$ is the average of marks obtained by all the students appeared in that particular paper in that semester.

σ is the standard deviation.

DISCIPLINE SPECIFIC CORE COURSES (DSC)

SEMESTER-I

Course Code DSC-1: CHEMISTRY- I
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 behavior 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).

PRACTICALS: **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.

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 and
- 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

11.1.2: Course Code: DSC-4 CHEMISTRY- II

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 I: 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 II: 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

PRACTICALS: — 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 2 Cr 2 O 7 using

a). internal indicator
b). external indicator

10. Estimation of Cu (II) ions iodometrically using Na 2 S 2 O 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.

Practical:

- 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: DSC-7 CHEMISTRY - III
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, exergenic and endergenic reactions with examples such conversion of ATP to ADP or vice verca,, 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.

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: DSC 10- CHEMISTRY- IV
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 I: 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 II: 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 HNO_2, 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.

PRACTICALS: **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.

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.

4. Pasricha, S., Chaudhary, A. (2021), **Practical Organic Chemistry: Volume II**, I K International Publishing House Pvt. Ltd., New Delhi.

5. Vogel, A.I. (1972), **Textbook of Practical Organic Chemistry**, Prentice-Hall.

6. 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: DSC-13 CHEMISTRY- V

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 I: 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 II: 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 III: 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.

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: DSC-16 CHEMISTRY - VI
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.

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.

CHEMISTRY DISCIPLINE ELECTIVE (DSE) COURSES

Course Code: DSE 1- CHEMISTRY

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

Practicals — 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.

Practicals:

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: DSE-2 CHEMISTRY

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 I: 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 II: 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 III: 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).

PRACTICALS: **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 UVvisible 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.

Practical:

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: DSE -3 CHEMISTRY

Course Title: Inorganic Materials of Industrial Importance

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

Objectives:

The course introduces learners to the importance of Inorganic compounds in Industries. It gives an insight into how the inorganic materials form a basis of the products used in day-to-day life like silicates, fertilizers, surface coatings. The course helps develop the interest of students in the frontier areas of inorganic and material chemistry.

Learning Outcomes:

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

- Learn the composition and applications of the different kinds of glass.
- Understand glazing of ceramics and the factors affecting their porosity.
- Give the composition of cement and discuss the mechanism of setting of cement.
- Explain the suitability of fertilizers for different kinds of crops and soil.
- Explain the process of formulation of paints and the basic principle behind the protection offered by the surface coatings.

Unit 1: Silicate Industries Lectures:10

Glass: Glassy state and its properties, classification (silicate and non-silicate glasses). Manufacture and processing of glass. Composition and properties of the following types of glasses: Soda lime glass, lead glass, armoured glass, different types of safety glass, borosilicate glass, fluorosilicate glass, coloured glass, photosensitive glass, photochromic glass, glass wool and optical fibre.

Ceramics: Brief introduction to types of ceramics. glazing of ceramics.

Cement: Manufacture of Portland cement and the setting process, Different types of cements: quick setting cements, eco-friendly cement (slag cement), pozzolana cement.

Unit 2: Fertilizers Lectures:08

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. Environmental impact of fertilizers.

Unit 3: Surface Coatings Lectures:12

Brief introduction to and classification of surface coatings, paints and pigments: formulation, composition and related properties, pigment volume concentration (PVC)and critical pigment volume concentration (CPVC), fillers, thinners, enamels and emulsifying agents. Special paints: heat retardant, fire retardant, eco-friendly paints, plastic paints, water and oil paints. Preliminary methods for surface preparation, metallic coatings (electrolytic and electroless with reference to chrome plating and nickel plating), metal spraying and anodizing. Contemporary surface coating methods like physical vapor deposition, chemical vapor deposition, galvanising, carburizing, sherardising, boriding, nitriding and cementation.

PRACTICALS: **Credits: 02**

(Laboratory periods: 60)

1. Detection of constituents of CAN fertilizer (Calcium, Ammonium and Nitrate ions) fertilizer and estimation of Calcium content.
2. Detection of constituents of Superphosphate fertilizer (Calcium and Phosphate ions) and estimation of phosphoric acid content.
3. Detection of constituents of Dolomite (Calcium, Magnesium and carbonate ions) and determination of composition of Dolomite (Complexometric titration).
4. Analysis of (Cu, Ni) in alloy or synthetic samples (Multiple methods involving Complexometry, Gravimetry and Spectrophotometry).
5. Analysis of (Cu, Zn) in alloy or synthetic samples (Multiple methods involving Iodometry, Complexometry and Potentiometry).
6. Preparation of following Inorganic Pigments:

   a). Barium white

   b). Chrome Yellow

   c). Malachite

   d). Chromium oxide

   e). Prussian Blue

7. Any suitable experiment other than the listed ones.

References:

Theory:

1. West, A. R. (2014), **Solid State Chemistry and Its Application**, Wiley & sons.
2. Smart, L. E.; Moore, E. A. (2012), **Solid State Chemistry An Introduction**, CRC Press Taylor & Francis.
3. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A.(2010), **Inorganic Chemistry**, W. H. Freeman and Company.
4. Kent, J. A. (ed**)** (1997), **Riegel's Handbook of Industrial Chemistry**, CBS Publishers, New Delhi.
5. Jain P.C., Jain M., **Engineering Chemistry**, Dhanpat Rai & Sons, Delhi.
6. Gopalan R., Venkappaya D.,Nagarajan S., **Engineering Chemistry**, Vikas Publications, New Delhi.
7. Sharma, B.K., **Engineering Chemistry**, Goel Publishing House, Meerut.
8. *Kingery W.D., Bowen H. K., Uhlmann, D.R., (1976*), **Introduction to Ceramics**, Wiley & sons, Delhi.

PRACTICALS:

1. **Vogel's** Quantitative Inorganic Analysis
2. 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:

- 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 based on regular class test, presentations and assignments as a part of internal assessment during the course as per the curriculum.

Semester End University examination will be held for both theory and practicals.

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

Keywords: Silicates, Ceramics, Cement, Fertilizers, Surface Coatings, Batteries, Engineering materials for mechanical construction**.**

Course Code: DSE-4 CHEMISTRY

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 familiarize students with the concepts of sampling, errors in analysis, accuracy, precision and introduce basics of statistical analysis. The course introduces students to important instrumentation and separation techniques routinely used in the laboratory analysis of samples. The experiments expose students to instrumentation and they learn to detect and separate analytes in a mixture.

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

- Understand various sources of errors in chemical analysis.

- Learn about methods to minimize error.
- Understand basic principle of instrumentation (Flame Photometer, UV-vis spectrophotometer, Atomic Absorption spectrophotometer).
- Apply the principles of analysis and instrumentation to analyse soil samples, soft drinks and synthetic mixtures provided in the laboratory.
- Learn basic principles of separation techniques (chromatography and solvent extraction) and apply them to separate mixtures.
- Understand principles of Gravimetric analysis and apply them in determination of Ni^{2+} and Al^{3+}
- Analyse samples independently in the laboratory.

Unit I: Errors in Chemical Analysis — Lectures: 08

Types of errors, Accuracy and Precision, Absolute and relative uncertainty, propagation of uncertainty. The Gaussian distribution, mean and standard deviation, confidence intervals.

UNIT II: Optical methods of analysis — Lectures: 10

Origin of spectra, interaction of radiation with matter, fundamental laws of spectroscopy and selection rules, Beer's-Lambert Law.

UV-Visible Spectrometry

Basic principles of instrumentation for single and double beam instruments. Determination of concentration of unknown compounds, composition of metal complexes using Job's method of continuous variation and mole ratio method.

Flame Atomic Absorption and Emission Spectrometry

Basic principles of instrumentation. Techniques of atomization and sample introduction; Method of background correction, sources of chemical interferences and their method of removal.

Application of these techniques in analysis of samples.

UNIT III: Separation Techniques — Lectures: 12

Solvent extraction

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

Chromatography

Principles of Chromatographic separations, Classification of Chromatographic techniques, Thin Layer Chromatography, Column Chromatography, efficiency of separation (Resolution, Efficiency of Resolution, Plate Height) Application of these techniques in analysis of samples.

PRACTICALS: **Credits: 02**

(Laboratory periods: 60)

1. Analysis of soil**.**
   a) Determination of pH of soil, Total soluble salts, carbonate and bicarbonate, calcium and magnesium by titration.
   b) Estimation of Potassium, calcium and magnesium by flame photometry.
2. Separation of constituents of leaf pigments by thin layer chromatography.
3. Determination of the ion exchange capacity of an anion exchange resin.
4. Determination of the ion exchange capacity of a cation exchange resin.
5. Separation of amino acids by ion exchange chromatography.
6. Spectrophotometric analysis of Co^{2+} and Ni^{2+} ions in a mixture.
7. Spectrophotometric analysis of Caffeine and Benzoic acid in a soft drink
8. Gravimetric estimation of Ni^{2+} using Dimethylglyoxime.
9. Gravimetric estimation of Al^{3+} using oxine.
10. Any suitable experiment (other than the listed ones) based upon analytical techniques discussed in theory section.

References:

Theory:

1. Willard, H.H. (1988), **Instrumental Methods of Analysis**, 7th Edition, Wardsworth Publishing Company.
2. Christian, G.D. (2004), **Analytical Chemistry, 6th Edition**, John Wiley & Sons, New York.
3. Harris, D. C. (2007), **Quantitative Chemical Analysis,6th Edition**, Freeman.
4. Skoog, D.A.; Holler F.J.; Nieman, T.A. (2005), **Principles of Instrumental Analysis**, Thomson Asia Pvt. Ltd.
5. Jeffery, G.H.; Bassett, J.; Mendham, J.; Denney, R.C. (1989), **Vogel's Textbook of Quantitative Chemical Analysis**, John Wiley and Sons.

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. Christian, G.D. (2004), **Analytical Chemistry, 6th Edition**, John Wiley & Sons, New York.
3. Harris, D. C. (2007), **Quantitative Chemical Analysis,6th Edition**, Freeman.
4. Skoog, D.A.; Holler F.J.; Nieman, T.A. (2005**), Principles of Instrumental Analysis**, Thomson Asia Pvt. Ltd.

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 analyze 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: Analytical Chemistry, UV-Visible Spectroscopy, Flame atomic absorption spectrometry, Flame emission spectrometry, Errors in analysis, chromatography, solvent extraction.

Course Code: DSE-5 CHEMISTRY

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).

3. Benzoin condensation using thiamine hydrochloride as a catalyst instead of cyanide.

4. Extraction of D-limonene from orange peel using liquid CO_2 prepared from dry ice.

5. Mechanochemical solvent free, solid-solid synthesis of azomethine using *p*-toluidine and *o*-vanillin/*p*-vanillin.

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.

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: CHEMISTRY- DSE-6

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

Practicals: **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.

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 DSE – 7: CHEMISTRY

Course Title: Polynuclear Hydrocarbons, Pharmaceutical Compounds, UV-Visible & IR Spectroscopy

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

Objectives: The purpose of this course to introduce the chemistry and applications of polynuclear hydrocarbons and heterocyclic compounds. The learners are introduced to spectroscopy, an important analytical tool which allows identification of organic compounds by correlating their spectra to structure.

Learning Outcomes:

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

- Understand the fundamentals of polynuclear hydrocarbons and heterocyclic compounds through the study of methods of preparation, properties and chemical reactions with underlying mechanism.
- Gain insight into the basic fundamental principles of IR and UV-Vis spectroscopic techniques.
- Use basic theoretical principles underlying UV-visible and IR spectroscopy as a tool for functional group identification in organic molecules.

Unit 1: Polynuclear Hydrocarbons **Lectures:05**

Introduction, classification, uses, aromaticity of polynuclear compounds, Structure elucidation of naphthalene, preparation and properties of naphthalene and anthracene.

Unit 2: Pharmaceutical Compounds Lectures: 13

Introduction, classification, general mode of action of antipyretics and analgesics, aspirin; Synthesis, uses and side effects of the following drugs:

Antipyretics - Paracetamol (with synthesis and mode of action); Analgesics- Ibuprofen (with synthesis and overview of the mode of action); Antimalarials - Chloroquine (synthesis and mode of action).

An elementary treatment of Antibiotics and detailed study of chloramphenicol including mode of action. Medicinal values of curcumin (haldi), azadirachtin (neem), vitamin C and antacid (ranitidine)**.**

Unit 3: UV-Visible and IR Spectroscopy Lectures:12

UV-Visible and IR Spectroscopy and their application to simple organic molecules. Electromagnetic radiations and their properties; double bond equivalence and hydrogen deficiency. UV-Visible spectroscopy (electronic spectroscopy): General electronic transitions, λ_{max} & ε_{max}, chromophores &auxochromes, bathochromic & hypsochromic shifts. Application of Woodward rules for the calculation of λ_{max} for the following systems: conjugated dienes - alicyclic, homoannular and heteroannular; α, β-unsaturated aldehydes and ketones, charge transfer complex.

Infrared (IR) Spectroscopy: Infrared radiation and types of molecular vibrations, the significance of functional group & fingerprint region. IR spectra of alkanes, alkenes, aromatic hydrocarbons (effect of conjugation and resonance on IR absorptions), simple alcohols (inter and intramolecular hydrogen bonding and IR absorptions), phenol, carbonyl compounds, carboxylic acids and their derivatives (effect of substitution on >C=O stretching absorptions).

PRACTICALS: Credits: 02

(Laboratory periods: 60)

1. Isolation and estimation of the amount of aspirin in a commercial tablet.
2. Synthesis of ibuprofen.
3. Systematic qualitative identification and derivative preparation of organic compounds (Aromatic hydrocarbons, Aryl halides)
4. Detection of simple functional groups through examination of IR spectra (spectra to be provided). IR spectra of simple compounds like phenols, aldehydes, ketones, carboxylic acids may be given.

5. Differentiation between of o-/p-hydroxybenzaldehyde by IR spectroscopy (Spectra to be provided).
6. Differentiation between benzoic acid and cinnamic acid by UV spectroscopy.
7. Laboratory preparation of Paracetamol.
8. Diel's Alder reaction using Anthracene and Maleic anhydride.

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. **Organic Chemistry,** Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
3. Bahl, A; Bahl, B. S. (2012), **Advanced Organic Chemistry**, S. Chand.
4. Pavia, D.L. **Introduction to Spectroscopy**, Cengage learning (India) Pvt. Ltd.
5. Kemp, W. (1991), **Organic Spectroscopy**, Palgrave Macmillan.

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. Vogel, A.I. (1972), **Textbook of Practical Organic Chemistry**, Prentice-Hall.
4. 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 I**, I K International Publishing House Pvt. Ltd., New Delhi.

Teaching Learning Process:

- Conventional chalk and board teaching
- Class interactions and discussions
- Power point presentation on important topics.
- Teaching Learning process is largely student focused
- Engaging students in cooperative learning.

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: Polynuclear hydrocarbons, Pharmaceutical compounds, UV-visible spectroscopy; IR spectroscopy;

Course Code: DSE – 8: CHEMISTRY
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.

Practicals: **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. Preparation of Methyl Orange.
6. (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.

7. Qualitative test for identification of alkaloids (Dragendorff Reagent and Mayer's reagent test) and terpenoids (Salkowski test).

8. Preparation of perichromic dye using p-amino Phenol and p-nitro benzaldehyde.

References:

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: DSE – 9 CHEMISTRY
Course Title: Chemistry of Colloids and Adsorption
Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives: The course focuses upon basic concepts of colloids and colloidal phenomenon. Preparation and characterization of sols, understanding about applications of colloid in food, petroleum and cosmetic industry. Basic understanding of adsorption, types of adsorptions, chemistry of adsorption and its applications.

Learning Objectives:

On completion of the course, the student will be able to:

- Understand colloid solutions, preparation of sols.
- Understand the concept of Electrical double layer, charge on colloidal particles.
- Characterize the colloids sols, learn colloid phenomenon like Tyndall effect, Brownian movement, electrophoresis, dialysis, coagulation and flocculation.
- Understand adsorption, types of adsorption. Characteristics, factors affecting adsorption and its applications

Unit I: Colloidal State — Lectures: 12

Distinction among true solutions, colloids and suspensions, components of Colloids, classification of colloids - lyophilic, lyophobic; Preparation methods and properties of lyophobic solutions, Hydrophile-lyophile balance (HLB), multi molecular, macromolecular and associated colloids (micelles formation), Schulze -Hardy law.

Unit II: Preparation and properties of colloids — Lectures: 10

Methods of preparation of colloids, Tyndall effect, Brownian movement, coagulation and flocculation; electrophoresis, dialysis.

Emulsification by surfactants, selection of surfactants as emulsifying agent, colloidal phenomenon in food chemistry, Protein based functional colloids.

UNIT II: Surface Chemistry — Lectures: 08

Adsorption, Distinction between adsorption and absorption, Types of Adsorption, Physisorption and chemisorption and their characteristics, factors affecting adsorption of gases

on solids - Freundlich and Langmuir adsorption isotherms, Adsorption from solutions. Applications of Adsorption phenomenon in living systems.

PRACTICALS: **Credits: 02**

(Laboratory periods: 60)

1. Preparation of Colloidal Sols of following
   a. Arsenic sulphide,
   b. Antimony sulphide
   c. Ferric chloride
   d. Aluminum hydroxide
2. To find out the precipitation values of arsenious sulphide sol by using monovalent, bivalent and trivalent cations.
3. To verify the Schulze -Hardy law.
4. To verify the Freundlich's Adsorption isotherms.
5. Study of adsorption of HAc on charcoal and prove the validity of Langmuir's adsorption isotherms
6. Study of adsorption of Oxalic acid on charcoal and prove the validity of Langmuir's adsorption isotherms.

References:

Theory:

1. Principles of Physical Chemistry, Puri, Sharma and Pathaniya (2020) Vishal Publishing Co. Jalandhar, Punjab, India
2. Text Book of Physical Chemistry, K L Kapoor, Vol. 4 McGraw Hill Education (India) Private Limited, Chennai, India.
3. Evans and Wennerström's book The Colloidal Domain, Second Edition. (Wiley)
4. A. W. Adamson and A. Gast, Physical Chemistry of Surfaces (Main text)
5. J. C. Berg, An Introduction to Interfaces and Colloids
6. J. N. Israelachvili, Intermolecular and Surface Forces

Practical:

1. Giri, S; Bajpai, D.N.; Pandey, O.P. **Practical Chemistry**, S. Chand Limited.
2. Khosla, B.D.; Garg, V.C.; Gulati, A.(2015), **Senior Practical Physical Chemistry**, R. Chand & Co.

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: Colloids, Sol, Tyndall Effect, Emulsions, Physisorption, Chemisorption, Adsorption Isotherms.

Course Code DSE- 10: CHEMISTRY

Course Title: Conductance, Electrochemistry and Chemical Kinetics

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

Objectives: In this course the students will learn about electrolytic and galvanic cells, measurement of conductance and its applications, measurement of emf and its applications. 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:

- Explain the factors that affect conductance, migration of ions and application of conductance measurement.
- Understand the importance of Nernst equation, measurement of emf, calculations of thermodynamic properties and other parameters from the emf measurements.
- Understand rate law and rate of reaction, theories of reaction rates and catalysts; both chemical and enzymatic.

Unit 1: Conductance — 8 Lectures

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes, Kohlrausch Law of independent migration of ions, Ionic velocity, mobility and their determination, transference number and its relation to ionic mobility, Conductometric titrations (only acid-base).

Unit 2: Electrochemistry — 12 Lectures

Concept of reversible and irreversible electrochemical cells, Standard hydrogen electrode, standard electrode potential, concept of EMF of a cell, measurement of EMF of a cell, Nernst equation and its importance, types of electrodes (Reference and inert electrodes), electrochemical series.

Thermodynamics of a reversible cell, calculation of thermodynamic properties: G, H and S from EMF data. Calculation of equilibrium constant from EMF data. pH determination using glass electrode, Potentiometric titrations-qualitative treatment (acid-base and oxidation-reduction only).

Unit 3: Chemical Kinetics and Catalysis — 10 Lectures

The concept of reaction rates, effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction, integrated rate equations for zero, first and second order reactions (derivation not required), half–life of a reaction, Concept of activation energy and its calculation from Arrhenius equation.

Catalysis: Types of catalyst, specificity and selectivity, generalized treatment of catalyzed reactions at solid surfaces. Enzyme catalysis, Michaelis-Menten mechanism, acid-base catalysis.

Practicals: — Laboratory periods: 60

1. Determination of molar conductance, degree of dissociation and dissociation constant of a weak acid.
2. Perform the following conductometric titrations: Strong acid vs strong base.
3. Perform the following conductometric titrations: Weak acid vs strong base.
4. Determination of TDS of water from different sources.
5. Determination of Soil pH of soil collected from various locations.
6. Perform the potentiometric titrations of strong acid vs strong base
7. Perform the potentiometric titrations of Weak acid vs strong base.
8. Perform the potentiometric titrations of Potassium dichromate vs. Mohr's salt.
9. Perform the potentiometric titrations of $KMNO_4$ vs. Mohr's salt.
10. Study the kinetics of acid hydrolysis of methyl acetate with hydrochloric acid.

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.5, 3rd Edition, McGraw Hill Education.
4. Puri, B.R., Sharma, L.R. and Pathania M.S. (2020),**Principles of Physical Chemistry,** Vishal Publishing Co.

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.

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: Rate law, Order of reaction, Activation Energy, Conductance, Transference Number, Electrode potential, Electrochemical series.

Course Code: DSE – 11 CHEMISTRY

Course Title: Phase Equilibria and Photochemistry

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

Objectives: This course aims to make the students understand the concept of Phase, Component, Degree of freedom, basic principles of phase equilibria, Phase diagram of one, two and three component systems. The students will also gain an understanding of Binary solution, distillation

of binary solution, CST and distribution law & its applications.

Learning Outcomes*:*

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

- Understand phase equilibrium, criteria, CST, Gibbs-Duhem-Margules equation.
- Apply the concepts of phase, conductance and distribution law while studying other chemistry courses and every-day life.
- Explain low and high quantum yield, photosensitized reactions

Unit1: Phase Equilibria **Lectures: 22**

Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems;

Clausius-Clapeyron equation and its applications to solid- liquid, liquid-vapour and solid-vapour equilibria,

Phase diagram for one component systems (H_2O and S). Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points.

Binary solutions: Gibbs-Duhem-Margules equation, its derivation and applications to fractional distillation of binary miscible liquids (ideal and non-ideal), azeotropes, lever rule, partial miscibility of liquids, CST, miscible pairs,steam distillation. Nernst distribution law: its derivation and applications.

Unit 2: Photochemistry **Lectures: 08**

Characteristics of electromagnetic radiation. Lambert-Beer's law and its limitations, physical significance of absorption coefficients. Laws of photochemistry, quantum yield, examples of low and high quantum yields

Photosensitized reactions, Jablonski's diagram. Role of photochemical reactions in biochemical processes, chemiluminescence.

PRACTICALS: **Credits: 02**

(Laboratory periods: 60)

Phase Equilibrium

1. Determination of critical solution temperature and composition at CST of the phenol water system.
2. Effect of impurity on CST of phenol-water system (NaCl and succinic acid).
3. Construction of the phase diagram using cooling curves :
   (i) Simple eutectic.
   (ii) Congruently melting systems.
4. Distribution of acetic/ benzoic acid between water and chloroform or cyclohexane.
5. Study of equilibrium of any one of the following reactions by distribution method:

(i) I_2 (aq) + I^- (aq) ⇌ I_3^-(aq)
(ii) Cu^{2+} (aq) + nNH_3⇌ $[Cu(NH_3)n]^{2+}$

References:

Theory:

1. Atkins, P.W.; Paula, J.de. (2014), **Atkin's Physical Chemistry Ed**., 10th Edition, Oxford University Press.
2. Ball, D. W. (2017), **Physical Chemistry**, 2nd Edition, Cengage Learning, India.
3. Castellan, G. W. (2004), **Physical Chemistry**, 4th Edition, Narosa.
4. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol 1, 6th Edition, McGraw Hill Education.
5. Kapoor, K.L., **A Textbook of Physical Chemistry**, Vol 3, 5th Edition, McGraw Hill Education.

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. Moore, W.J. (1972), **Physical Chemistry**, 5th Edition, Longmans Green & Co. Ltd.
2. Glasstone, S. (1948), **Textbook of Physical Chemistry**, D. Van Nostrand company, NewYork.

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:
Phase rule, Phase diagram of one-component system, Eutectic, Congruent, Incongruent, Raoult's,law, Gibbs-Duhem-Margules, Critical solution temperature.

Course Code: DSE – 12 CHEMISTRY

Course Title: Biophysical Chemistry

Total Credits: 04 (Credits: Theory-02, Practical-02)
Total Lectures: Theory- 30, Practical-60

Objectives: The objective of the course is to provide students with a sound background of latest techniques used in biophysical research and to provide them with an understanding of the principles underlying these techniques.

Learning Objectives:

On completion of the course, the student will be able to:

1. The students will acquire knowledge of structure and biological functions of proteins and enzyme.
2. Students will acquire knowledge about the principles and applications of latest methodsused to analyse amino acid and proteins.
3. The course will also provide students an opportunity for hands-on-experience to develop their laboratory skills expected for working in a biophysical research lab.

Unit I: Fundamentals of Biological Macromolecules Lectures: 10

Structure and physical properties of amino acids, structure, function, and folding of proteins, internal rotational angle, conformations of proteins (Ramachandran plot, secondary, tertiary and quaternary structure). Structures of nucleic acids, Properties of nucleosides and nucleotides; composition of nucleic acids, Stabilizing interactions in biomolecules.

Unit II: Biophysical techniques for the Structural and Conformational Analysis

Lectures: 20

Overview: X-ray crystallography, Single and multidimensional NMR spectroscopy, UV-vis absorption spectroscopy, Circular dichroism (CD) spectroscopy, Fluorescence spectroscopy and Vibrational spectroscopy. Determination of protein structures by spectroscopic methods (CD, FTIR, NMR), thermodynamics of protein folding by spectroscopic and calorimetric methods, ultrafast folding dynamics study by laser flash photolysis, protein conformational study by NMR and fluorescence spectroscopy, measurement of hydrodynamic radii by dynamic light scatter. Methods for the separation of biomolecules: General principles, including Chromatography; Sedimentation, Moving Boundary Sedimentation, Zonal Sedimentation, Electrophoresis, Isoelectric focusing, Capillary electrophoresis, MALDI-TOF.

PRACTICALS: **Credits: 02**

(Laboratory periods: 60)

1. To determine the isoelectric point of the given proteins.
2. To check the purity of the proteins by calculating A260/ A280 ratio spectrophotometrically
3. To carry out SDS PAGE for the separation and purification of proteins.
4. To perform Agarose gel electrophoresis to check the size of DNA (For example- Calf Thymus DNA)
5. To Characterize the DNA(genomic/ designed oligonucleotide) as a function of pH, salt concentration spectrophotometrically
6. To determine the isobestic point by titrating DNA sample with any ligand using UV- Visible spectrophotometer.

References:

Theory:

1. Lesk, A.M., **Introduction to Protein Science: Architecture, Function, and Genomics**, 2nd edition, 2010, OUP.
2. Cantor, C.R. and Schimmel, P.R., **Biophysical Chemistry**, 1980, Freeman.
3. van Holde, K.E., Johnson, W.C. and Ho, P.S., **Principles of Physical Biochemistry**, 2nded, 2006, Pearson Education.
4. Harding, S.E. and Chowdhry, B. Z. **Protein-Ligand Interactions**, 2001, Oxford University Press.

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 vivavoce.

Keywords: Proteins, Enzymes, Protein structure, Protein folding, Spectroscopic techniques.

Course Code: DSE-25 CHEMISTRY

Course Title: Research Methodology for Chemists

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

Objectives: To make the students aware of fundamental but mandatory ethical practices in chemistry. To make the students aware of data analysis. To make the students aware of literature survey in different modes. To make the students aware of safety handling and safe storage of chemicals. This paper will help student to learn to avoid plagiarism. To learn different e-resources.

Learning Outcomes:

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

- Understand ethical practices in chemistry
- Carry out Data analysis
- Carry out literature survey in different modes
- Use e-resources for research
- Understand plagiarism, consequences and how to avoid

Theory:

Unit 1: Scope of Research — Lectures: 03

Introduction, overview of research process: define research problem, review literature, formulate hypothesis, design research/experiment, collect and analyse data, interpret and report, scope and importance

Unit 2: Literature Survey, Databases and Research metrics — Lectures: 08

Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, Digital: Databases and their responsible use: Google Scholar, Scopus SciFinder, Search techniques: Phrase, Field, Boolean, Proximity, Concept, Limiting/Refining Search Results

Research metrics: Impact factor of Journal, h-index, i10 index, Altmetrics, Citation index.

Unit 3: Communication in Science — Lectures: 08

Types of technical documents: Full length research paper, book chapters, reviews, short communication, project proposal, Letters to editor, and thesis.

Thesis writing – different steps and software tools (Word processing, Chemdraw etc) in the design and preparation of thesis, layout, structure (chapter plan) and language of typical reports, Illustrations and tables, bibliography, referencing: Styles (APA, Oxford etc), annotated

bibliography, Citation management Tools: Mendeley; Oral presentation/posters – planning, software tools, creating and making effective presentation, use of visual aids, electronic manuscript submission

Unit 4: Research and Publication ethics **Lectures: 05**

Publication Ethics: Introduction, COPE (Committee on Publication Ethics) guidelines; Conflicts of interest, Publication misconduct: problems that lead to unethical behaviour and vice versa, violation of publication ethics, authorship and contributorship, software tools for finding plagiarism (Turnitin, Urkund etc), redundant publications

IPR - Intellectual property rights and patent law, commercialization, copy right, royalty, trade related aspects of intellectual property rights (TRIPS)

Unit 5: Statistical analysis for chemists **Lectures: 06**

Types of data, data collection-Methods and tools, data processing, hypothesis testing, Normal and Binomial distribution, tests of significance: t-test, F-test, chi- square test, ANOVA, multiple range test, regression and correlation.

Features of data analysis with computers and softwares-Microsoft Excel, Origin, SPSS

Practicals: **Credits: 02**

(Laboratory periods: 60)

1. Collection of journal articles on a particular topic using Google Scholar and creating a database.
2. Collection of journal articles on a particular topic using Science Direct and creating a database.
3. Collection of journal articles on a particular topic using Scopus and creating a database.
4. Collection of chemical structure using ChemSpider and creating a database.
5. Collection of chemical structure using SciFinder and creating a database.
6. Curve fitting using freely available softwares/apps (any one)
7. Making of power point presentation
8. Poster presentation on defined topics.
9. Technical writing on topics assigned.
10. Demonstration for checking of plagiarism using recommended software

Reference:

1. Dean, J. R., Jones, A. M., Holmes, D., Reed, R., Weyers, J. & Jones, A. (2011) **Practical skills in chemistry**. 2nd Ed. Prentice-Hall, Harlow.
2. Hibbert, D. B. & Gooding, J. J. (2006) **Data analysis for chemistry**. Oxford University Press.
3. Topping, J. (1984) **Errors of observation and their treatment**. Fourth Ed., Chapman Hall, London.
4. Harris, D. C. **Quantitative chemical analysis**. 6th Ed., Freeman (2007) Chapters 3-5.

5. Levie, R. de, **how to use Excel in analytical chemistry and in general scientific data analysis**. Cambridge Univ. Press (2001) 487 pages.
6. **Chemical safety matters – IUPAC – IPCS**, Cambridge University Press, 1992.
7. OSU safety manual 1.01.

Teaching Learning Process:

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

Assessment Methods:

- Internal assessment through assignments and class test.
- End semester written and practical examination.

Keywords: Research methodology, Literature Survey, Chemical Safety, safe storage, disposal, Ethical Handling, Data Analysis, print, digital and Information Technology and Library Resources.

Course Code: DSE – 26 CHEMISTRY

Course Title: Computer Applications in Chemistry

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 will help them in solving chemistry problems using spreadsheets and BASIC language. It acquaints the students with different software for data tabulation, calculation, graph plotting, data analysis and document. preparation. The students will also learn about the molecular modelling, its applications to various molecular systems, energy minimization techniques, analysis of Mulliken Charge and ESP Plots.

Learning Objectives:

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

- Become familiar with the simple use of BASIC language.
- 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 Energy minimization methods through use of different force fields.
- Learn ESP Plots by suitable soft wares, 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 I: Programming using BASIC — Lectures: 20

Programming Language – Elements of BASIC language, Numeric and string Constants and Variables, arithmetic expressions, hierarchy of operations, inbuilt functions. Syntax and use of the various QBASIC commands: REM, CLS, INPUT, PRINT, GOTO, IF, IF….THEN, IF..THEN..ELSE, IF and END IF, FOR and NEXT etc., DIM, READ, DATA, GOSUB, RETURN, RESTORE, DEF FNR and Library Functions, Simple programs based on usage of the commands mentioned above.

Statistical analysis using BASIC: Mean, Least square fit - Linear regression, variance, standard deviation.

UNIT II: Handling of Numerical Data — Lectures: 5

Spreadsheet software: MS Excel. Creating a spreadsheet, entering and formatting information, 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 III: Molecular Modelling — Lectures: 5

Introduction to molecular modelling, overview of classical and quantum mechanical methods (molecular mechanics, semi empirical, ab initio and DFT), general considerations and comparison of these methods.

PRACTICALS: — Credits: 02

(Laboratory periods: 60)

Exercises of Programing

1. Calculate pressure of a real gas using Van der Waal's Equation.
2. Calculate the most probable speed, average speed and root men square velocity of an ideal gas.
3. Roots of quadratic equations
4. Binomial coefficient using GOSUB statement.
5. Mean, standard deviation
6. Least square curve fitting method for linear equation.

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 and determine the pK_a of the weak acid

5. Plot the graphs for the kinetics of first order reaction and determine the rate constant
6. Plot the UV-vis absorbance spectra and determine the molar absorption coefficient.

Molecular Modelling

1. Optimize and compare the geometry parameters of H_2O and H_2S using Argus Lab.
2. Compare the basicities of N atom in ammonia, methylamine, dimethylamine and trimethylamine using Argus Lab by comparing Mulliken charges and ESP map in Argus Lab.
3. Compare C-C bond lengths and bond order in ethane, ethene and ethyne using Argus Lab.
4. Determine enthalpy of isomerization of cis and trans-2-butene in Argus Lab.
5. 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. Venit, S.M. (1996),**Programming in BASIC: Problem solving with structure and style**. Jaico Publishing House.
3. Lewars, E. (2003), **Computational Chemistry,** Kluwer academic Publisher.
4. Cramer, C.J.(2004), **Essentials of Computational Chemistry,** John Wiley & Sons.
5. Hinchcliffe, A. (1996), **Modelling Molecular Structures,** John Wiley & Sons.
6. Leach, A.R.(2001), **Molecular Modelling,** Prentice-Hall.

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.

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:

Software, BASIC, spreadsheet, Molecular modelling, Quantum Mechanical Method, Force Field, charts, tables, graphs.

SKILL ENHANCEMENT COURSES (SEC)

Note: These are suggested SEC courses. A student may however choose any SEC from the central pool of Chemistry/Physics/Maths

Course Code: CHEMISTRY- SEC I

Course Title: Chemistry Lab Standard Operations and Safety Measures

Total Credits: 02 (Credits: Theory-00, Practical-02)

Total Lectures: Theory- 00, Practical-60

Objectives: The course is aimed at introduction to a Chemistry Laboratory and cultivation of working skills in chemistry laboratory among the students for enhanced learning and to create a trained workforce which can responsibly learn imbibe and explore verticals on structured knowledge safely, as envisaged in the syllabi of the discipline.

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

- Conversant about the safe working practices in chemistry laboratory.
- Familiar with different glass apparatus
- Able to handle the apparatus, chemicals and equipment safely properly.
- Able to understand working protocols related to various methods and instruments in chemistry laboratory.

Practical/ Hands-on Training:
Credits: 02

(Laboratory periods: 60)

Part A: Safety Measures

1) Design an illustrative chart exhibiting creativity at transaction of Do's and Don'ts instructions for working in a chemistry laboratory.
2) i. Carry out Classification and labelling of the given set of chemicals based upon Globally Harmonized System.

   ii. Carry out detailed survey of the Chemical Abstract Service (CAS) Registry Number and identify the given set of CAS RN and explain the different sections of CAS RN.

3) Carry out preparation of the indicative MSDS (Material Safety Data Sheet) of given set of chemicals as per standard MSDS format.

4) Design an illustrative chart exhibiting creativity at transaction of Common Safety Symbols along with its description. Associate appropriate safety symbol with each of the given set of chemicals.
5) Draw and elucidate the National Fire Protection Association Hazard Labels.
6) i. Identify and enlist the Incompatible Chemicals from a given set of chemicals available in the laboratory.

   ii. Carry out investigations on Labelling and storage of Chemical in laboratory.

7) i. On the basis of MSDS analysis, identify the required storage conditions for the given set of chemicals.

   ii. Describe procedure for the storage, maintenance and handling of compressed gas cylinders.

   iii. Explore guidelines for the Storage of shelf chemicals and reagents.

8) i. Carry out a brief review of common pathways by which working Chemicals can enter the Body.

   ii. Carry out a detailed study of the Limits of Exposure of given Chemicals.

9) i. Classify the Hazard based on storage, handling, and disposal of chemicals.

   ii. Identification and describe handling protocols for Substances with Greater Hazardous Nature.

10) Carry out detailed investigations on procedural protocols for safe Disposal of Chemicals.
11) i. Carry out study on recommended Safety and Emergency Equipment essential for the safe practices in a Chemistry Laboratory.

   ii. Study the guidelines in the Event of a Chemical Accident or Spill.

12) i. Write detailed description on Fire Safety in the laboratory.

   ii. Carry out investigations of the data regarding Institute Safety Policies: Safety Audits / Inspections.

Part B: Chemistry Lab Standard Operations

1) Carry out exploration on Holding, Handling and use of Common Laboratory Apparatus as per given list of laboratory apparatus (Appendix A).
2) Carry out investigations of various types of apparatus in labs based on material they are made of such as Pyrex Glass (borosilicate Glass) Apparatus, Fused Silica Apparatus: Corning Vycor Glass, Porcelain apparatus, Plastic Apparatus, Metal Apparatus.
3) Understanding the protocol of Cleaning and drying and polishing of Glassware apparatus.

4) Carry out detailed investigations on Identification, diagrammatic representation, set up of Apparatus assemblies and details exploration on operational procedural protocols for glassware apparatus with Interchangeable ground glass joints: Typical Assemblies.

5) i. Carry out calibration of Volumetric/ Graduated Glassware Apparatus along with description on Temperature Standards.

ii. Carry out Calibration of thermometers.

6) i. Carry out exploration and investigations of working protocol for various heating equipment in laboratory: Burners, Hot Plates, Electrical Heating Mantles, Electric Oven, Microwave Oven, Muffle Furnace, Infrared lamps, Crucible and Beaker Tongs and Emersion heaters.

ii. Carry out exploration and investigations of working protocol for various Stirring apparatus in laboratory: Stirring rods; Policeman, Boiling rods, Use of Mechanical agitation-Magnetic Stirrer and Mechanical Shaker.

iii. Carefully analyze the Glass, Cork and Rubber Stoppers and investigate their preparation and appropriate applications.

7) i. Carry out detailed investigations of Heating and Cooling Bath, and determine their working ranges and working protocols.

ii. Explore and differentiate between different forms of water for Laboratory Use: Distilled (Grade I to III), De-ionized and tap water, and carry out conductance measurement /other analytical investigations for the differentiation purpose.

8) i. Differentiate among Various types of Filter Paper and explore their applications.

ii. Preparation of a fluted filter paper and its advantages.

iii. Classification of reagents as AR/ GR grade.

9) i. Care and Use of Analytical Balance: Mass and Weight, Two-Pan Balance and Electronic Balance.

ii. Carry out Calibration of weighing balances and accuracy in measurement.

10) Introduction to Chromatographic adsorption: Paper and Thin Layer Chromatography.

Preparation of Thin Layer Chromatography (TLC) Plates.

11) i. Use of melting point apparatus. Experimental determination of the melting point using various methods.

ii. Experimental determination of the boiling point using various methods.

12) To Purify given organic solvents.

13) i. Hand on training for working with typical assemblies of apparatus for distillation and refluxing.

ii. Assessment of Fire hazards attending the distillation of inflammable solvents.

14) i. Purification of given solid organic compounds by crystallisation method.

ii. Recrystallization of given non-volatile organic solids and outline the Difficulties encountered in recrystallization process.

15) Removal of traces of colouring matter and use of decolourising carbon.

16) i. Carry out exploration and investigations of working and working protocol for Filtration Apparatus: Filtration with suction.

ii. Explore and imbibe knowledge about types of Vacuum Pump; Water and Oil Pump and their applications.

17) Investigate Conventions for Drying of the recrystallized material.

18) i. Introduction to Gas absorption traps and their importance.

ii. Recrystallization in an atmosphere of inert gas.

19) i. Performing Evaporation of the solvent in the laboratory.

ii. Preparation of anhydrous liquids or solutions of organic compounds in organic solvents.

20) i. Various procedures for the precipitation and washing of the precipitates.

ii. Application of various methods and instruments for drying of solid organic compounds.

21) i. Incineration of Filter paper with precipitate.

ii. Differentiate between various types of centrifugation methods, principle, uses and application of centrifugation method.

iii. Calculation of yields for different chemical processes.

22) In-depth Understanding and Preparation of Chemical Laboratory Reagents.

23) Explore methodologies of Preparation and Storage of Standard Solutions.

Important Instruction Note on working approach:

- A minimum of 5 exercises from Part A and 10 exercises from Part B is required to be diecussed/performed/investigate. Moreover, exercises related to MSDS, CASRN safety symbols identification is required to be performed mandatorily.

Mandatory exercises:

Part A Exercise No.:- 2, 3, 4, 5 and 9

Part B Exercise No.:- 1 to 10.

- 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.

References:

1. Skoog D.A., West D.M., Holler F.J., Stanley R.C., **Fundamentals of analytical chemistry**, 9th Edition, Cengage Learning.
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. Garland, C. W.; Nibler, J. W.; Shoemaker, D. P.(2003),**Experiments in Physical Chemistry**, 8th Edition, McGraw-Hill, New York.
5. https://iupac.org/
6. 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: Glass apparatus, Reagents, Safety measures, Laboratory guidelines.

Course Code: CHEMISTRY- SEC - 2

Course Title: CHEMISTRY: IT SKILLS & DATA ANALYSIS

Total Credits: 02 (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/ Hands-on Training:
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 - 3

Course Title: Chemistry of Cosmetics and Toiletries

Total Credits: 02 (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

Practicals: **Credits: 02**

(Laboratory periods: 60)

1. Definition, History and Classification of cosmetic & cosmeceutical products.

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

2. **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

3. **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

4. **Nail preparation**: Structure of nail, Nail lacquers, Nail polish remover. General Ingredients and preparation of:

(a) Nail polish and nail polish remover

5. **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

6. **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:

1. Flick, E.W. (1990), **Cosmetic and toiletry formulations,** Noyes Publications / William Andrew Publishing.
2. Natural Ingredients for Cosmetics; EU Survey 2005
3. Formulation Guide for cosmetics; The Nisshin OilliO Group, Ltd.
4. 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/powerpoint 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 - 4

Course Title: Materials Characterization Techniques

Total Credits: 02 (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/ Hands-on Training:
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.

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-5

Course Title: Chemical Aspects of Forensic Science

Total Credits: 02 (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

11.3.6 Course Code: CHEMISTRY- SEC-6

Course Title: Green Methods in Chemistry

Total Credits: 02 (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.

Practicals: **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.

Preparation of propene by two methods can be studied

(I) Hoffman elimination

(II) Dehydration of propanol

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

3. 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.

4. 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

5. 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.

6. 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.

7. 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

8. 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.
5. Matlack, A.S. (2010), **Introduction to Green Chemistry**, 2nd Edn., CRC Press.
6. Alhuwalia, V.K.; Kidwai, M.R. (2012), **New Trends in Green chemistry**, Kluwer Academic Publishers, Springer.
7. Sidhwani, I.T; Sharma, R.K. (2020), **An Introductory Text on Green Chemistry**, Wiley India Pvt Ltd.
8. Etzkorn, F. A . (2019), **Green Chemistry: Principles and Case Studies**, Royal Society of Chemistry.

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.

GENERIC ELECTIVES COURSES (GE)

Note: These are suggested GE courses. A student may however choose any GE from the central pool for Chemistry/Physics/Mathematics

Course Code: CHEMISTRY- GE-1

Course Title: Chemistry: Statistical Methods and Data Analysis

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

Objective: In this course the students will be given insight about the statistical treatment on the chemical analysis data along with illustration about the analysis of collected analytical data to take up a job of technician, scientist and laboratory manager. The presentation of data in different form such as "Table, Graph, Bar Diagram, Pie Chart, Venn diagram" are explained along with their reliability and validity.

Learning outcomes:

At the end of this course student will be:

- Familiar with interpretation and use of analytical data collected by different techniques,
- Significance of different analytical techniques and their applications,
- Reliability and presentation of data for reporting to different forum.

Theory:

Unit 1: Basics of Chemical Analysis **Lectures: 6**

Analytical Chemistry, Qualitative and quantitative analysis, Analytical methodology. Calibration of glass wares, recording laboratory data.

Unit 2: Different Methods of Analysis **Lectures: 8**

Titrimetric method: volumetric titrimetry, standard solution, titrimetric curve, calculation; Gravimetric method: precipitation gravimetry, calculation and applications of gravimetry; and Spectrometric methods: introduction, principle and instrument, working quantitative aspects absorbance, applications in chemical analysis

Unit 3: Statistical Method of Chemical Analysis **Lectures: 8**

Accuracy and Precision, Comparison of precision, Errors, Distribution of random errors, propagation of errors, measurement of errors, significant figure, inter laboratory error, methods of least square analysis of variance, Q test, Z test, T test, statistical treatment of finite sample, recommendations for treating outliers. Minimising errors in analytical procedure.

Unit 4: Data Analysis and Validation **Lectures: 5**

Confidence interval, Testing of hypothesis, plotting of data, least square method, Figures of merit: sensitivity, detection limit, linear dynamic range, control test, upper control limit and lower control limit, Validation, reporting analytical results and significant figures

Unit 5: Sampling, Standardisation, Labelling and Calibration **Lectures: 7**

Analytical samples, sample size, constituent sample, real samples, sample, sample handling, preparing laboratory samples, automated sample handling, lab on chip and General laboratory principles, recording laboratory data, standards, comparison of standards, internal standard, external standards calibration, least square method, and multivariant calibration.

Practicals:
Credits: 02

(Laboratory periods: 60)

1. Calibrate the volume of laboratory glass wares i.e. volumetric flask, beaker, burette and calibration constant.
2. Demonstrate the good laboratory practices like effect of dilution, temperature, taking observation, personal and apparatus safety.
3. Determine the quantitative presence of heavy metals like copper, chromium and iron in natural and laboratory samples using volumetric and gravimetric titration.
4. Determine the presence of magnesium ion in heavy water by EDTA method and prepare calibration curve.
5. Evaluate the absolute and method errors in a set of data collected during determination of nitrogen in an organic compound.
6. Calculate the standard deviation and predict precision of analytical results.
7. Determine the concentration of pollutant in natural sample after using external standards methods.
8. Compare the inter laboratory error of a spectroscopic results.
9. Evaluate the limit of detection for colorimetric analysis of dyes and coloured metals in wastes water samples.
10. Demonstrate the control of interference by masking by complexation.
11. Report the ten analytic results in significant numbers along with standard deviation.
12. Determine the confidence limit and interval for a laboratory instrument like breath alcohol analyser
13. Demonstrate the internal standard method for calibration of metal estimation.
14. Estimate the comparative effectiveness of different types of graphs like line, pi chart and bar graph.
15. Demonstrate the working of lab on chip like glucose sensor.

References:

1. Dey, R. A. and Underwood, A. L., **Quantitative Analysis**, 6th Edition, Pearson.
2. Skoog, D. A., West, D. M., Holler, F. J., Crouch, S. R., **Fundamental analytical chemistry**, Thomson Asia Ltd.
3. Meyor, R. A. (Eds), **Encyclopaedia of analytical chemistry: Applications, Theory, and Instrumentation**, Wiley and Sons (2000).

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 for enhanced understanding of the concepts
- Engaging students in collaborative learning.
- Pre-lab learning of theoretical concept of the experiment.
- Performing the experiment, recording the data, calculating the result.
- Interpreting the result.
- Comparing the results of the class.
- Discussing the sources of error.

Assessment Methods:

- Class Tests at Periodic Intervals.
- Written assignment(s)
- Continuous evaluation of laboratory work and record file.
- Oral assessment, quizzes.
- Mock practical examination.
- Semester end University examination.

Keywords: Chemical analysis**,** Statistical method, Sampling, Standardisation, labelling and calibration.

Course Code: CHEMISTRY- GE-2

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.

Theory:

Unit 1: General Introduction Lectures: 8

Introduction-Health, disease, drugs, chemotherapy, approaches in drug designing, classification of drugs and their origin.

Unit 2: Different class of medicines Lectures: 22

Structure of active ingredients, uses, dosage, side effects and their natural remedies:

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 – fluconazole, 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- Atracurium, Desflurane

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

Practicals: **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)

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./

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-3

Course Title: Chemistry : Molecular Modelling, Artificial Intelligence and 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 modernscientific machine (programming) language i.e., Python, 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:

- Conversant with the Python Programming Language.
- 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.

Theory:

Part A: Molecular Modelling

Introduction to computational chemistry: **Lectures: 7**

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

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.

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

Part B: 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 andtypes of regression. Elementary Idea of Quantitative structure-activity relationship (QSAR).

An insight into Artificial Intelligence & Machine learning and potentialareas 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 Modeling 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.

Suggestive: 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 dipolemoments 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, determine the heat of hydrogenation of Ethene.

6) Based on the calculations of enthalpies of the participating chemical 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 theparticipating 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 6-31-G(d) basis set on a given set of small molecules i.e. BH_3, CH_4.

Suggestive: 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 in total.
- 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:

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. Sarkar, P., Bhattacharyya, S. P., **Soft Computing in Chemical and Physical Sciences A Shift in Computing Paradigm** (z-lib.org)
6. Sarkar, P., Bhattacharyya, S. P., **Understanding Properties of Atoms, Molecules and Materials,** (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 Modeling, Potential Energy Surface (PES), Geometry Optimization, Frequency calculation, Artificial Intelligence, Machine Learning, Nural Networks, Genetic Algorithm.

Course Code: CHEMISTRY- GE-4

Course Title: Chemistry and Society

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

Objective: The course is designed to expand the literacy of chemistry among the non-chemistry student even arts as well as commerce with objective increase general awareness, background of chemistry and its importance. This paper will be helpful for a common student to understand the importance and role of chemistry in development of civilization, societal issues related to chemistry and their expected solutions.

Learning Outcomes:

At the end of this course the student will be able to:

- Increase the literacy of chemistry even in non-science students
- Understand the basic concept, principle and importance of chemistry
- Realize the importance of chemistry in daily life and future requirement

Theory:

Unit 1: Basics of chemistry — Lectures: 4

Periodic table, Atom and molecules, chemical bonding, properties and chemical reactions with simple examples and illustration.

Unit 2: Chemistry in Heritage — Lectures: 8

Extraction and uses of metals like iron and stone in ancient times, metals in ornaments, medicines, weapons and chemistry for preservatives, basics of preservation and few examples of preservatives.

Unit 3: Chemistry in Life — Lectures: 8

Edible and non- edible molecules, biochemistry of foods and medicine with examples: Aspirin, Paracetamol. Ibuprofen and Penicillin, Cephalosporin, Chemistry for industry: Artificial sweeteners, Soaps and detergents and cosmetics, Polymer and Plastics: Uses and environmental issues.

Unit 4: Chemical pollution and Toxicity — Lectures: 4

Chemical source of water, air and soil pollution, biomagnification and metal toxicity with example and illustrations. monitoring of air pollution.

Unit 5: Testing of chemicals — Lectures: 4

Flame test, solubility test, qualitative and quantitative identification of ions in natural samples like metal copper, iron and chromium ores and adulterant in foods.

Unit 6: Future of chemistry — Lectures: 2

Basics of green chemistry, Reuse and recycling of by-products, zero waste chemistry and Alternate fuel and energy providing chemicals: biodiesel, natural gas and hydrogen.

Practicals/Hands-on Training: — Credits: 02

(Laboratory periods: 60)

1. Determine the calcium and magnesium contents in water samples using EDTA methods.
2. Determine the organic contents and pH of soil sample.
3. Estimate the food adulterants in edible items
4. Quantify the presence metals by flame test method
5. Demonstrate the conversion of PET into bottle into value added products.
6. Determine the quantitative presence of heavy metals like copper and chromium in natural sample like ore.
7. Demonstrate the exothermic and endothermic reaction in laboratory
8. Preparation aspirin and paracetamol as well as identify.
9. Compare the fuel efficiency of biodiesel and petrol.
10. Preparation of representative compound using microwave
11. Demonstrate the biodegradability of natural and synthetic plastics.
12. Demonstrate the protection of rusting of iron after surface spray coating.
13. Estimate the protein contents in edible samples using chemical methods.
14. Small working project on heritage chemistry like bio compatibility of metals and medicinal importance of metals like iron, gold and silver.

References:

1. Lee, J. D., **Concise Inorganic Chemistry**, Wiley India Pvt. Ltd.
2. Sharma, B. K., **Industrial chemistry**, Goel Publishing House, India
3. Christian, Gary D., Dasgupta, Purnendu K., Schug, Kevin A., **Analytical chemistry**, Wiley
4. V. Subramanian, **A text book of Environmental chemistry**, Wiley

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: Fundamental of chemistry, Chemistry for advancement in society, Chemistry and industry, Sustainable future of chemistry.

Course Code: CHEMISTRY- GE -5

Course Title: Role of Metals in Medicines

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

Objective: To make the learners familiar about role of metal ions in some commercially available medicines.

Learning Outcomes:

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

- Role of metal ions in various biomolecules and their functions.
- Role of metals in commercially available medicines and their functions

Theory:

Unit 1: Role of Metals in Biological system — Lectures: 4

Brief introduction of following metals in biological system
Fe, Cu, Zn, Mn, Cr(III), V, Mo, W, Co, Ni, Na, K, Mg and Ca

Chemical structure, Commercial name, Name of the disease it is made for and its brief mechanism of action shall be taught for all the mentioned metals below.

Unit 2: Diagnostic and therapeutic agents — Lectures: 8

Diagnostic and therapeutic agents with Pt (Cisplatin) and Ga for cancer, Au (auranofin) for arthritis and Vanadium for diabetes.

Unit 3: Metals in drugs — Lectures:6

Li_2CO_3 (Camcolit) for manic-depressive illness, $NaHCO_3$ (Alka-seltzer) for heartburn, $Al(OH)_3$ (Gaviscon) for heartburn, As (melarsoprol) for sleeping sickness, Bi subsalicylate (pepto-Bismol) for heartburn and diarrhea, Bi subcitrate (De-nol) peptic ulcer, Zinc oxide with Fe_2O_3 (Calamine lotion) as antimicrobial agent.

Unit 4: Metals in Multivitamins — Lectures:6

Cyanocobalamin (Co), Ferrous fumerate (Fe), Magnesium oxide (Mg), Zinc Sulfate (Zn), Manganese sulphate (Mn), Copper Sulfate (Cu), Sodium selenite (Se) and Chromium trichloride (Cr).

Unit 5: Radiopharmaceuticals and MRI contrast agents — Lectures:6

^{99m}Tc for heart, brain and bone imaging, ^{123}I radiopharmaceuticals, $BaSO_4$for X-ray contrast agent, Fe(III) and Gd (III) as MRI contrast agents.

Practicals:
Credits: 02

(Laboratory periods: 60)

Volumetric titrations:

1. To estimate the acidity of commercially available antacids.
2. To estimate the concentration of Fe in commercially available medicines.
3. To estimate the concentration of Ca in commercially available medicinces.
4. To estimate the strength of carbonate in tablets containing Li_2CO_3
5. To estimate the sodium bicarbonate in synthetic/commercially available drug.
6. To estimate the zinc and iron present in Calamine lotion.
7. To estimate the Mg present in multivitamins.

References:

1. **Metals in Medicine**, John Wiley & Sons Ltd, Nov 2009
2. Chapter-9, **Metals in Medicine**, Stephen J. Lippard
3. Jones, Chris and Thornback, John, **Medicinal applications of coordination chemistry**, Cambridge, UK: Royal Society of Chemistry, 2007

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.

Key words: Diagnostic, therapeutic agents, multivitamins, radiopharmaceuticals and MRI contrast agents.

Course Code: CHEMISTRY- GE- 6

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

Theory:

Unit 1: **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: **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: **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: **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.

Practicals:
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

- 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:

The effectiveness of learning can be judged by assessing the students. Various types of assessment methods can be followed depending on the branch of student opting the course. Assessment can be in form of 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 -7

Course Title: Fragrances and Flavors: 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.

Theory:

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: Flavors — Lectures: 18

- Introduction to flavors, types of flavors, flavor raw materials
- Understanding of terms like, Flavor and Flavouring agents. Attributes of flavor, taste, odour, odour stimulation, basic tastes and the human olfactory system.
- Stability of flavor in food, sensory evaluation of flavors in foods, Various flavor formulation

- Systematic approach to understanding flavor formation during food processing, food matrix, interaction of added flavors
- Flavor enhancers, modifiers, precursors, suppressors, solvents.
- Key chemical reactions for conversion of raw materials to flavours
- Forms of flavor and the manufacturing processes involving all types of flavors. Aroma recovery during processing.
- Biogenesis of flavours in fruits and vegetables, reaction flavours, off flavours.
- Selection and application of flavors in foods and beverages
- Legal aspects (natural flavors and natural flavouring substances, nature identical flavouring substances, artificial flavouring substances), and the *FSSAI* act.

Unit 4: Extraction, Isolation and Purification of Perfumes& Flavour Compound Lectures: 05

- 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

Practicals:
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:

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:

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:

The effectiveness of learning can be judged by assessing the students. Various types of assessment methods can be followed depending on the branch of student opting the course. Assessment can be in form of 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: Fragrances, Flavours, pharmaceutical formulation, distillation, extraction techniques

Course Code: CHEMISTRY- GE-8

Course Title: Radio-chemistry in Energy, Medicine and Environment

Total Credit: 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

Theory:

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:

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-9

Course Title: States of Matter

Total Credits: 04 (Credits: Theory-02, Practical-02)

Total Lectures: Theory- 30, Practical-60

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.

Theory:

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: Liquid 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.

Practicals: **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:

1. Atkins, P.W.; Overton, T.L.; Rourke, J.P.; Weller, M.T.; Armstrong, F.A. (2010), **Shriver and Atkin's Inorganic Chemistry**, Oxford.
3. Miessler, G. L.; Tarr, D.A. (2014), **Inorganic Chemistry**, Pearson.
4. Castellan, G. W. (2004), **Physical Chemistry**, Narosa.
5. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol.1, 6th Edition, McGraw Hill Education.
6. Kapoor, K.L. (2015), **A Textbook of Physical Chemistry**, Vol.5, 3rd Edition, McGraw Hill Education.

Practicals:

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