Oriental College

B.Sc. (Honours) Chemistry

Four-Year Undergraduate Programme
(Eight - Semester Course)

Learning Outcomes based Curriculum Framework (LOCF)
for (B.Sc. with Chemistry)
Undergraduate Programme 2022
(Course effective from Academic Year 2022-23)

Under
CHOICE BASED CREDIT SYSTEM
in view of NEP - 2020

COURSE CONTENTS

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Preamble

In view of the National Education Policy 2020 of Government of India and the University Grants Commission's Guidelines for Learning Outcomes-based Curriculum Framework (LOCF) under Choice Based Credit System (CBCS), the Oriental College, Imphal has decided to introduce the LOCF for four-year undergraduate programme from the session 2022-23. The LOCF syllabus under CBCS for the B.Sc. (Honours) is prepared in the model of syllabus prepared by the UGC.

Learning outcomes-based curriculum framework (LOCF) planning for Bachelor degree programme in Chemistry/Chemistry (Honours) is a novel approach towards teaching in terms of imparting knowledge, understanding, skill, attitudes and values to undergraduate students, in particular. In this context, the course/curriculum has been designed to provide in- depth knowledge in core discipline of chemistry with special emphasis on use of technology in chemical applications. Further, the generic discipline subjects have been framed to overall improve the students' capability in other allied discipline of sciences as well as technology. It is understood that the outcome of the curriculum frame-work can be helpful in enhancing employability of graduates in various sectors, both private and public, in addition to enhancing self-employable, entrepreneurship characteristics among graduate thus raising the quality of teaching and research outcomes in higher educational institutes. The integration of teaching and learning process can further articulate the essential societal learning that can promote the improvement in practical use of knowledge and investment in higher education with targeted and effective equity-related initiative.

1. Introduction

The LOCF based programme intended to follow flexibility and innovation in design of the programme, its assessment, and expect graduate attributes demonstrating the level of learning outcome. It is further expected to provide effective teaching – learning strategies including periodic review of the programme and its academic standard. The learning outcome-based curriculum framework for B.Sc. degree in Chemistry is intended to provide a broad framework and hence designed to address the needs of the students with chemistry as the core subject of study. The framework is expected to assist in the maintenance of the standard of chemistry degrees/programmes across the country and periodic programme review within a broad framework of agreed/expected graduate attributes, qualification descriptors, programme learning outcomes and course-level learning outcomes. The framework is intended to allow flexibility and innovation in programme design, syllabi development, teaching-learning process and quality assessment of students learning levels.

This curriculum framework for the bachelor-level program in Chemistry is developed keeping in view of the student centric learning pedagogy, which is entirely outcome-oriented and curiosity driven. To avoid rote-learning approach and foster imagination, the curriculum is more leaned towards self-discovery of concepts. The curriculum framework focuses on pragmatist approach whereby practical application of theoretical concepts is taught with substantial coverage of practical and field works. The platform aims at equipping the graduates with necessary skills for

Chemistry-related careers, careers with general graduate-level aptitude and for higher education in Chemistry and allied subjects.

2. Learning Outcomes based Curriculum Framework programme in B.Sc. Chemistry

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

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

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

b. Aims of Bachelor's degree programme in Chemistry

The broad aims of bachelors degree programme in Chemistry are:

The aim of bachelor's degree programme in chemistry is intended to provide:

(i) Broad and balance knowledge in chemistry in addition to understanding of key chemical concepts, principles and theories.

(ii) To develop students' ability and skill to acquire expertise over solving both theoretical and applied chemistry problems.

(iii) To provide knowledge and skill to the students' thus enabling them to undertake further studies in chemistry in related areas or multidisciplinary areas that can be helpful for self-employment/entrepreneurship.

(iv) To provide an environment that ensures cognitive development of students in a holistic manner. A complete dialogue about chemistry, chemical equations and its significance is fostered in this framework, rather than mere theoretical aspects

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

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

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

3. Graduate Attributes for B.Sc. Chemistry

Attributes of a Chemistry Graduate

Some of characteristic attributes of chemistry graduate under the outcome-based teaching-learning framework are:

- **Core competency:** The chemistry graduates are expected to know the fundamental concepts of chemistry and applied chemistry. These fundamental concepts would reflect the latest understanding of the field, and therefore, are dynamic in nature and require frequent and time-bound revisions.
- **Communication skills:** Chemistry graduates are expected to possess minimum standards of communication skills expected of a science graduate in the country. They are expected to read and understand documents with in-depth analyses and logical arguments. Graduates are expected to be well-versed in speaking and communicating their idea/finding/concepts to wider audience
- **Critical thinking:** Chemistry graduates are expected to know basics of cognitive biases, mental models, logical fallacies, scientific methodology and constructing cogent scientific arguments.
- **Psychological skills:** Graduates are expected to possess basic psychological skills required to face the world at large, as well as the skills to deal with individuals and students of various socio-cultural, economic and educational levels. Psychological skills may include feedback loops, self-compassion, self-reflection, goal-setting, interpersonal relationships, and emotional management.
- **Problem-solving:** Graduates are expected to be equipped with problem-solving philosophical approaches that are pertinent across the disciplines;

- **Analytical reasoning:** Graduates are expected to acquire formulate cogent arguments and spot logical flaws, inconsistencies, circular reasoning etc.
- **Research-skills:** Graduates are expected to be keenly observant about what is going on in the natural surroundings to awake their curiosity. Graduates are expected to design a scientific experiment through statistical hypothesis testing and other *a priori* reasoning including logical deduction.
- **Teamwork:** Graduates are expected to be team players, with productive co-operations involving members from diverse socio-cultural backgrounds.
- **Digital Literacy:** Graduates are expected to be digitally literate for them to enrol and increase their core competency via e-learning resources such as MOOC and other digital tools for lifelong learning. Graduates should be able to spot data fabrication and fake news by applying rational skepticism and analytical reasoning.
- **Moral and ethical awareness:** Graduates are expected to be responsible citizen of India and be aware of moral and ethical baseline of the country and the world. They are expected to define their core ethical virtues good enough to distinguish what construes as illegal and crime in Indian constitution. Emphasis be given on academic and research ethics, including fair Benefit Sharing, Plagiarism, Scientific Misconduct and so on.
- **Leadership readiness:** Graduates are expected to be familiar with decision making process and basic managerial skills to become a better leader. Skills may include defining objective vision and mission, how to become charismatic inspiring leader and so on.

4. Qualification Descriptors

i. B.Sc. Chemistry (Honours)

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

(i) Systematic and fundamental understanding of chemistry as a discipline.
(ii) Skill and related developments for acquiring specialization in the subject.
(iii) Identifying chemistry related problems, analysis and application of data using appropriate methodologies.
(iv) Applying subject knowledge and skill to solve complex problems with defined solutions.
(v) Finding opportunity to apply subject-related skill for acquiring jobs and self-employment.
(vi) Understanding new frontiers of knowledge in chemistry for professional development.
(vii) Applying subject knowledge for solving societal problems related to application of chemistry in day to day life.
(viii) Applying subject knowledge for sustainable environment friendly green initiatives.
(ix) Applying subject knowledge for new research and technology.

ii. B.Sc. Chemistry (H) & Chemistry (Pass)

The qualification descriptors for a Bachelor's degree in Chemistry also include following:

(i) To demonstrate a systematic, extensive and coherent knowledge and understanding of academic fields of study as a whole and its applications and links to disciplinary areas of the study; including critical understanding of the established theories, principles and concepts of a number of advanced and emerging issues in the field of chemistry;

(ii) To demonstrate procedural knowledge that creates different types of professionals in the field of chemistry. Further application of knowledge can enhance productivity of several economically important product. Knowledge of Chemistry is also necessary for the development and management of industry, manufacturing of fine chemicals, etc.

(iii) Developing skills and ability to use knowledge efficiently in areas related to specializations and current updates in the subject

(iv) Demonstrate comprehensive knowledge about chemistry, current research, scholarly and professional literature of advanced learning areas of Chemistry

(v) Use knowledge understanding and skills for critical assessment of wide range of ideas and problems in the field of Chemistry.

(vi) Communicate the results of studies in the academic field of Chemistry using main concepts, constructs and techniques

(vii) Apply one's knowledge and understanding of Chemistry to new/unfamiliar contexts and to identify problems and solutions in daily life.

(viii) To think any apply understanding of the subject of Chemistry, Chemical Sciences in identifying the problems which can be solved through the use of chemistry knowledge.

(ix) To think of the adopting expertise in chemical sciences and solve the problems of environment, green chemistry, ecology, sustainable development, hunger, etc.

5. Program Learning Outcomes

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

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

(i) Systematic and coherent understanding of the fundamental concepts in Physical chemistry, Organic Chemistry, Inorganic Chemistry, Analytical Chemistry and all other related allied chemistry subjects.

(ii) Students will be able to use the evidence based comparative chemistry approach to explain the chemical synthesis and analysis.

(iii) The students will be able to understand the characterization of materials.

(iv) Students will be able to understand the basic principle of equipments, instruments used in the chemistry laboratory.

(v) Students will be able to demonstrate the experimental techniques and methods of their area of specialization in Chemistry.

(vi) ***Disciplinary knowledge and skill***: A graduate student is expected to be capable of demonstrating comprehensive knowledge and understanding of both theoretical and experimental/applied chemistry knowledge in various fields of interest like Analytical Chemistry, Physical Chemistry, Inorganic Chemistry, Organic Chemistry, Material Chemistry, etc. Further, the student will be capable of using of advanced instruments and related soft-wares for in-depth characterization of materials/chemical analysis and separation technology.

(vii). ***Skilled communicator***: The course curriculum incorporates basics and advanced training in order to make a graduate student capable of expressing the subject through technical writing as well as through oral presentation.

(viii). ***Critical thinker and problem solver***: The course curriculum also includes components that can be helpful to graduate students to develop critical thinking ability by way of solving problems/numerical using basic chemistry knowledge and concepts.

(ix). ***Sense of inquiry***: It is expected that the course curriculum will develop an inquisitive characteristics among the students through appropriate questions, planning and reporting experimental investigation.

(x) ***Team player***: The course curriculum has been designed to provide opportunity to act as team player by contributing in laboratory, field based situation and industry.

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

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

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

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

6. Course Learning Outcomes

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

In course learning outcomes, the student will attain subject knowledge in terms of individual course as well as holistically.

The core courses would fortify the students with in-depth subject knowledge concurrently; the discipline specific electives will add additional knowledge about applied aspects of the program as well as its applicability in both academia and industry. Generic electives will introduce integration among various interdisciplinary courses. The skill enhancement courses would further add additional skills related to the subject as well as other than subject. In brief the student graduated with this type of curriculum would be able to disseminate subject knowledge along with necessary skills to suffice their capabilities for academia, entrepreneurship and Industry.

A student opting for honours course in chemistry must have and passed the Mathematics as a subject in the Senior Secondary level examination.

7. Structure of B.Sc. Honours (Chemistry) 4 - Year LOCF Programme

Semester	CC (18 courses x 6 credit each)	#DSEC (4 courses x 6 credit each)	GEC (6 courses x 6 credit each)	SEC (2 courses x 4 credit each)	AECC (2 courses x 4 credit each)	VAC (8 courses x 2credit each)
Year I (Level 5) total credits: 2 Sem. x24=48						
I	CHM-HC 501			CHM-SE 501	GEN-AE 1/ MAN-AE 1	VAC 1
	CHM-HC 502					VAC 2
II	CHM-HC 503			CHM-SE 502	EVS-AE 2	VAC 3
	CHM-HC 504					VAC 4
Year II (Level 6) total credits: 2 Sem. x 26 = 52						
III	CHM-HC 601		CHM-HG 601			VAC 5
	CHM-HC 602					
	CHM-HC 603					
IV	CHM-HC 604		CHM-HG 602			VAC 6
	CHM-HC 605					
	CHM-HC 606					
Year III (Level 7) total credits: 2 Sem. x 26 = 52						
V	CHM-HC 701	CHM-HE 701/ CHM-HE 701/ CHM-HE 701	CHM-HG 701			VAC 7
	CHM-HC 702					
VI	CHM-HC 703	CHM-HE 702/ CHM-HE 702/ CHM-HE 702	CHM-HG 702			VAC 8
	CHM-HC 704					
Year IV (Level 8) total credits: 2 Sem. x 24 = 48						
VII	CHM-HC 801	CHM-HE 801/ CHM-HE 801/ CHM-HE 801	CHM-HG 801			
	CHM-HC 802					
VIII	CHM-HC 803	CHM-HE 802 Dissertation	CHM-HG 802			
	CHM-HC 804					
Grand Total Credits = 200						

Abbreviation:

CHM - Chemistry
CHM-HC - Chemistry Honours Core Course (**Course Code: HC**)
DSEC - Discipline Specific Elective Course (**Course Code: HE**)
GEC - Generic Elective Course (**Course Code : HG**)
SEC - Skill Enhancement Course **(Course Code: SE)**
AECC - Ability Enhancement Compulsory Course (**Course Code: AE)**
VAC = Value Addition Courses

TOTAL:
Core Course (CC): 18 courses for 108 credits; DSEC: 4 courses for 24 credits; GEC: 6 courses for 36 credits; SEC: 2 courses for 8 credits; AECC: 2 courses for 8 credits; VAC: 8 courses for 16 credits. **(altogether 40 courses/papers & 200 Credits)**

Undergraduate Degree Programmes for 4 – year duration:

- Award of Bachelor's **Certificate** in Chemistry on completion of first year (Two Semesters) equal to **minimum** 46 credits in 1 year
- Award of Bachelor's **Diploma** in Chemistry on completion of second year (Four Semesters) equal to **minimum** 96 credits in 2 years
- Award of Bachelor's **Degree** in Chemistry on completion of third year (Six Semesters) equal to **minimum** 140 credits in 3 years
- Award of Bachelor's **Degree with Honours** in Chemistry on completion of fourth year (Eight Semester) equal to **minimum** 182 credits in 4 years.

8. SCHEME FOR CHOICE BASED CREDIT SYSTEM in B.Sc. Honours (Chemistry)

SEMESTER	COURSE CODE	COURSE NAME	Credits
I	GEN-AE-1	English for Communications	4
	CHM-HC 501	Inorganic Chemistry-I	4+2=6
		Inorganic Chemistry-Lab-I	
	CHM-HC 502	Organic Chemistry-I	4+2=6
		Organic Chemistry-Lab-I	
	CHM-SE 501	Skill Enhancement Course	4
	VAC 1	Value Addition Course 1	2
	VAC 2	Value Addition Course 2	2
Total credits in Semester I			24
II	EVS-AE 1	Environmental Studies	4
	CHM-HC 503	Analytical Chemistry	4+2=6
		Analytical Chemistry Laboratory	
	CHM-HC 504	Physical Chemistry-I	4+2=6
		Physical Chemistry Laboratory-I	
	CH-SE 502	Skill Enhancement Course	4
	VAC 3	Value Addition Course 3	2
	VAC 4	Value Addition Course 4	2
Total credits in Semester II			24

III	CHM-HC 601	Green Chemistry	4+2=6
		Green Chemistry Laboratory	
	CHM-HC 602	Inorganic Chemistry-II	4+2=6
		Inorganic Chemistry Laboratory-II	
	CHM-HC 603	Physical Chemistry-II	4+2=6
		Physical Chemistry Laboratory-II	
	CH-HG 601	Generic Elective Course	4+2/5+1=6
		Lab/tutorial	
	VAC 5	Value Addition Course 5	2
Total credits in Semester III			26
IV	CHM-HC 604	Molecular Spectroscopy & Photochemistry	4+2=6
		Molecular Spectroscopy & Photochemistry Laboratory	
	CHM-HC 605	Inorganic Chemistry-III	4+2=6
		Inorganic Chemistry Laboratory-III	
	CHM-HC 606	Organic Chemistry-II	4+2=6
		Organic Chemistry Laboratory-II	
	CH-HG 602	Generic Elective Course	4+2/5+1=6
		Lab/tutorial	
	VAC 6	Value Addition Course 6	2
Total credits in Semester IV			26
V	CHM-HC 701	Introduction to Quantum Chemistry	5+1=6
	CHM-HC 702	Organic Chemistry-III	4+2=6
		Organic Chemistry Laboratory	
	CHM-HE 701	Discipline Specific Elective	4+2/5+1=6
		Lab/tutorial	
	CH-HG 701	Generic Elective Course	4+2/5+1=6
		Lab/tutorial	
	VAC 7	Value Addition Course 7	2
Total credits in Semester V			26
VI	CHM-HC 703	Materials Chemistry	5+1=6
	CHM-HC 704	Physical Chemistry-III	4+2=6
		Physical Chemistry Laboratory-III	
	CHM-HE 702	Discipline Specific Elective	4+2/5+1=6
		Lab/tutorial	
	CH-HG 702	Generic Elective Course	4+2/5+1=6
		Lab/tutorial	
	VAC 8	Value Addition Course 8	2

Total credits in Semester VI			**26**
VII	**CHM-HC 801**	**Polymer Chemistry**	**4+2=6**
		Polymer Chemistry Laboratory	
	CHM-HC 802	**Inorganic Chemistry -IV**	**4+2=6**
		Inorganic Chemistry Laboratory -IV	
	CHM-HE 801	**Discipline Specific Elective**	**4+2/5+1 = 6**
	CHM-HG 801	**Generic Elective Course**	**4+2/5+1 = 6**
Total credits in Semester VII			**24**
VIII	**CHM-HC 803**	**Organic Chemistry - IV**	**4+2 = 6**
		Organic Chemistry Laboratory - IV	
	CHM-HC 804	**Physical Chemistry – IV**	**4+2 =6**
		Physical Chemistry Laboratory – IV	
	CHM-HE 802	**Discipline Specific Elective**	**5+1 = 6**
	CHM-HG 802	**Generic Elective Course**	**4+2/5+1 = 6**
Total credits in Semester VIII			**24**
Grand Total credits			**200**

***Core and DSE courses without practical will have tutorial and have credit distribution of 5 credits for theory and 1 credit for tutorial, total 6 credits, same as the papers with practical.*

9. Course Structure at a Glance

A. Core Courses (CC)

Sr. No.	Name of the course	Type of course	L	T	P	Credits
CC 1.	Inorganic Chemistry-I	Core course	3	1	0	**4**
	Inorganic Chemistry Laboratory -I	Core course	0	0	2	**2**
CC 2.	Organic Chemistry-I	Core course	3	1	0	**4**
	Organic Chemistry Laboratory	Core course	0	0	2	**2**
CC 3.	Analytical Chemistry	Core course	3	1	0	**4**
	Analytical Chemistry Laboratory	Core course	0	0	2	**2**
CC 4.	Physical Chemistry -I	Core course	3	1	0	**4**
	Physical Chemistry Laboratory -I	Core course	0	0	2	**2**

CC 5.	Green Chemistry	Core course	3	1	0	**4**
	Green Chemistry Laboratory	Core course	0	0	2	**2**
CC 6.	Inorganic Chemistry-II	Core course	3	1	0	**4**
	Inorganic Chemistry Laboratory - II	Core course	0	0	2	**2**
CC 7.	Physical Chemistry - II	Core course	3	1	0	**4**
	Physical Chemistry Laboratory – II	Core course	0	0	2	**4**
CC 8	Molecular Spectroscopy & Photochemistry	Core course	3	1	0	**4**
	Molecular Spectroscopy & Photochemistry Lab.	Core course	0	0	2	**2**
CC 9.	Inorganic Chemistry-III	Core course	3	1	0	**4**
	Inorganic Chemistry Laboratory - III	Core course	0	0	2	**2**

CC 10	Organic Chemistry-II	Core course	3	1	0	**4**
	Organic Chemistry Laboratory - II	Core course	0	0	2	**2**
CC 11	Introduction to Quantum Chemistry	Core course	5	1	0	**6**
CC 12.	Organic Chemistry-III	Core course	3	1	0	**4**
	Organic Chemistry Laboratory – III	Core course	0	0	2	**2**
CC 13	Physical Chemistry - III	Core course	3	1	0	**4**
	Physical Chemistry Laboratory – III	Core course	0	0	2	**2**
CC 14.	Materials Chemistry	Core course	5	1	0	**6**
CC 15	Polymer Chemistry	Core course	3	1	0	**4**
	Polymer Chemistry Laboratory		0	0	2	**2**
CC 16	Inorganic Chemistry - IV	Core course	3	1	0	**4**
	Inorganic Chemistry Laboratory - IV	Core course	0	0	2	**2**
CC 17	Organic Chemistry - IV	Core course	3	1	0	**4**
	Organic Chemistry Laboratory - IV	Core course	0	0	2	**2**
CC 18	Physical Chemistry - IV	Core course	3	1	0	**4**
	Physical Chemistry Laboratory - IV	Core course	0	0	2	**2**

B. Discipline Specific Elective Courses: (Credit: 06 each) (4 papers to be selected)-

DSE for Semester V

DSE-1(Any One from the following)

1. CHM-**HE 701:** Applications of Computers in Chemistry (4) + Lab (2)
2. CHM-**HE 701:** Analytical Methods in Chemistry (4) + Lab (2)
3. CHM-**HE 701:** Molecular Modelling & Drug Design (4) + Lab (2)

DSE for Semester VI

DSE-2(Any One from the following)

4. CHM-**HE 702:** Novel Inorganic Solids (4) + Lab (2)
5. CHM-**HE 702:** Introduction to Nanochemistry & applications (4) + Lab (2)
6. CHM-**HE** 702: Heterocyclic Chemistry (4) + Lab (2)

DSE for Semester VII

DSE-3 (Any One from the following)

7. CHM-**HE 801:** Biochemistry (4) + Lab (2)
8. CHM-**HE 801:** Research Methodology for Chemistry (5) + Tutorial (1)
9. CHM-**HE 801:** Inorganic Materials of Industrial Importance (4) + Lab (2)

DSE for Semester VIII

DSE-4 (Any One from the following)

10. CHM-**HE 802:** Industrial Chemicals & Environment (4) + Lab (2)
11. CHM-**HE 802:** Dissertation

C. Skill Enhancement Courses (02 papers) (Credit: 04 each)

SEC for Semester I

Any One from the following

1. CHM-**SE 501:** IT Skills for Chemists
2. CHM-**SE 501:** Basic Analytical Chemistry
3. CHM-**SE 501:** Chemical Technology & Society
4. CHM-**SE 501:** Chemoinformatics
5. CHM-**SE 501:** Business Skills for Chemists
6. CHM-**SE 501:** Intellectual Property Rights

SEC for Semester II

Any One from the following

7. CHM-**SE 502:** Analytical Clinical Biochemistry
8. CHM-**SE 502:** Pharmaceutical Chemistry
9. CHM-**SE 502:** Pesticide Chemistry
10. CHM-**SE 502:** Fuel Chemistry
11. CHM-**SE 502:** Renewable Energies (solar and biogas)
12. CHM-SE 502: Biofertilizer

D. Ability Enhancement Compulsory Courses (02 papers) (Credit: 04 each)

AECC for Semester I

1. GEN-AE 1: English Communications/MAN-AE 1

AECC for Semester II

2. EVS-AE 2: Environmental Science

E. Value Addition Courses (08 papers) (Credits: 02 each)

Semester I: VAC 1; VAC 2
Semester II: VAC 3; VAC 4
Semester III: VAC 5
Semester IV: VAC 6
Semester V: VAC 7
Semester VI: VAC 8

To be chosen from the following:

1. Yoga
2. Sports
3. Health Care
4. NCC
5. NSS
6. Ethics
7. Culture.

(The courses will be finalised by college administration subject to the feasibility.)

F. Generic Elective Courses (GEC) (for PCM & PCB combination)

Sr. No.	Name of the course	Type of course	L	T	P	Credits
1	Chemistry 1: Atomic Structure, Bonding, General Organic Chemistry & Aliphatic Hydrocarbonds	Generic Elective Courses	3	1	2	**6**
2	Chemistry 2: s-and p-Block Elements, Transition Elements & States of Matter	Generic Elective Courses	3	1	2	**6**
3	Chemistry 3: Chemical Energetics, Equilibria & Functional Group Organic Chemistry -I	Generic Elective Courses	3	1	2	**6**
4	Chemistry 4: Solutions, Phase Equilibrium, Conductance & Functional Group Organic Chemistry - II	Generic Elective Courses	3	1	2	**6**
5	Chemistry 5: Coordination Chemistry, Acids and Bases, Noble Gases, Stereochemistry, Amino Acids, Peptides and Proteins	Generic Elective Courses	3	1	2	**6**
6	Chemistry 6: Electrochemistry, Chemical Kinetics, Transition Elements, Lanthanoids and Actinoids	Generic Elective Courses	3	1	2	**6**

**** Students can choose minimum of two GEC papers from other disciplines.***

CORE COURSES (HONOURS IN CHEMISTRY)

Semester I

CHM-HC 501: INORGANIC CHEMISTRY-I

(Credits: Theory-04, Practicals-02)

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

***Course Objective*:**

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

Course Learning Outcomes:

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

Unit-1 : ***(10 classes of 60 minutes each)*** **17m**

AtomicStructure:

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics de-Brogle equation, Heisenberg's uncertainty principle and its significance, Schrodinger wave equation, significance of Ψ and $\Psi,^2 \cdot$ radial and angular wave functions, and probability distribution curves, shapes of s, p, and d orbitals, quantum numbers and their significance , Pauli's Exclusion Principle , Hunds rule of maximum multiplicity , aufbou's principle and its limitations, variation of energy of atomic orbitals with atomic number.

Unit-2: *(10 classes of 50 minutes each)* **20m**

Periodicity of Elements:

s, p, d, f block elements, the long form of periodic table. Detailed discussion of the following properties of the elements, with reference to *s* & *p*-block.

(a) Effective nuclear charge, shielding or screening effect, Slater rules, variation of effective nuclear charge in periodic table.

(b) Atomic radii (van der Waals)

(c) Ionic and crystal radii.

(d) Covalent radii (octahedral and tetrahedral)

(e) Ionization enthalpy, Successive ionization enthalpies and factors affecting ionization energy. Applications of ionization enthalpy.

(f) Electron gain enthalpy, trends of electron gain enthalpy.

(g) Electronegativity, Pauling's/ Mulliken's/ Allred Rachow's/ and Mulliken-Jaffé's electronegativity scales. Variation of electronegativity with bond order, partial charge, hybridization, group electronegativity. Sanderson's electron density ratio.

Unit-3: *(20 classes of 60 minutes each)* **30m**

Chemical Bonding:

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

(ii) *Covalent bond:* Lewis structure, Valence Bond theory (Heitler-London approach). Energetics of hybridization, equivalent and non-equivalent hybrid orbitals. Bent's rule, Resonance and resonance energy, Molecular orbital theory. Molecular orbital diagrams of diatomic and simple polyatomic molecules N_2, O_2, C_2, B_2, F_2, CO, NO, and their ions; HCl, BeF_2, CO_2, (idea of s-p mixing and orbital interaction to be given). Formal charge, Valence shell electron pair repulsion theory (VSEPR), shapes of simple molecules and ions containing lone pairs and bond pairs of electrons, multiple bonding (σ and π bond approach) and bond lengths. Covalent character in ionic compounds, polarizing power and polarizability. Fajan's rules and consequences of polarization.

Ionic character in covalent compounds: Bond moment and dipole moment. Percentage ionic character from dipole moment and electronegativity difference.

(iii) *Metallic Bond:* Qualitative idea of valence bond and band theories. Semiconductors and insulators, defects in solids.

(iv) *Weak Chemical Forces:* van der Waals forces, ion-dipole forces, dipole-dipole interactions, induced dipole interactions, Instantaneous dipole-induced dipole interactions. Repulsive forces, Hydrogen bonding (theories of hydrogen bonding, valence bond treatment) Effects of chemical force, melting and boiling points, solubility energetics of dissolution process.

Unit-4: *(5 classes of 60 minutes each)* **8m**

Oxidation-Reduction:

Redox equations, Standard Electrode Potential and its application to inorganic reactions. Principles involved in volumetric analysis to be carried out in class.

Recommended Books:

1. Lee, J. D. Concise Inorganic Chemistry, 5th Ed., Oxford University Press, 2008.

2. Douglas, B.E. and Mc Daniel, D.H., Concepts and Models of Inorganic Chemistry, 3rd Ed. Wiley India, 2006.

3. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.

4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.

5. Atkins, P.W. & Paula, J. Physical Chemistry, 11th Ed., Oxford University Press, 2018.
6. Housecroft, C. E. and Sharpe, A. G. Inorganic Chemistry, 5th Ed., Pearson, 2018.
7. Day, M.C. and Selbin, J. Theoretical Inorganic Chemistry, Literary Licensing, LLC, 2012.

CHE-HC 501(P): LABORATORY

(A) Titrimetric Analysis

(i) Calibration and use of common laboratory apparatus
(ii) Preparation of solutions of different Molarity/Normality of titrants

(B) Acid-Base Titrations

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

(C) Oxidation-Reduction Titrimetry

(i) Estimation of Fe(II) and oxalic acid using standardized $KMnO_4$ solution.
(ii) Estimation of oxalic acid and sodium oxalate in a given mixture.
(ii) Estimation of Fe(II) with $K_2Cr_2O_7$ using internal (diphenylamine, anthranilic acid) and external indicator.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis; 6th Ed. Pearson Education, 2009.
2. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. II.* S. Chand & Co Ltd., New Delhi
3. G. N. Mukherjee: *Advanced Experiments in Inorganic Chemistry.* U. N. Dhur & Sons Pvt Ltd. Kolkata 700073.

CHM-HC 502: ORGANIC CHEMISTRY - I

(Credits: Theory-04, Practicals-02)

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

Course Objectives:

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

Course Learning Outcomes:

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

Unit-1 ***(12 classes of 60 minutes each)*** **15m**

Basics of Organic Chemistry:

Organic Compounds: Classification, and Nomenclature, Hybridization, Shapes of molecules, Influence of hybridization on bond properties.

Electronic Displacements: Inductive, electromeric, resonance and mesomeric effects, hyperconjugation and their applications; Dipole moment; Organic acids and bases; their relative strength. Homolytic and Heterolytic fission with suitable examples. Curly arrow rules, formal charges; Electrophiles and Nucleophiles; Nucleophlicity and basicity; Types, shape and their relative stability of Carbocations, Carbanions, Free radicals and Carbenes. Introduction to types of organic reactions and their mechanism: Addition, Elimination and Substitution reactions.

Unit-2: ***(7 classes of 60 minutes each)*** **15m**

Stereochemistry:

Fischer Projection, Newmann and Sawhorse Projection formulae and their interconversions; Geometrical isomerism: cis–trans and, syn-anti isomerism E/Z notations with C.I.P rules.

Optical Isomerism: Optical Activity, Specific Rotation, Chirality/Asymmetry, Enantiomers, Molecules with two or more chiral-centres, Distereoisomers, meso structures, Racemic mixture and resolution. Relative and absolute configuration: D/L and R/S designations.

Unit-3: ***(20 classes of 60 minutes each)*** **30m**

Chemistry of Aliphatic Hydrocarbons

A. Carbon-Carbon sigma bonds:

Chemistry of alkanes: Formation of alkanes, Wurtz Reaction, Wurtz-Fittig Reactions, Free radical substitutions: Halogenation -relative reactivity and selectivity.

B. Carbon-Carbon pi bonds:

Formation of alkenes and alkynes by elimination reactions, Mechanism of E1, E2, E1cb reactions. Saytzeff and Hofmann eliminations.

Reactions of alkenes: Electrophilic additions and their mechanisms (Markownikoff/ Anti Markownikoff addition), mechanism of oxymercuration-demercuration, hydroborationoxidation, ozonolysis, reduction (catalytic and chemical), syn and antihydroxylation (oxidation). 1, 2-and 1,4-addition reactions in conjugated dienes and, Diels-Alder reaction; Allylic and benzylic bromination and mechanism, e.g. propene, 1-butene, toluene, ethyl benzene.

Reactions of alkynes: Acidity, Electrophilic and Nucleophilic additions. Hydration to form carbonyl compounds, Alkylation of terminal alkynes.

C. Cycloalkanes and Conformational Analysis:
Concept of alicyclic compounds Types of cycloalkanes and their relative stability, Baeyer strain theory, Conformation analysis of alkanes: Relative stability: Energy diagrams of cyclohexane: Chair, Boat and Twist boat forms; Relative stability with energy diagrams.

Uni-4: ***(6 classes of 60 minutes each)*** **15 m**

Aromatic Hydrocarbons

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

Recommended Books:

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. Eliel, E. L. &Wilen, S. H. *Stereochemistry of Organic Compounds*, Wiley: London, 1994.
4. Nasipuri, D. *Stereochemistry of Organic Compounds,* Wiley Eastern Limited.
5. Kalsi, P. S. *Stereochemistry Conformation and Mechanism*, New Age International, 2005.
6. Subrata Sen Gupta, *Basic Stereochemistry of Organic Molecules*, Oxford Higher Education.
7. Dhillon, R. S.; Singh, I. P. & Baskar, C. *Stereochemistry*, Narosa.
8. Loudon, G. M. *Organic Chemistry*, Oxford.
9. Sykes, P. *A guidebook to Mechanism in Organic Chemistry,* Pearson Education, 2003.
10. Clayden, J., Greeves, N. & Warren, S. *Organic Chemistry*, Second edition, Oxford University Press, 2012.

CHM-HC 502(P) : LAB0RATORY

1. Checking the calibration of the thermometer
2. Purification of organic compounds by crystallization using the following solvents:
   a. Water
   b. Alcohol
   c. Alcohol-Water
3. Determination of the melting points of above compounds and unknown organic Compounds.
4. Effect of impurities on the melting point – mixed melting point of two unknown organic Compounds.
5. Determination of boiling point of liquid compounds. (boiling point lower than and more than 100 °C by distillation and use of thiele tube method)
6. Chromatography
   a. Separation of a mixture of two amino acids by ascending and horizontal paper chromatography
   b. Separation of a mixture of two sugars by ascending paper chromatography
   c. Separation of a mixture of o-and p-nitrophenol or o-and p-aminophenol by thin layer chromatography (TLC)

Recommended Books

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009).
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012)

3. Vogel, A. I. *Elementary Practical Organic Chemistry*, Part 2: *Qualitative Organic Analysis,* CBS Publishers and Distributors.
4. Bhattacharyya, R. C, *A Manual of Practical Chemistry.*
5. Dutta, S, *B. Sc. Honours Practical Chemistry*, Bharati Book Stall.
6. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. III.* S. Chand & Co Ltd., New Delhi
7. N. K. Vishnoi: *Advanced Practical Organic Chemistry*. Vikas Publishing House, New Delhi
8. O. P. Agarwal: *Advanced Practical Organic Chemistry*. Geol Publishing House, Meerut

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Semester II

CHM-HC 503: ANALYTICAL CHEMISTRY

(Credits: Theory – 04; Practical – 02)

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

Course Objective:

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

Course Learning Outcomes:

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

Unit-1: *(4 classes of 60 minutes)* **5m**

Qualitative and quantitative aspects of analysis:

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

Unit-2: *(8 classes of 60 minutes)* **20m**

Optical methods of analysis:

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

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of metal complex composition using Job's method of continuous variation and mole ratio method.

Infrared Spectroscopy: Basic principles of instrumentation (choice of source, monochromator & detector) for continuous wave and Fourier transform spectrometers; sampling techniques. Structure elucidation through interpretation of data. Effect and importance of isotope substitution.

Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and detector, choice of flame and Burner designs. Techniques of atomization and sample introduction. Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples.

Unit-3: *(6 classes of 60 minutes)* **5m**

Thermal methods of analysis:

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

Unit-4: *(7 classes of 60 minutes)* **10m**

Electroanalytical methods:

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

Unit-5: *(20 classes of 60 minutes)* **35m**

Separation techniques:

Solvent extraction: Classification, principle and efficiency of the technique. Mechanism of extraction: extraction by solvation and chelation. Technique of extraction: batch, continuous and counter current extractions. Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media. Chromatography: Classification, principle and efficiency of the technique.

Mechanism of separation: adsorption, partition & ion exchange. Development of chromatograms: frontal, elution and displacement methods. Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of enantiomeric composition using NMR, Chiral solvents and chiral shift reagents. Chiral chromatographic techniques using chiral columns (GC and HPLC). Role of computers in instrumental methods of analysis.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. CBS Publishers & Distributors, 2004.
3. Christian, Gary D: Analytical Chemistry, 6th Ed. Wiley India (P) Ltd., 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, 4th Ed. W. H. Freeman, 2008.
5. Khopkar, S.M.: Basic Concepts of Analytical Chemistry, 3rd Ed. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, 6th Ed. Thomson Asia Pvt. Ltd. Singapore.
7. Mikes, O. and Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.1979
8. Ditts, R.V. *Analytical Chemistry: Methods of separation.* VanNostrand, New York, 1974.

CHM-HC 503(P) : Analytical Chemistry Laboratory

1. Separation Techniques

I. Chromatography:

(a) Separation of mixtures

(i) Paper chromatographic separation of Fe^{3+}, Al^{3+}, and Cr^{3+}.

(ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the Rf values.

(b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their Rf values.

(c) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

II. Solvent Extractions:

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

(ii) Solvent extraction of zirconium with amberliti LA-1, separation from a mixture of irons and gallium.

(iii) Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.

(iv) Determination of Na, Ca, Li in cola drinks and fruit juices using fame photometric techniques.

III. Analysis of soil:

(i) Determination of pH of soil.

(ii) Total soluble salt

(iii) Estimation of calcium, magnesium, phosphate, nitrate

IV. Ion exchange:

(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.

(ii) Separation of metal ions from their binary mixture.

(iii) Separation of amino acids from organic acids by ion exchange chromatography.

V. Spectrophotometry

(i) Determination of pKa values of indicator using spectrophotometry.

(ii) Structural characterization of compounds by infrared spectroscopy.

(iii) Determination of dissolved oxygen in water.

(iv) Determination of chemical oxygen demand (COD).

(v) Determination of Biological oxygen demand (BOD).

(vi) Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by Job's method.

Recommended Books:

1. Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery and others) 5th Ed. The English Language Book Society of Longman .
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, Gary D; Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd. Singapore.
7. Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
9. Ditts, R.V. *Analytical Chemistry: Methods of separation.* Van Nostrand, New York, 1974.
10. Dr. B. K. Sharma : *Instrumental Methods of Chemical Analysis.* Geol Publishing House, Meerut.

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CHM-HC 504: PHYSICAL CHEMISTRY - I

(Credits: Theory-04, Practicals-02)

Course Objectives:

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

Course Learning Outcomes:

1. Determination of lattice parameters of given salt.
2. Study of X-Ray diffraction pattern and finding out reference from JCPDI file.
3. Numerical related to salt hydrolysis, ionic equilibria.

Unit-1: *(12 classes of 60 minutes each)* **20m**

Gaseous state:

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

Behaviour of real gases: Deviations from ideal gas behaviour, compressibility factor, *Z*, and its variation with pressure for different gases. Causes of deviation from ideal behaviour. Van der Waals equation of state, its derivation and application in explaining real gas behaviour, mention of other equations of state (Berthelot, Dietrici); virial equation of state; van der Waals equation expressed in virial form and calculation of Boyle temperature. Isotherms of real gases and their comparison with van der Waals isotherms, continuity of states, critical state, relation between critical constants and van der Waals constants, law of corresponding states.

Unit-2: *(6 classes of 60 minutes each)* **10m**

Liquid state:

Qualitative treatment of the structure of the liquid state; Radial distribution function; physical properties of liquids; vapour pressure, surface tension and coefficient of viscosity, and their determination. Effect of addition of various solutes on surface tension and viscosity. Explanation of cleansing action of detergents. Temperature variation of viscosity of liquids and comparison with that of gases. Qualitative discussion of structure of water.

Unit-3: *(10 classes of 60 minutes each)* **12m**

Solid state:

Nature of the solid state, law of constancy of interfacial angles, law of rational indices, Miller indices,; X-ray diffraction, Bragg's law, a simple account of rotating crystal method and powder pattern method. Analysis of powder diffraction patterns of NaCl, CsCl and KCl. Defects in crystals. Liquid crystals (Introductory idea).

Unit-4: *(4 classes of 60 minutes each)* **8m**

Molecular and Crystal Symmetry :

Elementary ideas of symmetry, symmetry elements and symmetry operations, qualitative idea of point and space groups, seven crystal systems and fourteen Bravais lattices.

Unit-5 *(13 classes of 60 minutes each)* **25m**

Ionic equilibria:

Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect; dissociation constants of mono-, di-and triprotic acids (exact treatment). Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions; derivation of Henderson equation and its applications; buffer capacity,buffer range, buffer action and applications of buffers in analytical chemistry and biochemical processes in the human body. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle. Qualitative treatment of acid – base titration curves (calculation of pH at various stages). Theory of acid–base indicators; selection of indicators and their limitations. Multistage equilibria in polyelectrolyte systems; hydrolysis and hydrolysis constants.

Recommended Books:

1. Atkins, P. W. & Paula, J. de Atkin's Physical Chemistry Ed., Oxford University Press (2006).
2. Ball, D. W. Physical Chemistry Thomson Press, India (2007).
3. Castellan, G. W. Physical Chemistry 4th Ed. Narosa (2004).
4. Mortimer, R. G. Physical Chemistry 3rd Ed. Elsevier: NOIDA, UP (2009).
5. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co. (2017)
6. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 1) McGraw Hill Education; Sixth edition (2019)

CHM-HC 504 (P): Laboratory

1. **Surface tension measurements.**
   a. Determine the surface tension by (i) drop number (ii) drop weight method.
   b. Study the variation of surface tension of detergent solutions with concentration.
2. **Viscosity measurement using Ostwald's viscometer**.
   a. Determination of viscosity of aqueous solutions of (i) polymer (ii) ethanol and (iii) sugar at room temperature.
   b. Study the variation of viscosity of sucrose solution with the concentration of solute.

3. Indexing of a given powder diffraction pattern of a cubic crystalline system.

4. pH metry

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

Recommended Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed*.; McGraw-Hill: New York (2003).
3. Halpern, A. M. &McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York (2003).
4. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. II*. S. Chand & Co Ltd., New Delhi
5. G. N. Mukherjee: *Advanced Experiments in Inorganic Chemistry*. U. N. Dhur & Sons Pvt Ltd. Kolkata 700073.

Semester III

CHE-HC 601 : GREEN CHEMISTRY
(Credits: Theory-04, Practicals-02)

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

Course Objectives:

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

Course Learning Outcomes:

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

Unit-1 ***(4 classes of 60 minutes)*** **5m**

Introduction to Green Chemistry:

What is Green Chemistry? Need for Green Chemistry. Goals of Green Chemistry. Limitations/ Obstacles in the pursuit of the goals of Green Chemistry.

Unit-2 ***(15 classes of 60 minutes)*** **30m**

Principles of Green Chemistry and Designing a Chemical synthesis:

Twelve principles of Green Chemistry with their explanations and examples; Designing a Green Synthesis using these principles; Prevention of Waste/ byproducts; maximum incorporation of the materials used in the process into the final products (Atom Economy); prevention/ minimization of hazardous/ toxic products; designing safer chemicals – different basic approaches to do so; selection of appropriate auxiliary substances (solvents, separation agents), green solvents, solvent less processes, immobilized solvents and ionic liquids; energy requirements for reactions - use of microwaves, ultrasonic energy; selection of starting materials; avoidance of unnecessary derivatization – careful use of blocking/protecting groups; use of catalytic reagents (wherever possible) in preference to stoichiometric reagents; designing of biodegradable products; prevention of chemical accidents; strengthening/ development of analytical techniques to prevent and minimize the generation of hazardous substances in chemical processes.

Unit-3 *(18 classes of 60 minutes)* **30m**

Examples of Green Synthesis/ Reactions:

1. Green Synthesis of the following compounds: adipic acid, catechol, BHT, methyl methacrylate, urethane, citral, ibuprofen, paracetamol, furfural.
2. Microwave assisted reactions in water: Oxidation of toluene, alcohols. Microwave assisted reactions in organic solvents: Esterification, Fries rearrangement, Diels-Alder Reaction. Microwave assisted solid state reactions: Deacetylation, Deprotection. Saponification of esters, Alkylation of reactive methylene compounds, reductions, benzimidazoles.
3. Selective methylation of active methylene group using dimethylcarbonate: Solid-state polymerization of amorphous polymers using diphenylcarbonate; Use of "Clayan", a nonmetallic oxidative reagent for various reactions; Free Radical Bromination; Role of Tellurium in organic syntheses; Biocatalysis in organic syntheses.

Unit-4 *(8 classes of 60 minutes)* **10m**

Future Trends in Green Chemistry:

Oxidation reagents and catalysts; Biomimetic, multifunctional reagents; Solventless reactions; Green chemistry in sustainable development.

Recommended Books:

1. V.K. Ahluwalia & M.R. Kidwai: New Trends in Green Chemistry, Anamalaya Publishers (2005).
2. P.T. Anastas& J.K. Warner: Oxford Green Chemistry- Theory and Practical, University Press (1998).
3. A.S. Matlack: Introduction to Green Chemistry, Marcel Dekker (2001).
4. M.C. Cann& M.E. Connely: Real-World cases in Green Chemistry, American Chemical Society, Washington (2000).
5. M.A. Ryan & M. Tinnesand, Introduction to Green Chemistry, American Chemical Society, Washington (2002).

CHM-HC 601(P): Green Chemistry Laboratory

1. Safer starting materials

The Vitamin C clock reaction using Vitamin C tablets, tincture of iodine, hydrogen peroxide and liquid laundry starch.

(i) Effect of concentration on clock reaction

(ii) Effect of temperature on clock reaction.

2. Using renewable resources

Preparation of biodiesel from vegetable oil.

3. Avoiding waste

Principle of atom economy.

Use of molecular model kit to stimulate the reaction to investigate how the atom economy can illustrate Green Chemistry.

Preparation of propene by two methods can be studied

(I) Triethylamine ion + OH^- → propene + trimethylpropene + water

(II) 1-propanol → propene + water

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

4. Use of enzymes as catalysts

Benzoin condensation using Thiamine Hydrochloride as a catalyst instead of cyanide

Alternative Green solvents

5. Diels Alder reaction in water

Reaction between furan and maleic acid in water and at room temperature rather than in

benzene and reflux.
6. Extraction of D-limonene from orange peel using liquid CO_2 prepared form dry ice.
7. Mechanochemical solvent free synthesis of azomethines
8. Co-crystal controlled solid state synthesis (C_2S_3) of N-organophthalimide using phthalic anhydride and 3-aminobenzoic acid.
Alternative sources of energy
9. Solvent free, microwave assisted one pot synthesis of phthalocyanine complex of copper (II).
10. Photoreduction of benzophenone to benzopinacol in the presence of sunlight.

Recommended Books:
1. Anastas, P.T & Warner, J.C. *Green Chemistry: Theory and Practice*, Oxford University Press (1998).
2. Kirchoff, M. & Ryan, M.A. *Greener approaches to undergraduate chemistry experiment*. American Chemical Society, Washington DC (2002).
3. Ryan, M.A. *Introduction to Green Chemistry*, Tinnesand; (Ed), American Chemical Society, Washington DC (2002).
4. Sharma, R.K.; Sidhwani, I.T. & Chaudhari, M.K. *Green Chemistry Experiment: A monograph*, I.K International Publishing House Pvt Ltd. New Delhi. Bangalore CISBN 978-93-81141-55-7 (2013).
5. Cann, M.C. & Connelly, M. E. *Real world cases in Green Chemistry*, American Chemical Society (2008).
6. Cann, M. C. & Thomas, P. *Real world cases in Green Chemistry*, American Chemical Society (2008).
7. Pavia, D. L. Lampman, G. H. &Kriz, G.S. *W B Introduction to Organic Laboratory Techniques: A Microscale Approach*, 4th Ed., Brooks/Cole; 2007.

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CHM-HC 602: INORGANIC CHEMISTRY-II
(Credits: Theory-04, Practicals-02)

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

Course Objectives:

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

Course Learning Outcomes:

1. Extraction of metals through metallurgical operations and their uses.
2. Bonding of various s andp block elements.

3. Use of boron compounds.
4. Chemistry of inorganic polymers and their uses.

Unit-1 *(8 classes of 60 minutes each)* **13m**

General Principles of Metallurgy:

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. Methods of purification of metals: Electrolytic Kroll process, Parting process, van Arkel-de Boer process and Mond's process, Zone refining.

Unit-2 *(8 classes of 60 minutes each)* **12m**

Acids and Bases:

Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB) Application of HSAB principle.

Unit-3 *(14 classes of 60 minutes each)* **25m**

Chemistry of *s* and *p* Block Elements:

Inert pair effect, Relative stability of different oxidation states, diagonal relationship and anomalous behaviour of first member of each group. Allotropy and catenation. Complex formation tendency of *s* and *p* block elements. Hydrides and their classification ionic, covalent and interstitial. Basic beryllium acetate and nitrate.

Study of the following compounds with emphasis on structure, bonding, preparation, properties and uses. Boric acid and borates, boron nitrogen compounds, boranes, carboranes and graphitic compounds, silanes, oxides and oxoacids of nitrogen, phosphorus and chlorine. Peroxo acids of sulphur, interhalogen compounds, polyhalide ions, pseudohalogens and basic properties of halogens.

Unit-4 *(8 classes of 60 minutes each)* **12m**

Noble Gases:

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2). Molecular shapes of noble gas compounds (VSEPR theory).

Unit-5 *(7 classes of 60 minutes each)* **13m**

Inorganic Polymers:

Types of inorganic polymers, comparison with organic polymers, synthesis, structural aspects and applications of silicones and siloxanes. Silicates – clays and zeolites, polyphosphazenes, metal-organic framework compounds (MOFs).

Recommended Books:

1. Lee, J. D., Concise Inorganic Chemistry, 5th Ed., Oxford University Press, 2008.
2. Douglas, B.E. and Mc Daniel, D.H., Concepts and Models of Inorganic Chemistry, 3rd Ed. Wiley India, 2006.
3. Greenwood, N.N. & Earnshaw, A., Chemistry of the Elements, 2nd Ed., Elsevier India, 2010.
4. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.
5. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.
6. Miessler, G. L. &Tarr, D. A., Inorganic Chemistry 4th Ed., Pearson, 2010.
7. Weller, M., Armstrong, F., Rourke, J. & Overton, T., Inorganic Chemistry 6th Ed. 2015.

CHM-HC 602(P): Inorganic Chemistry Laboratory - II

(A) Iodo / Iodimetric Titrations
(i) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodimetrically).
(ii) Estimation of (i) arsenite and (ii) antimony in tartar-emetic iodimetrically
(iii) Estimation of available chlorine in bleaching powder iodometrically.
(B) Inorganic preparations
(i) Cuprous Chloride, CuCl
(ii) Preparation of manganese(III) phosphate, $MnPO_4.H_2O$
(iii) Preparation of aluminium potassium sulphate $KAl(SO_4)_2.12H_2O$ (Potash alum) or Chrome alum.

Recommended Books:
1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold. 1972.
3. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. II*. S. Chand & Co Ltd., New Delhi.
4. G. N. Mukherjee: *Advanced Experiments in Inorganic Chemistry*. U. N. Dhur & Sons Pvt Ltd. Kolkata 700073.

CHM-HC 603: PHYSICAL CHEMISTRY- II

(Credits: Theory-04, Practicals-02)

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

Course Objective:

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

Course Learning Outcomes:

1. Use of thermochemical equations for calculation of energy and related terms.
2. Use of thermodynamics in explaining chemical behavior of solute/solvent and reactions.
3. Study of calorimeter principle and its use.

Unit-1 *(22 classes of 60 minutes each)* **30m**

Chemical Thermodynamics:

Intensive and extensive variables; state and path functions; isolated, closed and open systems; zeroth law of thermodynamics. *First law:* Concept of heat, *q*, work, *w*, internal energy, *U*, and statement of first law; enthalpy, *H*, relation between heat capacities, calculations of *q*, *w*, *U* and *H* for reversible, irreversible and free expansion of gases (ideal and van der Waals) under isothermal and adiabatic conditions. Law of equipartition of energy, degrees of freedom and molecular basis of heat capacities.

Thermochemistry: Heats of reactions: standard states; enthalpy of formation of molecules and ions and enthalpy of combustion and its applications; calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data, effect of temperature (Kirchhoff's equations) and pressure on enthalpy of reactions. Adiabatic flame temperature, explosion temperature.

Second Law*:* Concept of entropy; thermodynamic scale of temperature, statement of the second law of thermodynamics; molecular and statistical interpretation of entropy. Calculation of entropy change for reversible and irreversible processes.

Third Law*:* Nernst heat theorem, Statement of third law, concept of residual entropy, calculation of absolute entropy of molecules.

Free Energy Functions: Gibbs and Helmholtz energy; variation of S, G, A with T, V, P; spontaneous process-enthalpy change, entropy change and free energy change considerations. Relation between Joule-Thomson coefficient and other thermodynamic parameters; inversion temperature; Gibbs-Helmholtz equation; Maxwell relations; thermodynamic equation of state.

Unit-2 *(7 classes of 60 minutes each)* **12m**

Systems of Variable Composition:

Partial molar quantities, dependence of thermodynamic parameters on composition; Gibbs-Duhem equation, chemical potential of ideal mixtures, change in thermodynamic functions in mixing of ideal gases.

Unit-3 *(8 classes of 60 minutes each)* **18m**

Chemical Equilibrium:

Criteria of thermodynamic equilibrium, degree of advancement of reaction, chemical equilibria in ideal gases, concept of fugacity. Thermodynamic derivation of relation between Gibbs free energy of reaction and reaction quotient. Coupling of exoergic and endoergic reactions. Equilibrium constants and their quantitative dependence on temperature, pressure and concentration. Free energy of mixing and spontaneity; thermodynamic derivation of relations between the various equilibrium constants K_p, K_c and K_x. Le Chatelier principle (quantitative treatment); equilibrium between ideal gases and a pure condensed phase.

Unit-4 *(8 classes of 60 minutes each)* **15m**

Solutions and Colligative Properties:

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

Recommended Books

1. Peter, A. & Paula, J. de. *Physical Chemistry* 9^{th} *Ed.*, Oxford University Press (2011).

2. Castellan, G. W. *Physical Chemistry 4th Ed.,* Narosa (2004).
3. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.,* Prentice-Hall (2012).
4. McQuarrie, D. A. & Simon, J. D. *Molecular Thermodynamics* Viva Books Pvt. Ltd.: New Delhi (2004).
5. Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S. *Commonly Asked Questions in Thermodynamics.* CRC Press: NY (2011).
6. Levine, I .N. *Physical Chemistry* 6th Ed., Tata Mc Graw Hill (2010).
7. Metz, C.R. *2000 solved problems in chemistry,* Schaum Series (2006)
8. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co.; 47th Ed. (2017)
9. Kapoor, K. L. *A Textbook of Physical Chemistry (Volume 2)* McGraw Hill Education; Sixth edition (2019)

CHM-HC 603(P): Laboratory

Thermochemistry

(a) Determination of heat capacity of a calorimeter for different volumes using change of enthalpy data of a known system (method of back calculation of heat capacity of calorimeter from known enthalpy of solution or enthalpy of neutralization).
(b) Determination of heat capacity of the calorimeter and enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
(c) Calculation of the enthalpy of ionization of ethanoic acid.
(d) Determination of heat capacity of the calorimeter and integral enthalpy (endothermic and exothermic) solution of salts.
(e) Determination of basicity/proticity of a polyprotic acid by the thermochemical method in terms of the changes of temperatures observed in the graph of temperature versus time for different additions of a base. Also calculate the enthalpy of neutralization of the first step.
(f) Determination of enthalpy of hydration of copper sulphate.
(g) Study of the solubility of benzoic acid in water and determination of ΔH.
Any other experiment carried out in the class.

Recommended Books

1. Khosla, B. D.; Garg, V. C. & Gulati, A., *Senior Practical Physical Chemistry,* R. Chand & Co.: New Delhi (2011).
2. Athawale, V. D. &Mathur, P. *Experimental Physical Chemistry* New Age International: New Delhi (2001).
3. J. N. Gurtu & R. Kapoor; *Advanced Experimental Chemistry Vol. I.* S. Chand & Co Ltd., New Delhi.
4. J. B. Yadav: *Advanced Practical Physical Chemistry*. Geol Publishing House, Meerut.

Semester IV

CHM-HC 604: Molecular Spectroscopy and Photochemistry

(Credits : Theory 04; Practical -02)

Course objectives:

1. To understand the interaction of electromagnetic radiation with molecules.
2. To understand basic principles of spectroscopy.
3. Franck-Condon principles and electronic transitions.
4. Photochemical reactions.

Course Learning Outcomes:

1. Determination of bond length of diatomic and linear triatomic molecules.
2. Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.
3. Qualitative treatment of Rotational Raman effect
4. Discussion of Electronic spectra and photochemistry (Lambert-Beer law and its applications).

UNIT-1: ***(18 classes of 60 minutes each)*** **30m**

Interaction of electromagnetic radiation with molecules and various types of spectra;

Born-Oppenheimer approximation. Rotation spectroscopy: Selection rules, intensities of spectral lines, determination of bond lengths of diatomic and linear triatomic molecules, isotopic substitution.

Vibrational spectroscopy: Classical equation of vibration, computation of force constant, amplitude of diatomic molecular vibrations, anharmonicity, Morse potential, dissociation energies, fundamental frequencies, overtones, hot bands, degrees of freedom for polyatomic molecules, modes of vibration, concept of group frequencies. Vibration-rotation spectroscopy: diatomic vibrating rotator, P, Q, R branches.

Unit-2: ***(10 classes of 60 minutes each)*** **15m**

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.

Electronic spectroscopy: Franck Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and pre dissociation.

Unit-3: ***(17 classes of 60 minutes each)*** **30m**

Photophysical and photochemical processes:

Laws of photochemistry, quantum yield. Jablonski diagrams: Franck-Condon principle, Law of photochemical equivalence, quantum efficiency, low and high quantum efficiency. kinetics of photochemical reactions (H_2+Br_2 = 2HBr, 2HI = H_2+I_2), energy transfer in photochemical reactions (photosensitization and quenching), fluorescence, phosphorescence, chemiluminescence, Discussion of Electronic spectra and photochemistry (Lambert-Beer law

and its applications).

***Recommended books/References**:*

1. Laideler K.J. and Meiser J.M. *Physical Chemistry* Third Edition (International) 1999
2. LevineI.N., *Physical Chemistry*, Fourth Edition, McGraw-Hill (International), 1995.
3. McQuarrie D.A. and Simon J.D. *Physical Chemistry-A Molecular Approach*, University Science Books, 1998
4. Rohatgi-Mukherjee K. K. *Fundamentals of Photochemistry*, New age (revised second edition).
5. Banwell,C.N.&McCash,E.M.*FundamentalsofMolecularSpectroscopy*4th Ed. Tata McGraw-Hill: New Delhi (2006).

CHM-HC 604(P): Laboratory

Suggested laboratory experiments:

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

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

Suggested books/reference books:

1. Practicals in Physical Chemistry - a modern approach, P.S. Sindhu, Macmillan

2. Experiments in Physical Chemistry, J.M. Wilson, R.J. Newcomb, A.R. Denaro, 2nd Edn., Elsevier.

CHM-HC 605: INORGANIC CHEMISTRY-III

(Credits: Theory-04, Practicals-02)

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

Course Objectives:

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

magnetic behavior.

8. Understanding the bioinorganic chemistry of metals in biological systems.
9. Hemoglobin and its importance in biological systems.

Course Learning Outcomes:

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

Unit-1: ***(15 classes of 60 minutes each)*** **25m**

Coordination Chemistry:

Coordination compounds, types of ligands, Werner's theory, IUPAC nomenclature and isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers. Valence bond theory (inner and outer orbital complexes), electroneutrality principle and back bonding. Crystal field theory, measurement of 10 Dq (Δ_o), CFSE in weak and strong fields, pairing energies, factors affecting the magnitude of 10 Dq (Δ_o, Δ_t).Octahedral vs. tetrahedral coordination, tetragonal distortions from octahedral geometry Jahn-Teller theorem, square planar geometry. Qualitative aspects of ligand field and MO Theory. Chelate effect, polynuclear complexes, labile and inert complexes.

Unit-2: ***(10 classes of 60 minutes each)*** **20m**

Transition Elements:

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

Unit-3: ***(10 classes of 60 minutes each)*** **12m**

Lanthanoids and Actinoids:

Electronic configuration, oxidation states, colour, spectral and magnetic properties, lanthanide contraction, separation of lanthanides (ion-exchange method only).

Unit-4: ***(10 classes of 60 minutes each)*** **18m**

Bioinorganic Chemistry:

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

Recommended Books:

1. Cotton, F.A., Wilkinson, G. and Gaus, P. L., Basic Inorganic Chemistry, 3rd Ed., Wiley, 2007.
2. Huheey, J. E., Keiter, E. A., Keiter, R. L., Medhi, O. K., Inorganic Chemistry: Principles of Structure and Reactivity, 4th Ed., Pearson Education India, 2006.
3. Lippard, S.J. & Berg, J.M. Principles of Bioinorganic Chemistry, Panima Publishing Company, 1994.
4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.

5. Basolo, F, and Pearson, R.C., Mechanisms of Inorganic Chemistry, John Wiley & Sons, NY, 1967.
6. Greenwood, N.N. & Earnshaw, A., Chemistry of the Elements, 2nd Ed., Elsevier India, 2010.

CHM-HC 605(P): Laboratory

Gravimetric Analysis:

i. Estimation of nickel(II) using dimethylglyoxime (DMG).
ii. Estimation of copper as CuSCN
iii. Estimation of iron as Fe_2O_3 by precipitating iron as $Fe(OH)_3$.
iv. Estimation of Al (III) by precipitating with oxine and weighing as $Al(oxine)_3$ (aluminiumoxinate).

Inorganic Preparations:

i. Tetraamminecopper(II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$
ii. *Cis* and *trans* $K[Cr(C_2O_4)_2.(H_2O)_2]$ Potassium dioxalatodiaquachromate (III)
iii. Tetraamminecarbonatocobalt (III) ion
iv. Potassium tris(oxalato)ferrate(III)

Chromatography of metal ions

Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:

i. Ni(II) and Co(II)
ii. Fe(III) and Al(III)

Recommended Book:

1. Mendham, J. et al.: Vogel's Textbook of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold. 1972.
3. *Inorganic Syntheses*, Vol. 1-10.
4. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. II.* S. Chand & Co Ltd., New Delhi.
5. G. N. Mukherjee: *Advanced Experiments in Inorganic Chemistry*. U. N. Dhur & Sons Pvt Ltd. Kolkata 700073.

CHM-HC 606: ORGANIC CHEMISTRY-II
(Credits: Theory-04, Practicals-02)

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

Course Objectives:

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

Course Learning Outcomes:

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

Unit-1: ***(9 classes of 60 minutes each)*** **17m**

Chemistry of Halogenated Hydrocarbons:

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

Aryl halides: Preparation, including preparation from diazonium salts. nucleophilic aromatic substitution; SNAr, Benzyne mechanism. Relative reactivity of alkyl, allyl/benzyl, vinyl and aryl halides towards nucleophilic substitution reactions.

Organometallic compounds of Mg and Li – Use in synthesis of organic compounds.

Unit-2: ***(10 classes of 60 minutes each)*** **18m**

Alcohols, Phenols, Ethers and Epoxides:

Alcohols: preparation, properties and relative reactivity of 1°, 2°, 3°alcohols, Bouveault-Blanc Reduction; Preparation and properties of glycols: Oxidation by periodic acid and lead tetraacetate, Pinacol-Pinacolone rearrangement;

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

Ethers and Epoxides: Preparation and reactions with acids. Reactions of epoxides with alcohols, ammonia derivatives and $LiAlH_4$

Unit-3: ***(10 classes of 60 minutes each)*** **18m**

Carbonyl Compounds:

Preparation, properties, structure and reactivity; Nucleophilic additions, Nucleophilic addition-elimination reactions with ammonia derivatives with mechanism; Mechanisms of Aldol and Benzoin condensation, Knoevenagel condensation, Claisan-Schmidt, Perkin, Cannizzaro and Wittig reaction, Beckmann and Benzil-Benzilic acid rearrangements, haloform reaction and Baeyer Villiger oxidation, α- substitution reactions, oxidations and reductions (Clemmensen, Wolff-Kishner, $LiAlH_4$,$NaBH_4$, MPV, PDC and PGC); Addition reactions of unsaturated carbonyl compounds: Michael addition. Active methylene compounds: Keto-enol tautomerism. Preparation and synthetic applications of diethyl malonate and ethyl acetoacetate.

Unit-4: ***(10 classes of 60 minutes each)*** **17m**

Carboxylic Acids and their Derivatives:

Preparation, physical properties and reactions of monocarboxylic acids: Typical reactions of dicarboxylic acids, hydroxy acids and unsaturated acids: succinic/phthalic, lactic, malic, tartaric, citric, maleic and fumaric acids; Preparation and reactions of acid chlorides, anhydrides, esters and amides; Comparative study of nucleophilic sustitution at acyl group -Mechanism of acidic and alkaline hydrolysis of esters, Claisen condensation, Dieckmann and Reformatsky reactions, Hofmann bromamide degradation and Curtius rearrangement.

Unit-5: ***(6 classes of 60 minutes each)*** **5m**

Sulphur containing compounds: Preparation and reactions of thiols, thioethers and sulphonic acids.

Recommended Books:

1. Morrison, R. T. & 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. Graham Solomons, T.W. *Organic Chemistry*, John Wiley & Sons, Inc.
4. Clayden, J., Greeves, N. & Warren, S. *Organic Chemistry*, Second edition, Oxford University Press, 2012.
5. Keeler, J., Wothers, P. *Chemical Structure and Reactivity – An Integrated approach*, Oxford University Press.
6. Smith, J. G. *Organic Chemistry*, Tata McGraw-Hill Publishing Company Limited.
7. Carey, F. A.; Sundberg, R. J. *Advanced Organic Chemistry: Reactions and Synthesis (Part B)*, Springers.

CHM-HC 606(P): Laboratory

1. Test of functional groups like alcohols, phenols, carbonyl and carboxylic acid group.
2. Organic preparations:
   i. Acetylation of one of the following compounds: amines (aniline, *o*-, *m*-, *p*toluidines*o*-, *m*-, *p*-anisidine) and phenols (β-naphthol, vanillin, salicylic acid) by any one method:
      a. Using conventional method.
      b. Using green approach
   ii. Benzolyation of one of the following amines (aniline, *o*-, *m*-, *p*- toluidines and *o*-, *m*-, *p*-anisidine) and one of the following phenols (β-naphthol, resorcinol, pcresol) by Schotten-Baumann reaction.
   iii. Oxidation of ethanol/ isopropanol (Iodoform reaction).
   iv. Bromination of any one of the following:
      a. Acetanilide by conventional methods
      b. Acetanilide using green approach (Bromate-bromide method)
   v. Nitration of any one of the following:
      a. Acetanilide/nitrobenzene by conventional method
      b. Salicylic acid by green approach (using ceric ammonium nitrate).
   vi. Selective reduction of *meta* dinitrobenzene to *m*-nitroaniline.
   vii. Reduction of *p*-nitrobenzaldehyde by sodium borohydride.
   viii. Hydrolysis of amides and esters.
   ix. Semicarbazone of any one of the following compounds: acetone, ethyl methyl ketone, cyclohexanone, benzaldehyde.
   x. *S*-Benzylisothiouronium salt of one each of water soluble and water insoluble acids (benzoic acid, oxalic acid, phenyl acetic acid and phthalic acid).
   xi. Aldol condensation using either conventional or green method.
   xii. Benzil-Benzilic acid rearrangement.

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

Recommended Books

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.,* Pearson (2012)
3. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).

4. Ahluwalia, V.K. &Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis*, University Press (2000).
5. Vogel, A. I. *Elementary Practical Organic Chemistry*, Part 1: *Small scale Preparations*, CBS Publishers and Distributors.
6. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. III*. S. Chand & Co Ltd., New Delhi.
7. N. K. Vishnoi: *Advanced Practical Organic Chemistry*. Vikas Publishing House, New Delhi.

Semester V

CHM-HC 701: Introduction to Quantum Chemistry
(Credits: Lecture -05, Tutorial -01)

Course Objectives:

The aim of this course is to introduce the students with three important areas- quantum chemistry, molecular spectroscopy and photochemistry. In quantum chemistry unit the students will be taught the postulates of quantum mechanics and the application of quantum mechanical ideas in some simple systems such as particle in a box, rigid rotor, simple harmonic oscillator etc.

Course Learning Outcome:

After completion of this course the students are expected to understand the application of quantum mechanics in some simple chemical systems such as hydrogen atom or hydrogen like ions.

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Unit-1: ***(15 classes of 60 minutes each)*** **25m**

Quantum Chemistry: Introduction to black – body radiation and distribution of energy, photoelectric effect, concept of quantization, wave particle duality (de-Broglie's hypothesis). The uncertainty principle, the wave function: wave function and its interpretation, conditions of normalization, and Orthogonality and its significance.

Unit-2: ***(15 classes of 60 minutes each)*** **25m**

Postulates of quantum mechanics, quantum mechanical operators, Schrödinger equation and its application to free particle and "particle-in-a-box" (rigorous treatment), quantization of energy levels, zero-point energy Extension to two and three dimensional boxes, separation of variables, degeneracy.

Unit-3: ***(15 classes of 60 minutes each)*** **25m**

Qualitative treatment of simple harmonic oscillator model of vibrational motion: Setting up of Schrödinger equation and discussion of solution and wave functions. Vibrational energy of diatomic molecules and zero-point energy.

Angular momentum: Commutation rules, quantization of square of total angular momentum and z-component. Rigid rotator model of rotation of diatomic molecule. Schrödinger equation,

transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution.

Unit-4: ***(15 classes of 60 minutes each)*** **25m**

Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus. Setting up of Schrödinger equation for many-electron atoms (He, Li). Need for approximation methods. Statement of variation theorem and application to simple systems (particle-in-a-box, harmonic oscillator, hydrogen atom).

Chemical bonding: Covalent bonding, valence bond and molecular orbital approaches, LCAO-MO treatment of H_2^+. Bonding and anti bonding orbitals. Qualitative extension to H_2. Comparison of LCAO-MO and VB treatments of H_2 (only wave functions, detailed solution not required) and their limitations. Refinements of the two approaches (Configuration Interaction for MO, ionic terms in VB). Qualitative description of LCAO-MO treatment of homonuclear and heteronuclear diatomic molecules (HF, LiH). Localised and non-localised molecular orbitals treatment of triatomic (BeH_2, H_2O) molecules. Qualitative MO theory and its application to AH_2 type molecules.

Recommended Books:

1. Chandra, A. K. Introductory Quantum Chemistry Tata McGraw-Hill (2001).
2. House, J. E. Fundamentals of Quantum Chemistry 2nd Ed. Elsevier: USA (2004).
3. Lowe, J. P. & Peterson, K. Quantum Chemistry, Academic Press (2005).
4. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 4) McGraw Hill Education; 5th edition (2017)
5. Sen, B. K. Quantum Chemistry- Including Spectroscopy, Kalyani Publishers; 4th edition (2011)
6. McQuarrie, D. A. Quantum Chemistry, Viva Books (2016)

CHM-HC 702: ORGANIC CHEMISTRY-III
(Credits: Theory-04, Practicals-02)

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

Course Objectives:

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

Course Learning Outcomes:

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

Unit-1: ***(12 classes of 60 minutes each)*** **20m**

Nitrogen Containing Functional Groups: Preparation and important reactions of nitro and compounds, nitriles and isonitriles

Amines: Effect of substituent and solvent on basicity; Preparation and properties: Gabriel phthalimide synthesis, Carbylamine reaction, Mannich reaction, Hoffmann's exhaustive methylation, Hofmann-elimination reaction; Distinction between 1^0, $2^0$and 3^0 amines with Hinsberg reagent and nitrous acid.

Diazonium Salts: Preparation and their synthetic applications.

Unit-2 ***(6 classes of 60 minutes each)*** **10m**

Polynuclear Hydrocarbons: Reactions of naphthalene phenanthrene and anthracene Structure, Preparation and structure elucidation and important derivatives of naphthalene and anthracene; Polynuclear hydrocarbons.

Unit-3 ***(14 classes of 60 minutes each)*** **25m**

Heterocyclic Compounds: Classification and nomenclature, Structure, aromaticity in 5-numbered and 6-membered rings containing one heteroatom;Synthesis, reactions and mechanism of substitution reactions of:

Furan, Pyrrole (Paal-Knorr synthesis, Knorr pyrrole synthesis, Hantzschsynthesis),Thiophene, Pyridine (Hantzsch synthesis), Pyrimidine.Indole: Fischer indole synthesis and Madelung synthesis).Quinoline and isoquinoline: Skraup synthesis, Friedlander's synthesis, Knorr quinoline synthesis, Doebner- Miller synthesis, Bischler-Napieralski reaction, Pictet-Spengler reaction, Pomeranz-Fritsch reaction.

Unit-4 ***(7 classes of 60 minutes each)*** **10m**

Alkaloids: Natural occurrence, General structural features, Isolation and their physiological action Hoffmann's exhaustive methylation, Emde's modification, Structure elucidation and synthesis of Nicotine. Medicinal importance of Nicotine, Hygrine, Quinine, Morphine, Cocaine, and Reserpine.

Unit-5 ***(6 classes of 60 minutes each)*** **10m**

Terpenes: Occurrence, classification, isoprene rule; Elucidation of structure and synthesis of Citral, Neral and α-terpineol.

Recommended Books:

1. Morrison, R. T. & 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. Finar, I. L. *Organic Chemistry* (*Volume 2: Stereochemistry and the Chemistry of Natural Products*), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
4. Graham Solomons, T.W. *Organic Chemistry,* John Wiley & Sons, Inc.
5. Kalsi, P. S. *Textbook of Organic Chemistry 1st Ed.*, New Age International (P) Ltd. Pub.
6. Clayden, J.; Greeves, N.; Warren, S.; Wothers, P.; *Organic Chemistry*, Oxford University Press.
7. Singh, J.; Ali, S.M. & Singh, J. *Natural Product Chemistry*, Prajati Parakashan (2010).

CHM-HC 702(P): Laboratory

1. Detection N, S, halogens in organic compounds.
2. Functional group test for nitro, amine and amide groups.
3. Qualitative analysis of unknown organic compounds containing simple functional groups (alcohols, carboxylic acids, phenols and carbonyl compounds)

Recommended Books

1. Mann, F.G. & Saunders, B.C. *Practical Organic Chemistry,* Pearson Education (2009)
2. Furniss, B.S.; Hannaford, A.J.; Smith, P.W.G.; Tatchell, A.R. *Practical Organic Chemistry, 5th Ed.*, Pearson (2012)
3. Ahluwalia, V.K. & Aggarwal, R. *Comprehensive Practical Organic Chemistry: Preparation and Quantitative Analysis,* University Press (2000).
4. Ahluwalia, V.K. &Dhingra, S. *Comprehensive Practical Organic Chemistry: Qualitative Analysis,* University Press (2000).
5. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. III*. S. Chand & Co Ltd., New Delhi.
6. N. K. Vishnoi: *Advanced Practical Organic Chemistry*. Vikas Publishing House, New Delhi.
7. O. P. Agarwal: *Advanced Practical Organic Chemistry*. Geol Publishing House, Meerut

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Semester VI

CH-HC 703: Materials Chemistry

(Credits: Lectures- 05; Tutorial-01)

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

Course Objectives:

1. Crystalline solids–parameters, symmetry.
2. Silica based materials in applications.
3. Technological importance of ionic liquids, preparation of materials–using sol-gel technique.
4. Nano-structured materials, self-assembled structure.
5. Composites and its applications
6. Understanding basic parameters of crystalline solids, symmetry and crystal structures.
7. Mesoporous/microporous silica based materials, functionalized hybrid materials and its applications.
8. Preparation of inorganic solids, host-guest chemistry, ionic liquids and its significance.
9. Understanding self-assembled structures, nano-structured materials, carbon nanotubes, applications.
10. Understanding composites and their industrial applications.

Course Learning Outcomes:

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

UNIT-1: Basics of crystalline solids (12 classes of 60 minutes each) **20m**

Crystalline solids, crystal systems, Bravais lattices, coordination number, packing factors –cubic, hexagonal, diamond structures, lattice planes, Miller indices, interplanar distances, directions, types of bonding , lattice energy, Madelung constants, Born Haber cycle, cohesive energy, Symmetry elements, operations, translational symmetries - point groups, space groups, equivalent positions, close packed structures, voids, crystal structures, Pauling rules, defects incrystals, polymorphism, twinning.

UNIT-2: Silica based materials (12 classes of 60 minutes each) **20m**

Introduction to Zeolites, metallosilicates, silicalites and related microporous materials, Mesoporous silica, metaloxides and related functionalized mesoporous materials: Covalent organic frameworks, Organic-Inorganic hybrid materials,

periodic mesoporous organo silica, metalorganic frameworks: H_2/CO_2 gas storage and catalytic applications.

UNIT-3: Inorganic solids/ionic liquids of technological importance (12 classes of 60 minutes each) **20m**

Preparation of inorganic solids: Conventional heat and beat methods, Co-precipitation method, Sol-gel methods, Hydro-thermal method, Ion-exchange and Intercalation methods. Introduction to Solid electrolytes, inorganic liquid crystals. Ionic liquids, forces responsible for ionic liquids, synthesis and application of imidazolium and phosphonium based ionic liquids. Host-guest chemistry (elementary ideas).

UNIT-4: Nanomaterials (12 classes of 60 minute seach) **20m**

Overview of nanostructures and nano-materials: classification. Preparation of gold and silver metallic nanoparticles, self-assembled nano structures-control of nano-architecture-one dimensional control. Carbon nanotubes and inorganic nanowires.

UNIT-5: Composite materials (8 classes of 60 minutes each) **20m**

Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

Recommend books/References:

1. Atkins P, Overton T., Rourke J. Weller M. and Armstrong F Shriver and Atkins. *Inorganic Chemistry* Oxford University Press, Fifth Edition, 2012.
2. Adam, D.M. *Inorganic Solids: An introduction to concepts in solid-state structural chemistry*. John Wiley, 1974.
3. Poole, C.P. & Owens, F.J. *Introduction to Nanotechnology* John Wiley 2003.
4. Rodger, G.E. *Inorganic and Solid State Chemistry*, Cengage Learning, 2002.

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CHM-HC 704: PHYSICAL CHEMISTRY-III
(Credits: Theory-04, Practicals-02)

Course Objectives:

1. Phases, components, Gibbs phase rule, Phase diagrams and applications.
2. Chemical kinetics: type of reactions, determination of rate, theories of reaction rate, steady state approximation.
3. Catalyst – mechanism, acid base catalysis, enzyme catalysis.

4. Adsorption isotherms.
5. Understanding phases, components, Gibb's phase rule and its applications, construction of phase diagram of different systems, the application of phase diagram.
6. Understanding the basics of chemical kinetics: determination of order, molecularity, and understanding theories of reaction rates, determination of rate of opposing/parallel/chain reactions with suitable examples, application of steady state kinetics, Steady-state approximation.
7. Catalyst – mechanism of catalytic action, enzyme catalysis.
8. Langmuir, Freundlich – adsorption isotherms, significance, multilayer adsorption – theory and significance.

Course Learning Outcomes:

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

Unit-1 ***(15 classes of 60 minutes each)*** **25m**

Phase Equilibria: Concept of phases, components and degrees of freedom, derivation of Gibbs Phase Rule for nonreactive and reactive systems; Clausius-Clapeyron equation and its applications to solid-liquid, liquid-vapour and solid-vapour equilibria, phase diagram for one component systems, with applications. Phase diagrams for systems of solid-liquid equilibria involving eutectic, congruent and incongruent melting points, solid solutions.

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

Nernst distribution law: its derivation and applications.

Unit-2 ***(18 classes of 60 minutes each)*** **28m**

Chemical Kinetics: Order and molecularity of a reaction, rate laws in terms of the advancement of a reaction, differential and integrated form of rate expressions up to second order reactions, experimental methods of the determination of rate laws, kinetics of complex reactions (integrated rate expressions up to first order only): (i) Opposing reactions (ii) parallel reactions and (iii) consecutive reactions and their differential rate equations (iv) chain reactions. Temperature dependence of reaction rates; Arrhenius equation; activation energy. Collision theory of reaction rates, Lindemann mechanism, qualitative treatment of the theory of absolute reaction rates. Reaction mechanism- steady-state approximation and rate determining step approximation methods.

Unit-3: ***(8 classes of 60 minutes each)*** **15m**

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

Unit-4: ***(4 classes of 60 minutes each)*** **7m**

Surface chemistry: Physical adsorption, chemisorption, adsorption isotherms, nature of adsorbed state.

Recommended Books:

1. Peter Atkins & Julio De Paula, *Physical Chemistry 9th Ed.*, Oxford University Press(2010).

2. Castellan, G. W. *Physical Chemistry*, 4th Ed., Narosa (2004).
3. McQuarrie, D. A. & Simon, J. D., *Molecular Thermodynamics*, Viva Books Pvt. Ltd.:New Delhi (2004).
4. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.*, Prentice-Hall (2012).
5. Assael, M. J.; Goodwin, A. R. H.; Stamatoudis, M.; Wakeham, W. A. & Will, S. *Commonly Asked Questions in Thermodynamics.* CRC Press: NY (2011).
6. Zundhal, S.S. *Chemistry concepts and applications* Cengage India (2011).
7. Ball, D. W. *Physical Chemistry* Cengage India (2012).
8. Mortimer, R. G. *Physical Chemistry 3rd Ed.*, Elsevier: NOIDA, UP (2009).
9. Levine, I. N. *Physical Chemistry 6th Ed.*, Tata McGraw-Hill (2011).
10. Metz, C. R. *Physical Chemistry 2nd Ed.*, Tata McGraw-Hill (2009).
11. Puri, B. R.; Sharma, L. R.; Pathania, M. S. *Principles of Physical Chemistry*, Vishal Publishing Co.; 47th Ed. (2017)
12. Kapoor, K. L. *A Textbook of Physical Chemistry (Volume 5)*. McGraw Hill Education; 5th edition (2017)

CHM-HC 704(P): Laboratory

I. Determination of critical solution temperature and composition of the phenol-water system and to study the effect of impurities on it.

II. Phase equilibria: Construction of the phase diagram using cooling curves or ignition tube method:a. simple eutectic andb. congruently melting systems.

III. Distribution of acetic/ benzoic acid between water and cyclohexane.

IV. Study the equilibrium of at least one of the following reactions by the distribution method:
(i) $I_2(aq) + I^- \rightarrow I_3(aq)^{2+}$
(ii) $Cu^{2+}(aq) + nNH_3 \rightarrow Cu(NH_3)_n$
V. Study the kinetics of the following reactions.
1. Initial rate method: Iodide-persulphate reaction
2. Integrated rate method:
a. Acid hydrolysis of methyl acetate with hydrochloric acid.
b. Saponification of ethyl acetate.
3. Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methyl acetate.

VI. Adsorption
I. Verify the Freundlich and Langmuir isotherms for adsorption of acetic acid on activated charcoal.

Recommended Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.*; McGraw-Hill: New York (2003).
3. Halpern, A. M. & McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York (2003).
4. J. N. Gurtu & R. Kapoor; *Advanced Experimental Chemistry Vol. I.* S. Chand & Co Ltd., New Delhi
5. J. B. Yadav: *Advanced Practical Physical Chemistry.* Geol Publishing House, Meerut

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Semester VII

CHM-HC 801: POLYMER CHEMISTRY
(Credits: Theory-04, Practicals-02)

Course Objectives: *This is an introductory level course in polymer chemistry. The aim of the course is to introduce the theory and applications of polymer chemistry to the students. Some industrially important polymers and conducting polymers, a promising class of polymeric materials for next generation devices will also be introduced in this course.*

Course Learning Outcomes: *After completion of this course the students will learn the definition and classifications of polymers, kinetics of polymerization, molecular weight of polymers, glass transition temperature, and polymer solutions etc. They also learn the brief introduction of preparation, structure and properties of some industrially important and technologically promising polymers.*

Unit-1: ***(10 classes of 60 minutes each)*** **15m**
Introduction and history of polymeric materials: Different schemes of classification of polymers, Polymer nomenclature, Molecular forces and chemical bonding in polymers, Texture of Polymers.
Functionality and its importance: Criteria for synthetic polymer formation, classification of polymerization processes, Relationships between functionality, extent of reaction and degree of polymerization. Bifunctional systems, Poly-functional systems.

Unit-2: ***(6 classes of 60 minutes each)*** **10m**
Kinetics of Polymerization: Mechanism and kinetics of step growth, radical chain growth, ionic chain (both cationic and anionic) and coordination polymerizations, Mechanism and kinetics of copolymerization, polymerization techniques.

Unit-3 : ***(8 classes of 60 minutes each)*** **10m**
Crystallization and crystallinity: Determination of crystalline melting point and degree of crystallinity, Morphology of crystalline polymers, Factors affecting crystalline melting point.
Nature and structure of polymers- Structure Property relationships.

Unit-4: ***(10 classes of 60 minutes each)*** **20m**
Determination of molecular weight of polymers (M_n, M_w, etc) by end group analysis, viscometry, light scattering and osmotic pressure methods. Molecular weight distribution and its significance. Polydispersity index.
Glass transition temperature (Tg) and determination of Tg, Free volume theory, WLF equation, Factors affecting glass transition temperature (Tg).

Unit-5: ***(5 classes of 60 minutes each)*** **10m**
Polymer Solution - Criteria for polymer solubility, Solubility parameter, Thermodynamics of polymer solutions, entropy, enthalpy, and free energy change of mixing of polymers solutions, Flory- Huggins theory, Lower and Upper critical solution temperatures.

Unit-6 : ***(6 classes of 60 minutes each)*** **10m**
Properties of Polymers (Physical, thermal, Flow & Mechanical Properties).

Brief introduction to preparation, structure, properties and application of the following polymers: polyolefins, polystyrene and styrene copolymers, poly(vinyl chloride) and related polymers, poly(vinyl acetate) and related polymers, acrylic polymers, fluoro polymers, polyamides and related polymers. Phenol formaldehyde resins (Bakelite, Novalac), polyurethanes, silicone polymers, polydienes, Polycarbonates, Conducting Polymers, [polyacetylene, polyaniline, poly(p-phenylene sulphide polypyrrole, polythiophene)].

Recommended Books:

1. *Seymour's Polymer Chemistry,* Marcel Dekker, Inc.
2. G. Odian: Principles of Polymerization, John Wiley.
3. F.W. Billmeyer: Text Book of Polymer Science, John Wiley.
4. P. Ghosh: Polymer Science & Technology, Tata Mcgraw-Hill.
5. R.W. Lenz: Organic Chemistry of Synthetic High Polymers.

CHM-HC 801(P): Polymer Chemistry Laboratory

1. **Polymer synthesis**
    1. Free radical solution polymerization of styrene (St) / Methyl Methacrylate (MMA) /Methyl Acrylate (MA) / Acrylic acid (AA).
        a. Purification of monomer
        b. Polymerization using benzoyl peroxide (BPO) / 2, 2'-azo-bis-isobutylonitrile (AIBN)
    2. Preparation of nylon 66/6

    1. Interfacial polymerization, preparation of polyester from isophthaloyl chloride (IPC) and phenolphthalein
        a. Preparation of IPC
        b. Purification of IPC
        c. Interfacial polymerization
    3. Redox polymerization of acrylamide
    4. Precipitation polymerization of acrylonitrile
    5. Preparation of urea-formaldehyde resin
    6. Preparations of novalac resin/resold resin.
    7. Microscale Emulsion Polymerization of Poly(methylacrylate).

Polymer characterization

1. Determination of molecular weight by viscometry:
    (a) Polyacrylamide-aq.$NaNO_2$ solution
    (b) (Poly vinyl proplylidine (PVP) in water
2. Determination of the viscosity-average molecular weight of poly(vinyl alcohol) (PVOH) and the fraction of "head-to-head" monomer linkages in the polymer.
3. Determination of molecular weight by end group analysis: Polyethylene glycol (PEG) (OH group).
4. Testing of mechanical properties of polymers.
5. Determination of hydroxyl number of a polymer using colorimetric method.

Polymer analysis

1. Estimation of the amount of HCHO in the given solution by sodium sulphite method
2. Instrumental Techniques
3. IR studies of polymers
4. DSC analysis of polymers
5. Preparation of polyacrylamide and its electrophoresis

*at least 7 experiments to be carried out.

Recommended Books:

1. Malcohm P. Stevens, Polymer Chemistry: An Introduction, 3rd Ed.
2. Harry R. Allcock, Frederick W. Lampe and James E. Mark, Contemporary Polymer Chemistry, 3rd ed. Prentice-Hall (2003)
3. Fred W. Billmeyer, Textbook of Polymer Science, 3rd ed. Wiley-Interscience (1984)
4. Joel R. Fried, Polymer Science and Technology, 2nd ed. Prentice-Hall (2003)
5. Petr Munk and Tejraj M. Aminabhavi, Introduction to Macromolecular Science, 2nd ed. John Wiley & Sons (2002)
6. L. H. Sperling, Introduction to Physical Polymer Science, 4th ed. John Wiley & Sons (2005)
7. Malcolm P. Stevens, Polymer Chemistry: An Introduction, 3rd ed. Oxford University Press (2005)
8. Seymour/ Carraher's Polymer Chemistry, 9th ed. by Charles E. Carraher, Jr. (2013).

CHM-HC 802: INORGANIC CHEMISTRY-IV

(Credits: Theory-04, Practicals-02)

Course Objectives: *The unit on reaction mechanism is included for the students to get acquainted with the kinetic and thermodynamic factors governing the reaction path and stability of inorganic compounds. Organometallic compounds are introduced so as to apprise students about the importance of metal carbon bond to form complexes and their application as catalysts. Students are expected to learn factors leading to stability of organometallic compounds, their synthesis, reactivity and uses. Qualitative inorganic analysis is included to give students an idea and hands on experience of application of inorganic chemistry. Students should learn how differential reactivity under different conditions of pH can be used to identify variety of ions in a complex mixture. Experiments related to synthesis and characterization of coordination compounds are included to supplement their theoretical knowledge.*

Course Learning Outcomes:

By studying this course the students will be expected to learn about how ligand substitution and redox reactions take place in coordination complexes. Students will also learn about organometallic compounds, comprehend their bonding, stability, reactivity and uses. They will be familiar with the variety of catalysts based on transition metals and their application in industry. On successful completion, students in general will be able to appreciate the use of concepts like solubility product, common ion effect, pH etc. in analysis of ions and how a clever design of reactions, it is possible to identify the components in a mixture. With the experiments related to coordination compound synthesis, calculation of 10Dq, controlling factors etc. will make the students appreciate the concepts of theory in experiments.

Unit-1 ***(10 classes of 60 minutes each)*** **18m**

Mechanism of Inorganic Reactions: Introduction to inorganic reaction mechanisms. Substitution reactions in square planar complexes, Trans-effect, theories of trans effect, Mechanism of nucleophilic substitution in square planar complexes, Thermodynamic and Kinetic stability, Kinetics of octahedral substitution, Ligand field effects and reaction rates, Mechanism of substitution in octahedra complexes. Electron transfer reactions.

Unit-2 ***(15 classes of 60 minutes each)*** **27m**

Organometallic Compounds:

Definition and classification of organometallic compounds on the basis of bond type.
Concept of hapticity of organic ligands.

Metal carbonyls: 18 electron rule, electron count of mononuclear, polynuclear and substituted metal carbonyls of 3d series. General methods of preparation (direct combination, reductive carbonylation, thermal and photochemical decomposition) of mono and binuclear carbonyls of 3d series. Structures of mononuclear and binuclear carbonyls of Cr, Mn, Fe, Co and Ni using VBT. π-acceptor behaviour of CO (MO diagram of CO to be discussed), synergic effect and use of IR data to explain extent of back bonding. Zeise's salt: Preparation and structure, evidences of synergic effect and comparison of synergic effect with that in carbonyls.

Metal Alkyls: Important structural features of methyl lithium (tetramer) and trialkyl aluminium (dimer), concept of multicentre bonding in these compounds. Role of triethylaluminium in polymerisation of ethene (Ziegler – Natta Catalyst). Species present in ether solution of Grignard reagent and their structures, Schlenk equilibrium.
Ferrocene: Preparation and reactions (acetylation, alkylation, metallation, Mannich condensation). Structure and aromaticity. Comparison of aromaticity and reactivity with that of benzene.

Unit-3 ***(10 classes of 60 minutes each)*** **15m**

Transition Metals in Catalysis:
Study of the following industrial processes and their mechanism:
1. Alkene hydrogenation (Wilkinson's Catalyst)
2. Hydroformylation (Co catalysts)
3. Wacker Process
4. Synthetic gasoline (Fischer Tropsch reaction)
5. Synthesis gas by metal carbonyl complexes

Unit-4: ***(10 classes of 60 minutes each)*** **15m**

Theoretical Principles in Qualitative Inorganic Analysis (H_2S Scheme): Basic principles involved in analysis of cations and anions and solubility products, common ion effect. Principles involved in separation of cations into groups and choice of group reagents. Interfering anions (fluoride, borate, oxalate and phosphate) and need to remove them after Group II.

Recommended Books:

1. Vogel, A.I. *Qualitative Inorganic Analysis*, Longman, 1972.
2. Svehla, G. &Sivasankar, B., *Vogel's Qualitative Inorganic Analysis*, 7th Ed., Prentice Hall, 2012.
3. Cotton, F.A., Wilkinson, G. and Gaus, P. L., *Basic Inorganic Chemistry*, 3rd Ed., Wiley, 2007.
4. Cotton, F.A. & Wilkinson, G, Advanced Inorganic Chemistry. 6th Ed., Wiley-VCH, 2007.
5. Huheey, J. E., Keiter, E. A., Keiter, R. L., Medhi, O. K., *Inorganic Chemistry: Principles of Structure and Reactivity*, 4th Ed., Pearson Education India, 2006.
6. Sharpe, A.G. *Inorganic Chemistry*, 4th Indian Reprint (Pearson Education) 2005
7. Douglas, B.E. and Mc Daniel, D.H., Concepts and Models of Inorganic Chemistry, 3rd Ed. Wiley India, 2006.
8. Greenwood, N.N. & Earnshaw, A., Chemistry of the Elements, 2nd Ed., Elsevier India, 2010.
9. Lee, J. D., Concise Inorganic Chemistry, 5th Ed., Oxford University Press, 2008.
10. Powell, P. *Principles of Organometallic Chemistry*, Chapman and Hall, 1988.
11. Shriver, D.D. & Atkins, P., *Inorganic Chemistry 2nd Ed.*, Oxford University Press, 1994.
12. Basolo, F. & Person, R. *Mechanisms of Inorganic Reactions: Study of Metal Complexes in Solution* 2nd Ed.., John Wiley & Sons Inc; NY. 38
13. Purcell, K.F. &Kotz, J.C., *Inorganic Chemistry*, W.B. Saunders Co. 1977
14. Miessler, G. L. &Tarr, D. A., Inorganic Chemistry 4th Ed., Pearson, 2010.
15. Crabtree, Robert H. *The Organometallic Chemistry of the Transition Metals*. *j* New York, NY: John Wiley, 2000.

16. Spessard, Gary O., &Gary L. Miessler. *Organometallic Chemistry*. Upper Saddle River, NJ: Prentice-Hall, 1996.

CHM-HC 802(P): Laboratory

• Qualitative semi micro analysis of mixtures containing 3 anions and 3 cations. Emphasis should be given to the understanding of the chemistry of different reactions. The following radicals are suggested: CO_3^{-}, NO_2^{-}, S^{-}, SO_3^{2-}, $S_2O_3^{2-}$, CH_3COO^{-}, F^{-}, Cl^{-}, Br^{-}, I^{-}, NO_3^{-}, BO_3^{3-}, $C_2O_4^{2-}$, PO_4^{3-}, NH_4^{+}, K^{+}, Pb^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}, Sb^{3+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, Co^{2+}, Ni^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, Mg^{2+}.
• Mixtures should preferably contain one interfering anion, **or** insoluble component ($BaSO_4$, $SrSO_4$, $PbSO_4$, CaF_2 or Al_2O_3) **or** combination of anions e.g. CO_3^{2-} and SO_3^{2-}, NO_2^{-} and NO_3^{-}, Cl^{-} and Br^{-}, Cl^{-} and I^{-}, Br^{-} and I^{-}, NO_3^{-} and Br^{-}, NO_3^{-} and I^{-}.
• Spot tests should be done whenever possible.
• Synthesis of ammine complexes of Ni(II) and their ligand exchange reactions involving bidentate ligands like acetyl acetone, dimethylglyoxime, glycine, etc.
• Preparation of acetylacetanato complexes of Cu^{2+}/Fe^{3+}.
• Controlled synthesis of two copper oxalate hydrate complexes: kinetic vs. thermodynamic factors.
• Determination of ε_{max} value from UV-visible spectra of complexes.
• Measurement of 10 Dq by spectrophotometric method, verification of spectro chemical series.

Recommended Books

1. Vogel's *Qualitative Inorganic Analysis*, Revised by G. Svehla.
2. Marr, G. and Rockett, R.W. *Practical Inorganic Chemistry*, Van Nostrand Reinhold. 1972.
3. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. II.* S. Chand & Co Ltd., New Delhi
4. G. N. Mukherjee: *Advanced Experiments in Inorganic Chemistry.* U. N. Dhur & Sons Pvt Ltd. Kolkata 700073.

Semester VIII

CHM-HC 803: ORGANIC CHEMISTRY-IV
(Credits: Theory-04, Practicals-02)

Course Objectives: *This course introduces students to nucleic acids, amino acids and pharmaceutical compounds. Students will be familiarized with the importance of nucleic acids, amino acids and develop basic understanding of enzymes, bioenergetics and pharmaceutical compounds.*

Course Learning Outcomes*: Students will be able to explain/describe the important features of nucleic acids, amino acids and enzymes and develop their ability to examine their properties and applications.*

Unit-1: ***(8 classes of 60 minutes each)*** **10m**

Nucleic Acids: Components of nucleic acids; Nucleosides and nucleotides; Synthesis and reactions of Adenine, Guanine, Cytosine, Uracil and Thymine; Polynucleotides: DNA and RNA

Unit-2: ***(8 classes of 60 minutes each)*** **18m**

Amino Acids, Peptides and Proteins: Amino acids, Peptides and their classification.

α-Amino Acids - Synthesis, ionic properties and reactions. Zwitterions, pK_a values, isoelectric point and electrophoresis;

Study of peptides: determination of their primary structures-end group analysis, methods of peptide synthesis. Synthesis of peptides using N-protecting, C-protecting and C-activating groups -Solid-phase synthesis.

Unit-3: ***(8 classes of 60 minutes each)*** **10m**

Enzymes: Introduction, classification and characteristics of enzymes. Salient features of active site of enzymes. Mechanism of enzyme action (taking trypsin as example), factors affecting enzyme action, coenzymes and cofactors and their role in biological reactions, specificity of enzyme action (including stereospecificity), enzyme inhibitors and their importance, phenomenon of inhibition (competitive, uncompetitive and non-competitive inhibition including allosteric inhibition).

Unit-4: ***(5 classes of 60 minutes each)*** **7m**

Lipids: Introduction to oils and fats; common fatty acids present in oils and fats, Hydrogenntion of fats and oils, saponification value, acid value, iodine number, rancidity.

Unit-5: ***(8 classes of 60 minutes each)*** **15m**

Concept of Energy in Biosystems:

Cells obtain energy by the oxidation of foodstuff (organic molecules).

Introduction to metabolism (catabolism, anabolism).

ATP: The universal currency of cellular energy, ATP hydrolysis and free energy change.

Agents for transfer of electrons in biological redox systems: NAD^+, FAD.

Conversion of food to energy: Outline of catabolic pathways of carbohydrate- glycolysis, fermentation, Krebs cycle.

Overview of catabolic pathways of fat and protein.

Interrelationship in the metabolic pathways of protein, fat and carbohydrate.

Calorific value of food, standard calorie content of food types.

Unit-6: ***(8 classes of 60 minutes each)*** **15m**

Pharmaceutical Compounds: Structure and Importance

Classification, structure and therapeutic uses of antipyretics: Paracetamol (with synthesis), Analgesics: Ibuprofen (with synthesis), Antimalarials: Chloroquine (with synthesis). An elementary treatment of Antibiotics and detailed study of chloramphenicol, Medicinal values of curcumin (turmeric), azadirachtin (neem), vitamin C and antacid (ranitidine).

Recommended Books:

1. Berg, J.M., Tymoczko, J.L. and Stryer, L. (2006) Biochemistry. VIth Edition. W.H. Freeman and Co.

2. Nelson, D.L., Cox, M.M. and Lehninger, A.L. (2009) Principles of Biochemistry. IV Edition. W.H. Freeman and Co.

3. Murray, R.K., Granner, D.K., Mayes, P.A. and Rodwell, V.W. (2009) Harper's Illustrated Biochemistry. XXVIII edition. Lange Medical Books/ McGraw-Hill.

CHM-HC 803(P): Laboratory

1. Estimation of glycine by Sorenson's formalin method.
2. Study of the titration curve of glycine.
3. Estimation of proteins by Lowry's method.
4. Study of the action of salivary amylase on starch at optimum conditions.
5. Effect of temperature on the action of salivary amylase.
6. Saponification value of an oil or a fat.
7. Determination of Iodine number of an oil/ fat.
8. Isolation and characterization of DNA from onion/ cauliflower/peas.

Recommended Books:

1. Arthur, I. V. *Quantitative Organic Analysis,* Pearson.
2. Plummer, D. T. *An Introduction to Practical Biochemistry*, 3rd Edition, McGraw Hill.
3. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. III.* S. Chand & Co Ltd., New Delhi.
4. N. K. Vishnoi: *Advanced Practical Organic Chemistry.* Vikas Publishing House, New Delhi
5. O. P. Agarwal: *Advanced Practical Organic Chemistry.* Geol Publishing House, Meerut.

CHM-HC 804: PHYSICAL CHEMISTRY-IV

(Credits: Theory-04, Practicals-02)

Course Objectives: *The aim of this course is to introduce students with primarily two areas of physical chemistry- electrochemistry and electrical and magnetic properties of atoms and molecules. It contains three units- conductance, electrochemistry and electrical & magnetic properties of atoms and molecules.*

Course Learning Outcomes: *In this course the students will learn theories of conductance and electrochemistry. Students will also understand some very important topics such as solubility and solubility products, ionic products of water, conductometric titrations etc. The students are also expected to understand the various parts of electrochemical cells along with Faraday's Laws of electrolysis. The students will also gain basic theoretical idea of electrical & magnetic properties of atoms and molecules.*

Unit-1: ***(15 classes of 60 minutes each)*** **25m**

Conductance: Arrhenius theory of electrolytic dissociation. Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Molar conductivity at infinite dilution. Kohlrausch law of independent migration of ions. Debye- Hückel-Onsager equation, Wien effect, Debye-Falkenhagen effect, Walden's rules. Ionic velocities, mobilities and their determinations, transference numbers and their relation to ionic mobilities, determination of transference numbers using Hittorf and Moving Boundary methods. Applications of conductance measurement: (i) degree of dissociation of weak electrolytes, (ii) ionic product of water (iii) solubility and solubility product of sparingly soluble salts, (iv) conductometric titrations, and (v) hydrolysis constants of salts.

Unit-2: ***(20 classes of 60 minutes each)*** **30m**

Electrochemistry: Quantitative aspects of Faraday's laws of electrolysis, rules of oxidation/reduction of ions based on half-cell potentials. Chemical cells, reversible and

irreversible cells with examples. Electromotive force of a cell and its measurement, Nernst equation; Standard electrode (reduction) potential and its application to different kinds of half-cells. Application of EMF measurements in determining (i) free energy, enthalpy and entropy of a cell reaction, (ii) equilibrium constants, and (iii) pH values, using hydrogen, quinone-hydroquinone, glass and SbO/Sb_2O_3 electrodes. Concentration cells with and without transference, liquid junction potential; determination of activity coefficients and transference numbers. Qualitative discussion of potentiometric titrations (acid-base, redox, precipitation). Applications of electrolysis in metallurgy and industry.

Unit-3: ***(10 classes of 60 minutes each)*** **20m**

Electrical & Magnetic Properties of Atoms and Molecules: Basic ideas of electrostatics, Electrostatics of dielectric media, Clausius-Mosotti equation, Lorenz-Laurentz equation, Dipole moment and molecular polarizabilities and their measurements. Diamagnetism, paramagnetism, magnetic susceptibility and its measurement, molecular interpretation.

Recommended Books:

1. Atkins, P.W & Paula, J.D. *Physical Chemistry*, 9th Ed., Oxford University Press (2011).
2. Castellan, G. W. *Physical Chemistry 4th Ed.,* Narosa (2004).
3. Mortimer, R. G. *Physical Chemistry 3rd Ed.,* Elsevier: NOIDA, UP (2009).
4. Barrow, G. M., *Physical Chemistry 5th Ed.,* Tata McGraw Hill: New Delhi (2006).
5. Engel, T. & Reid, P. *Physical Chemistry 3rd Ed.,* Prentice-Hall (2012).
6. Rogers, D. W. *Concise Physical Chemistry* Wiley (2010).
7. Silbey, R. J.; Alberty, R. A. &Bawendi, M. G. *Physical Chemistry 4th Ed.,* John Wiley & Sons, Inc. (2005).
8. Puri, B. R.; Sharma, L. R.; Pathania, M. S. Principles of Physical Chemistry, Vishal Publishing Co.; 47th Ed. (2017)
9. Kapoor, K. L. A Textbook of Physical Chemistry (Volume 1) McGraw Hill Education; Sixth edition (2019)

CHM-HC 804(P): Laboratory

Conductometry

I. Determination of cell constant
II. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.
III. Perform the following conductometric titrations:
i. Strong acid vs. strong base
ii. Weak acid vs. strong base
iii. Mixture of strong acid and weak acid vs. strong base
iv. Strong acid vs. weak base

Potentiometry

I Perform the following potentiometric titrations:
31
i. Strong acid vs. strong base
ii. Weak acid vs. strong base
iii. Dibasic acid vs. strong base
iv. Potassium dichromate vs. Mohr's salt

Recommended Books:

1. Khosla, B. D.; Garg, V. C. & Gulati, A. *Senior Practical Physical Chemistry*, R. Chand & Co.: New Delhi (2011).
2. Garland, C. W.; Nibler, J. W. & Shoemaker, D. P. *Experiments in Physical Chemistry 8th Ed.;* McGraw-Hill: New York (2003).
3. Halpern, A. M. &McBane, G. C. *Experimental Physical Chemistry 3rd Ed.;* W.H. Freeman & Co.: New York (2003).
4. J. N. Gurtu & R. Kapoor: *Advanced Experimental Chemistry Vol. I.* S. Chand & Co Ltd., New Delhi
5. J. B. Yadav: *Advanced Practical Physical Chemistry*. Geol Publishing House, Meerut.

DISCIPLINE SPECIFIC ELECTIVE (DSE) COURSES

SEMESTER V

CHM-HE 701: APPLICATIONS OF COMPUTERS IN CHEMISTRY

(Credits: Theory-04, Practicals-02)

***Course Objectives*:** *This course intends to make learners familiar with basics of computer language, computer programming, handling of experimental data, curve fitting etc to analyze experimental results. This basic knowledge will help the students to perform and interpret results of various chemistry practicals.*

Course Learning Outcomes:

After the completion of this course it will help the student to interpret laboratory data, curve fitting of experimental work, also perform quantum mechanical calculations for various molecular models.

Unit-1: ***(20 classes of 60 minutes each)*** **30m**

Basics: Constants, variables, bits, bytes, binary and ASCII formats, arithmetic expressions, hierarchy of operations, inbuilt functions. Elements of the BASIC language. BASIC keywords and commands. Logical and relative operators. Strings and graphics. Compiled versus interpreted languages. Debugging. Simple programs using these concepts. Matrix addition and multiplication. Statistical analysis.

Unit-2: ***(25 classes of 60 minutes each)*** **45m**

Numerical methods:

Roots of equations: Numerical methods for roots of equations: Quadratic formula, iterative method, Newton-Raphson method, Binary bisection and Regula-Falsi.
Differential calculus: Numerical differentiation.
Integral calculus: Numerical integration (Trapezoidal and Simpson's rule), probability distributions and mean values.
Simultaneous equations: Matrix manipulation: addition, multiplication. Gauss-Siedal method.
Interpolation, extrapolation and curve fitting: Handling of experimental data.

Conceptual background of molecular modelling: Potential energy surfaces. Elementary ideas of molecular mechanics and practical MO methods.

Recommended Books:

1. Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
2. Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
3. Noggle, J. H. *Physical chemistry on a Microcomputer.* Little Brown & Co. (1985).
4. Venit, S.M. *Programming in BASIC: Problem solving with structure and style.* Jaico Publishing House: Delhi (1996).

CHM-HE 701: Laboratory

Computer programs based on numerical methods for
1. Roots of equations: (e.g. volume of van der Waals gas and comparison with ideal gas, pH of a weak acid).
2. Numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations).
3. Numerical integration (e.g. entropy/ enthalpy change from heat capacity data), probability distributions (gas kinetic theory) and mean values.
4. Matrix operations. Application of Gauss-Siedel method in colourimetry.
5. Simple exercises using molecular visualization software.

Recommended Books:

1. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).
2. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).
3. Steiner, E. The Chemical Maths Book Oxford University Press (1996).
4. Yates, P. Chemical Calculations. 2nd Ed. CRC Press (2007).
5. Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
6. Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
7. Noggle, J. H. *Physical Chemistry on a Microcomputer.* Little Brown & Co. (1985).
8. Venit, S.M. *Programming in BASIC: Problem solving with structure and style.* Jaico Publishing House: Delhi (1996).

CHM-HE 701: ANALYTICAL METHODS IN CHEMISTRY

(Credits: Theory-04, Practicals-02)

Course Objectives: *This is an elective course designed to complement the needs of students who wish to learn more about the qualitative/quantitative characterization and separation techniques. The content of this course aims to cover some of the widely used instrumental techniques for characterization of samples. Experiments included aim at giving students hands on experience using different instrumental techniques and chemical analysis.*

Course Learning Outcomes:

On successful completion students will be have theoretical understanding about choice of various analytical techniques used for qualitative and quantitative characterization of samples. At the same time through the experiments students will gain hands on experience of the discussed techniques. This will enable students to take judicious decisions while analyzing different samples.

Unit-1 ***(4 classes of 60 minutes each)*** **5m**

Qualitative and quantitative aspects of analysis: Sampling, evaluation of analytical data, errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and test, rejection of data, and confidence intervals.

Unit-2 ***(12 classes of 60 minutes each)*** **20m**

Optical methods of analysis:

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

UV-Visible Spectrometry: Basic principles of instrumentation (choice of source, monochromator and detector) for single and double beam instrument;

Basic principles of quantitative analysis: estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Determination of metal complex composition using Job's method of continuous variation and mole ratio method.

Infrared Spectroscopy: Basic principles of instrumentation (choice of source, monochromator & detector) for continuous wave and Fourier transform spectrometers; sampling techniques. Structure elucidation through interpretation of data. Effect and importance of isotope substitution.

Flame Atomic Absorption and Emission Spectrometry: Basic principles of instrumentation (choice of source, monochromator, and detector, choice of flame and Burner designs. Techniques of atomization and sample introduction. Method of background correction, sources of chemical interferences and their method of removal. Techniques for the quantitative estimation of trace level of metal ions from water samples.

Unit-3 ***(4 classes of 60 minutes each)*** **5m**

Thermal methods of analysis: Theory of thermogravimetry (TG), basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.

Unit-4 ***(7 classes of 60 minutes each)*** **10m**

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

Unit-5 ***(18 classes of 60 minutes each)*** **35m**

Separation techniques:

Solvent extraction: Classification, principle and efficiency of the technique.

Mechanism of extraction: extraction by solvation and chelation.

Technique of extraction: batch, continuous and counter current extractions.

Qualitative and quantitative aspects of solvent extraction: extraction of metal ions from aqueous solution, extraction of organic species from the aqueous and nonaqueous media.

Chromatography: Classification, principle and efficiency of the technique.

Mechanism of separation: adsorption, partition & ion exchange.

Development of chromatograms: frontal, elution and displacement methods.

Qualitative and quantitative aspects of chromatographic methods of analysis: IC, GLC, GPC, TLC and HPLC.

Stereoisomeric separation and analysis: Measurement of optical rotation, calculation of Enantiomeric excess (ee)/ diastereomeric excess (de) ratios and determination of enantiomeric composition using NMR, Chiral solvents and chiral shift reagents. Chiral chromatographic techniques using chiral columns (GC and HPLC).

Role of computers in instrumental methods of analysis.

Recommended Books:

1. Mendham, J. et al.: Vogel's Text Book of Quantitative Chemical Analysis ; 6th Ed. Pearson Education, 2009.
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. CBS Publishers & Distributors, 2004.
3. Christian, Gary D: Analytical Chemistry, 6th Ed. Wiley India (P) Ltd., 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, 4th Ed. W. H. Freeman, 2008.
5. Khopkar, S.M.: Basic Concepts of Analytical Chemistry, 3rd Ed. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, 6th Ed. Thomson Asia Pvt. Ltd. Singapore.
7. Mikes, O. and Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.1979
8. Ditts, R.V. *Analytical Chemistry: Methods of separation.*VanNostrand, New York, 1974.

CHM-HE 701(P): Laboratory

1. Separation Techniques

I. Chromatography:

(a) Separation of mixtures

(i) Paper chromatographic separation of Fe^{3+}, Al^{3+}, and Cr^{3+}

(ii) Separation and identification of the monosaccharides present in the given mixture (glucose & fructose) by paper chromatography. Reporting the Rf values.

(b) Separate a mixture of Sudan yellow and Sudan Red by TLC technique and identify them on the basis of their Rf values.

(c) Chromatographic separation of the active ingredients of plants, flowers and juices by TLC

II. Solvent Extractions:

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

(ii) Solvent extraction of zirconium with amberliti LA-1, separation from a mixture of irons and gallium.

3. Determine the pH of the given aerated drinks fruit juices, shampoos and soaps.

4. Determination of Na, Ca, Li in cola drinks and fruit juices using fame photometric techniques.

5. Analysis of soil:

(i) Determination of pH of soil.

(ii) Total soluble salt

(iii) Estimation of calcium, magnesium, phosphate, nitrate

6. Ion exchange:

(i) Determination of exchange capacity of cation exchange resins and anion exchange resins.

(ii) Separation of metal ions from their binary mixture.

(iii) Separation of amino acids from organic acids by ion exchange chromatography.

7. Spectrophotometry

(i) Determination of pKa values of indicator using spectrophotometry.

(ii) Structural characterization of compounds by infrared spectroscopy.

(iii) Determination of dissolved oxygen in water.

(iv) Determination of chemical oxygen demand (COD).

(v) Determination of Biological oxygen demand (BOD).

(vi) Determine the composition of the Ferric-salicylate/ ferric-thiocyanate complex by Job's method.

Recommended Books:

1. Vogel, Arthur I: A Test book of Quantitative Inorganic Analysis (Rev. by G.H. Jeffery and others) 5th Ed. The English Language Book Society of Longman .
2. Willard, Hobert H. et al.: Instrumental Methods of Analysis, 7th Ed. Wardsworth Publishing Company, Belmont, California, USA, 1988.
3. Christian, Gary D; Analytical Chemistry, 6th Ed. John Wiley & Sons, New York, 2004.
4. Harris, Daniel C: Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2001.
5. Khopkar, S.M. Basic Concepts of Analytical Chemistry. New Age, International Publisher, 2009.
6. Skoog, D.A. Holler F.J. and Nieman, T.A. Principles of Instrumental Analysis, Thomson Asia Pvt. Ltd. Singapore.
7. Mikes, O. & Chalmes, R.A. Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Ltd. London.
9. Ditts, R.V. *Analytical Chemistry: Methods of separation.* VanNostrand, New York, 1974.
10. Dr. B. K. Sharma: *Instrumental Methods of Chemical Analysis*. Geol; Publishing House, Meerut.

CHM-HE 701: MOLECULAR MODELLING & DRUG DESIGN

(Credits: Theory-04, Practicals-02)

Course Objective: *The course introduces students to the basic principles of computer assisted drug design, modelling and the important theoretical concepts and programming.*

Course Learning Outcome: *Students will be able to identify basic components of computer and programming as applied to computer assisted design and modelling of molecules.*

Unit-1: ***(5 classes of 60 minutes each)*** **10m**

Introduction to Molecular Modelling: Introduction. Useful Concepts in Molecular Modelling: Coordinate Systems. Potential Energy Surfaces. Molecular Graphics. Surfaces. Computer Hardware and Software. The Molecular Modelling Literature.

Unit-2: ***(10 classes of 60 minutes each)*** **18m**

Force Fields: Fields. Bond Stretching. Angle Bending. Introduction to nonbonded interactions. Electrostatic interactions. van der Waals Interactions. Hydrogen bonding in Molecular Mechanics. Force Field Models for the Simulation of Liquid Water.

Unit-3: ***(10 classes of 60 minutes each)*** ***15m***

Energy Minimization and Computer Simulation: Minimization and related methods for exploring the energy surface. Non-derivative method, First and second order minimization methods. Computer simulation methods. Simple thermodynamic properties and Phase Space. Boundaries. Analyzing the results of a simulation and estimating Errors.

Unit-4: ***(10 classes of 60 minutes each)*** **15m**

Molecular Dynamics & Monte Carlo Simulation: Molecular Dynamics Simulation Methods. Molecular Dynamics using simple models. Molecular Dynamics with continuous potentials. Molecular Dynamics at constant temperature and pressure. Metropolis method. Monte Carlo simulation of molecules. Models used in Monte Carlo simulations of polymers.

Unit-5: ***(10 classes of 60 minutes each)*** **17m**

Structure Prediction and Drug Design: Structure prediction - Introduction to comparative Modeling. Sequence alignment. Constructing and evaluating a comparative model. Predicting protein structures by 'Threading', Molecular docking. Structure based de novo ligand design, Drug Discovery – Chemoinformatics – QSAR.

Recommended Books:

1. A.R. Leach, Molecular Modelling Principles and Application, Longman, 2001.
2. J.M. Haile, Molecular Dynamics Simulation Elementary Methods, John Wiley and Sons, 1997.
3. Satya Prakash Gupta, QSAR and Molecular Modeling, Springer - Anamaya Publishers, 2008.

CHM-HE 701(P): Laboratory

i. Compare the optimized C-C bond lengths in ethane, ethene, ethyne and benzene. Visualize the molecular orbitals of the ethane σ bonds and ethene, ethyne, benzene and pyridine π bonds.

ii. (a) Perform a conformational analysis of butane. (b) Determine the enthalpy of isomerization of *cis* and *trans* 2-butene.

iii. Visualize the electron density and electrostatic potential maps for LiH, HF, N_2, NO and CO and comment. Relate to the dipole moments. Animate the vibrations of these molecules.

iv. (a) Relate the charge on the hydrogen atom in hydrogen halides with their acid character. (b) Compare the basicities of the nitrogen atoms in ammonia, methylamine, dimethylamine and trimethylamine.

v. (a) Compare the shapes of the molecules: 1-butanol, 2-butanol, 2-methyl-1-propanol, and 2-methyl-2-propanol. Note the dipole moment of each molecule. (b) Show how the shapes affect the trend in boiling points: (118 ºC, 100 ºC, 108 ºC, 82 ºC, respectively).

vi. Build and minimize organic compounds of your choice containing the following functional groups. Note the dipole moment of each compound: (a) alkyl halide (b) aldehyde (c) ketone (d) amine (e) ether (f) nitrile (g) thiol (h) carboxylic acid (i) ester (j) amide.

vii. (a) Determine the heat of hydration of ethylene. (b) Compute the resonance energy of benzene by comparison of its enthalpy of hydrogenation with that of cyclohexene.

viii. Arrange 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.

ix. (a) Compare the optimized bond angles H_2O, H_2S, H_2Se. (b) Compare the HAH bond angles for the second row dihydrides and compare with the results from qualitative MO theory.

Note: Software: ChemSketch, ArgusLab (www.planaria-software.com), TINKER 6.2 (dasher.wustl.edu/ffe), WebLab Viewer, Hyperchem, or any similar software.

Recommended Books:

1. A.R. Leach, Molecular Modelling Principles and Application, Longman, 2001.
2. J.M. Haile, Molecular Dynamics Simulation Elementary Methods, John Wiley and Sons, 1997.
3. Satya Prakash Gupta, QSAR and Molecular Modeling, Springer - Anamaya Publishers, 2008.

SEMESTER VI

CHM-HE 702: NOVEL INORGANIC SOLIDS
(Credits: Theory-04, Practicals-02)

Course Objectives: *This introductory course intends to make learners familiar with a wide variety of technologically important and emerging materials. It will prepare the learners for studying materials further at the master's level. Prior completion of one introductory UG level course on inorganic and physical chemistry will be essential.*

Course Learning Outcomes: *After the completion of this course it will also be possible for the students to opt for studying an interdisciplinary master's programme with an emphasis on the synthesis and applications of various materials or take up a job in the materials production and/or processing industry.*

Unit-1: ***(5 classes of 60 minutes each)*** **10m**
Synthesis and modification of inorganic solids: Conventional heat and beat methods, Co-precipitation method, Sol-gel methods, Hydrothermal method, Ion-exchange and Intercalation methods.

Unit-2 ***(8 classes of 60 minutes each)*** **12m**
Inorganic solids of technological importance: Solid electrolytes – Cationic, anionic, mixed Inorganic pigments – coloured solids, white and black pigments. Molecular material and fullerides, molecular materials & chemistry – one-dimensional metals, molecular magnets, metal containing liquid crystals.

Unit-3 ***(10 classes of 60 minutes each)*** **15m**
Nanomaterials: Overview of nanostructures and nanomaterials: classification. Preparation of gold and silver metallic nanoparticles, self-assembled nanostructures-control of nanoarchitecture-one dimensional control. Carbon nanotubes and inorganic nanowires.
Bio-inorganic nanomaterials, DNA and nanomaterials, natural and artificial nanomaterials, bionano composites.

Unit-4 ***(10 classes of 60 minutes each)*** **15m**
Introduction to engineering materials for mechanical construction: Composition, mechanical and fabricating characteristics and applications of various types of cast irons, plain carbon and alloy steels, copper, aluminium and their alloys like duralumin, brasses and bronzes cutting tool materials, super alloys thermoplastics, thermosets and composite materials.

Unit-5 ***(8 classes of 60 minutes each)*** **13m**
Composite materials: Introduction, limitations of conventional engineering materials, role of matrix in composites, classification, matrix materials, reinforcements, metal-matrix composites, polymer-matrix composites, fibre-reinforced composites, environmental effects on composites, applications of composites.

Unit-6 ***(4 classes of 60 minutes each)*** **10m**

Speciality polymers: Ceramics & Refractory: Introduction, classification, properties, raw materials, manufacturing and applications.

Recommended Books:

1. Shriver & Atkins. Inorganic Chemistry, Peter Alkins, Tina Overton, Jonathan Rourke, Mark Weller and Fraser Armstrong, 5th Edition, Oxford University Press (2011-2012)
2. Smart, L. E., Moore, E. A., Solid State Chemistry: An Introduction, 4th Ed., CRC Press, 2012.
3. Poole, C. P., Ovens, F. J., Introduction to Nanotechnology, Wiley India, 2009.
4. Murty, B. S., Shankar, P., Raj, B., Rath, B, B., Murday, J. Textbook of Nanoscience and Nanotechnology, Springer, 2013.

CHM-HE 702(P): Laboratory

1. Determination of cation exchange capacity.
2. Synthesis of oxides by ceramic method.
3. Synthesis of hydrogel by co-precipitation method.
4. Synthesis of silver and gold metal nanoparticles.

Recommended Book:

1. Fahlman, B. D., Materials *Chemistry*, Springer (2011).

CH-HE 702: INTRODUCTION TO NANOCHEMISTRY AND APPLICATIONS

(Credits: Theory-04, Practicals-02)

Course Objective: *This introductory course intends to make learners familiar with a wide variety of technologically important and emerging materials in nanoscience. It will prepare the learners for studying materials further at the master's level.*

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Course Learning outcome: *After the completion of this course it will also be possible for the students to opt for studying an interdisciplinary master's programme with an emphasis on the synthesis and applications of various nanomaterials or take up a job in the materials production and/or processing industry.*

UNIT-1: ***(12 classes of 60 minutes each)*** **20m**

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

UNIT-2: ***(10 classes of 60 minutes each)*** **15m**

Size dependent properties of nanomaterials (basic idea with few examples only): Quantum confinement, Electrical, Optical (Surface Plasmon resonance), variation in colors (Blueshift & Redshift), Magnetic,thermal and catalyticproperties.

UNIT-3: ***(12 classes of 60 minutes each)*** **20m**

Synthesis of Nanomaterials: Brief introduction about Top-down and Bottom-up approaches & self-assembly techniques of nanoparticles synthesis, Solvothermal process, Examples of preparation of gold and silver metallic nanoparticles, self-assembled nanostructures-control of nanoarchitecture-one dimensional control. Carbon nanotubes and inorganic nanowires.

UNIT-4: ***(12 classes of 60 minutes each)*** **20m**

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

Recommended Books/Referencesbooks:

1. C.N.R.Rao, A.Muller, A.K.Cheetam, *The Chemistry of Nanomaterials: Synthesis, Properties and Applications*, Willey-VCH Verlag, Germany, 2005.
2. G.Cao, *Nanostructures and Nanomaterials: Synthesis, Properties and Appications*, Imperial College Press, London, 2004.
3. R. W.Kelsall, I.W.Hameley, M.Geoghegan, *Nanoscale Science and Technology*, John Wiley & Sons, England, 2005.
4. Charles P. Poole and Frank J Owens, *Introduction to nano technology*, Wiley Interscience,2003.
5. Pradeep, T., *A text of book of nanoscience and nanotechnology*, Tata McGraw Hill Education Pvt. Ltd., NewDelhi,2012.

CHM-HE 702(P): List of Laboratory Experiments suggested:

1. Synthesis of ZnO nanoparticles.
2. Preparation of Silver nanoparticles. (Diverse nanoparticles can be prepared by various routes).
3. Verification of Beer-Lambert law using nano-particles (above prepared nano-particles may be used forthestudy).

(Depending upon the availability of infrastructure facilities, instructor may encourage the students to prepare bimetallic nano-particles, etc. and characterized them, study their various properties like magnetism, adsorption, etc.)

CHM-HE 702: HETEROCYCLIC CHEMISRTY
(Credits: Theory – 04, Practical – 02)

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

Course Objectives:

1. Three-membered rings with one heteroatom.
2. Three-membered heterocycles with two heteroatoms.
3. Four-membered heterocycles.
4. Five-membered aromatic heterocycles.
5. Understanding chemistry of the chemistry of Indoles.

Course Learning Outcomes:

1. Synthetic approaches and reactivities of oxiranes, aziridines, episulphides. oxaziranes, diaziridines, diazirines oxitanes, azatidanes and thietanes.
2. Synthesis of Peniciline and cephalosporine.
4. Understanding the chemistry of Benzofuran, indoles and benzothiazoles.

UNIT-1: (9 classes of 60 minutes each) **15m**

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

UNIT-2: (9 classes of 60 minutes each) **15m**

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

UNIT-3: (9 classes of 60 minutes each) **15m**

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

UNIT-4: (9 classes of 60 minutes each) **15m**

Five-membered aromatic heterocycles:

1. With one heteroatom: furans, pyrroles and thiophenes –general synthetic approaches, properties and reactivities.

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

UNIT-5: ***(9 classes of 60 minutes each)*** **15m**

Condensed five-membered Heterocycles:

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

Recommended Books/references:

1. J. A. Joule, K. Mills, *Heterocyclic Chemistry*, Wiley,2010.
2. A. R. Parikh, H. Parikh, R. Khunt, *The Essence of heterocyclic Chemistry*, New Age Int. Publication,
3. L. A. Paquette, W. A. Benjamin, *Principles of Modern Heterocyclic Chemistry*, New York, 1968.
4. J. A. Joule and G. F. Smith, *Heterocyclic Chemistry*, Van Nostrand, London,1978.
5. *Comprehensive Heterocyclic Chemistry. The structure, reactions, synthesis and use of Heterocyclic compounds*, (Ed. A. R. Katritzky and C. W. Rees), Vol 1-8, Pergamon Press,1984.
6. A.R. Katritzky, *Hand book of Heterocyclic Chemistry*, Pergamon Press, 1985.
7. Van der plas, H. C.*Ring transformations of Heterocycles, Vols 1 and2*, Academic Press, 1974.

CHM-HE 702(P): Heterocyclic Chemistry Laboratory

List of suggested laboratory experiments

1. Identification of hetero atoms (S, N, X) in given organic compounds in lab.

2. Identification/separation of simple organic compounds containing hetero atoms using column chromatorgapy/TLC) in lab.

3. Spectroscopic identification of simple organic compounds (spectra may be provided to the students and teachers may help the students to identify the compounds using spectra). Melting point/boiling point of the compounds may be checked for its purity.

4. Teacher may guide the students for preparation of : Indigo (using aldol

condensation reaction of 2-nitrobenzaldehyde with acetone in basic condition);

(Depending upon laboratory facilities, more preparation n of heterocyclic group of compounds may be incorporated by teacher).

SEMESTER VII

CHM-HE 801: BIOCHEMISTRY
(Credits: Theory-04, Practicals-02)

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

Course Objective:

Biological importance of Carbohydrates, Proteins, Enzymes, Lipids and biological roles of RNA and DNA.

Course Learning Outcome:

After successful completion of the course, students would have learnt about the classification of proteins, enzymes, nomenclature of enzymes and structures of RNA and DNA.

UNIT-1: Carbohydrates (9 classes of 60 minutes each) **15m**

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

UNIT-2: Proteins: (9 classes of 60 minutes each) **15m**

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

UNIT-3: Enzymes(9 classes of 60 minutes each) **15m**

Nomenclature, Characteristics (mention of Ribozymes), Classification; Activesite, Mechanism of enzyme action, Stereospecificity of enzymes, Coenzymes and cofactors, Enzyme inhibitors, Biocatalysis in Green Chemistry" and Chemical Industry

UNIT-4: Lipids (9 classes of 60 minutes each) **15m**

Biological importance of triglycerides and phosphor glycerides and cholesterol; Lipid membrane, Liposomes and their biological functions and underlying applications.

UNIT-5: Structure of DNA/RNA(9 classes of 60 minutes each) **15m**

Structure of DNA (Watson-Crick model) and RNA, Genetic Code, Biological roles of DNA and RNA: Replication, Transcription and Translation, Introduction to Gene therapy.

Recommended Books/References:

1. Berg, J.M., Tymoczko, J.L. and Stryer, L. *Biochemistry*. VI the Edition. W.H. Freeman and Co.(2006)
2. Nelson,D.L.,Cox,M.M.andLehninger,A.L.*principlesofBiochemistry*.IVEdition, W.H. Freeman a nd Co.(2009)
3. Murray,R.K.,Granner,D.K.,Mayes,P.A.andRodwell,V.W.*Harper'sIllustratedBiochemistry.*XXVIII edition. Lange medical Books/ McGraw-Hill(2009)

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

Suggested Practical in Biochemistry

1. Quantitative estimation of protein using Lowry's method. Determine the concentration of the unknown sample.
2. Action of salivary amylase at optimum conditions
3. Effect of pH on the action of salivary amylase
4. Effect of temperature on salivary amylase
5. Effect of inhibitor on salivary amylase
6. Study of the activity of Tryps in using fresh tissue extracts.
7. Effect of temperature, organic solvents, on semi-permeable membrane.
8. Isolation of Genomic DNA from E Coli

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

CHM-HE 801: RESEARCH METHODOLOGY FOR CHEMISTRY
(Credits: Theory-05, Tutorials-01)

Course Objectives:

1. *This course is introduced to impart knowledge about the basic concepts of research and to provide a road map for conducting research.*
2. *Students are expected to identify, explain and apply basic concepts of research; acquire information, recognize various issues related to research and to learn instrumental methods required for research in chemistry.*

Course Learning Outcomes:

After completing this course, students should be able to construct a rational research proposal to generate fruitful output in terms of publications and patents in the field of chemical sciences.

Unit-1 ***(18 classes of 60 minutes each)*** **30m**

Literature Survey:

Print: Sources of information: Primary, secondary, tertiary sources; Journals: Journal abbreviations, abstracts, current titles, reviews, monographs, dictionaries, text-books, current contents, Introduction to Chemical Abstracts and Beilstein, Subject Index, Substance Index, Author Index, Formula Index, and other Indices with examples.

Digital: Web resources, E-journals, Journal access, TOC alerts, Hot articles, Citation index, Impact factor, H-index, E-consortium, UGC infonet, E-books, Internet discussion groups and communities, Blogs, Preprint servers, Search engines, Scirus, Google Scholar, ChemIndustry, Wiki- Databases, ChemSpider, Science Direct, SciFinder, Scopus.

Information Technology and Library Resources: The Internet and World Wide Web. Internet resources for chemistry. Finding and citing published information.

Unit-2 ***(18 classes of 60 minutes each)*** **30m**

Methods of Scientific Research and Writing Scientific Papers:

Reporting practical and project work. Writing literature surveys and reviews. Organizing a poster display. Giving an oral presentation.

Writing scientific papers – justification for scientific contributions, bibliography, description of methods, conclusions, the need for illustration, style, publications of scientific work. Writing ethics. Avoiding plagiarism.

Unit-3 ***(8 classes of 60 minutes each)*** **15m**

Chemical Safety and Ethical Handling of Chemicals:

Safe working procedure and protective environment, protective apparel, emergency procedure and first aid, laboratory ventilation. Safe storage and use of hazardous chemicals, procedure for working with substances that pose hazards, flammable or explosive hazards, procedures for working with gases at pressures above or below atmospheric – safe storage and disposal of waste chemicals, recovery, recycling and reuse of laboratory chemicals, procedure for laboratory disposal of explosives, identification, verification and segregation of laboratory waste, disposal of chemicals in the sanitary sewer system, incineration and transportation of hazardous chemicals.

Unit-4 ***(8 classes of 60 minutes each)*** **15m**

Data Analysis:

The Investigative Approach: Making and Recording Measurements. SI Units and their use. Scientific method and design of experiments.

Analysis and Presentation of Data: Descriptive statistics. Choosing and using statistical tests. Chemometrics. Analysis of variance (ANOVA), Correlation and regression, Curve fitting, fitting of linear equations, simple linear cases, weighted linear case, analysis of residuals, General polynomial fitting, linearizing transformations, exponential function fit, *r* and its abuse. Basic aspects of multiple linear regression analysis.

Unit-5 ***(8 classes of 60 minutes each)*** **10m**

Electronics: Basic fundamentals of electronic circuits and their components used in circuits of common instruments like spectrophotometers, typical circuits involving operational amplifiers for electrochemical instruments. Elementary aspects of digital electronics.

Recommended Books

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.

CHM-HE 801: INORGANIC MATERIALS OF INDUSTRIAL IMPORTANCE
(Credits: Theory-04, Practicals-02)

Course Objectives: *To learn the synthetic process, properties and the utility of the industrially important inorganic materials (such as silicates, ceramics, cements, fertilizers, paints, batteries, alloys and explosives). To provide opportunity to learn some of the industrial process such as surface coating and catalysis in relevant to industry where heterogeneous catalysis dominates. Experiments are aimed at helping learners acquire hands on experience in qualitative and quantitative analysis of the inorganic materials which are basically manufactured in chemical industries. To learn some industrial techniques such as surface coating etc..*

Course Learning Outcomes: *This course will establish the basic foundation of industrial inorganic chemistry among the students. This will be helpful for pursuing further studies of industrial chemistry in future. Experiments will help the Students to gather the experience of qualitative and quantitative chemical analysis. Students will be capable of doing analysis of the inorganic materials which are used in our daily life. They will have insight of the industrial processes.*

Unit-1 : Silicate Industries: ***(12 classes of 60 minutes each)*** **20m**

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, safety glass, borosilicate glass, fluorosilicate, coloured glass, photosensitive glass.

Ceramics: Important clays and feldspar, ceramic, their types and manufacture. High technology ceramics and their applications, superconducting and semiconducting oxides,fullerenes carbon nanotubes and carbon fibre.
Cements: Classification of cement, ingredients and their role, Manufacture of cement and the setting process, quick setting cements.

Unit-2: Fertilizers ***(7 classes of 60 minutes each)*** **10m**

Different types of fertilizers. Manufacture of the following fertilizers: Urea, ammonium nitrate, calcium ammonium nitrate, ammonium phosphates; polyphosphate, superphosphate, compound and mixed fertilizers, potassium chloride, potassium sulphate.

Unit-3: ***(11 classes of 60 minutes each)*** **20m**
Surface Coatings: Objectives of coatings surfaces, preliminary treatment of surface, classification of surface coatings. Paints and pigments-formulation, composition and related properties. Oil paint, Vehicle, modified oils, Pigments, toners and lakes pigments, Fillers, Thinners, Enamels, emulsifying agents. Special paints (Heat retardant, Fire retardant, Eco-friendly paint, Plastic paint), Dyes, Wax polishing, Water and Oil paints, additives, Metallic coatings (electrolytic and electroless), metal spraying and anodizing.
Batteries: Primary and secondary batteries, battery components and their role, Characteristics of battery. Working of following batteries: Pb acid, Li-Battery, Solid state electrolyte battery. Fuel cells, Solar cell and polymer cell.

Unit-4: Alloys: ***(7 classes of 60 minutes each)*** **12m**

Classification of alloys, ferrous and non-ferrous alloys, Specific properties of elements in alloys. Manufacture of Steel (removal of silicon decarbonization, demanganization, desulphurization dephosphorisation) and surface treatment (argon treatment, heat treatment, nitriding, carburizing). Composition and properties of different types of steels.

Unit-5: Catalysis: ***(4 classes of 60 minutes each)*** **7m**

General principles and properties of catalysts, homogenous catalysis (catalytic steps and examples) and heterogenous catalysis (catalytic steps and examples) and their industrialapplications, Deactivation or regeneration of catalysts. Phase transfer catalysts, application of zeolites as catalysts.

Unit-6: Chemical explosives: ***(4 classes of 60 minutes each)*** **6m**

Origin of explosive properties in organic compounds, preparation and explosive properties of lead azide, PETN, cyclonite (RDX). Introduction to rocket propellants.

Recommended Books:
1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. R. M. Felder, R. W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: *Introduction to Ceramics*, Wiley Publishers, New Delhi.
4. Karl Heinz Büchel, Hans-Heinrich Moretto Peter, Woditsch; *Industrial Inorganic Chemistry*, Wiley-VCH.

5. J. A. Kent: Riegel's*Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
6. P. C. Jain, M. Jain: *Engineering Chemistry,* Dhanpat Rai & Sons, Delhi.
7. R. Gopalan, D. Venkappayya, S. Nagarajan: *Engineering Chemistry,* Vikas Publications, New Delhi.
8. B. K. Sharma: *Engineering Chemistry*, Goel Publishing House, Meerut

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CHM-HE 801(P): Laboratory

1. Determination of free acidity in ammonium sulphate fertilizer.
2. Estimation of Calcium in Calcium ammonium nitrate fertilizer.
3. Estimation of phosphoric acid in superphosphate fertilizer.
4. Electroless metallic coatings on ceramic and plastic material.
5. Determination of composition of dolomite (by complexometric titration).
6. Analysis of (Cu, Ni); (Cu, Zn) in alloy or synthetic samples.
7. Analysis of Cement.
8. Preparation of pigment (zinc oxide).

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. R. M. Felder, R. W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
3. W. D. Kingery, H. K. Bowen, D. R. Uhlmann: *Introduction to Ceramics,* Wiley Publishers, New Delhi.
4. J. A. Kent: Riegel's*Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
5. P. C. Jain, M. Jain: *Engineering Chemistry,* Dhanpat Rai & Sons, Delhi.
6. R. Gopalan, D. Venkappayya, S. Nagarajan: *Engineering Chemistry,* Vikas Publications, New Delhi.
7. B. K. Sharma: *Engineering Chemistry*, Goel Publishing House, Meerut

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SEMESTER VIII

CHM-HE 802: INDUSTRIAL CHEMICALS AND ENVIRONMENT
(Credits: Theory-04, Practicals-02)

Course Objectives: *This course provides an introduction to the various industrial gases and inorganic chemicals, their manufacturing processes, applications, storage and the hazards of handling them. Contribution of these industrial chemicals towards air and water pollution and their effects on living organisms and the environment has also been covered. Students are also expected to learn about metallurgy, energy generation industry and the pollution threat they pose. This course also discusses about management of the different kinds of wastes, their safe disposal and the importance of practicing green chemistry in chemical industry.*

Course Learning Outcomes: *After successful completion of the course, students would have learnt about the manufacture, applications and safe ways of storage and handling gaseous and inorganic industrial chemicals. Students will get to know about industrial metallurgy and the energy generation industry. Students will also learn about environmental pollution by various gaseous, liquid wastes and nuclear wastes and their effects on living beings. Finally, the students*

will learn about industrial waste management, their safe disposal and the importance of environment friendly "green chemistry" in chemical industry.

Unit-1: ***(10 classes of 60 minutes each)*** **13m**

Industrial Gases and Inorganic Chemicals:

Industrial Gases: Large scale production, uses, storage and hazards in handling of the following gases: oxygen, nitrogen, argon, neon, helium, hydrogen, acetylene, carbon monoxide, chlorine, fluorine, sulphur dioxide and phosgene.

Inorganic Chemicals: Manufacture, application, analysis and hazards in handling the following chemicals: hydrochloric acid, nitric acid, sulphuric acid, caustic soda, common salt, borax, bleaching powder, sodium thiosulphate, hydrogen peroxide, potash alum, chrome alum, potassium dichromate and potassium permanganate.

Unit-2 ***(5 classes of 60 minutes each)*** **7m**

Industrial Metallurgy:

Preparation of metals (ferrous and nonferrous) and ultrapure metals for semiconductor technology.

Unit-3 ***(20 classes of 60 minutes each)*** **30m**

Environment and its segments:

Ecosystems. Biogeochemical cycles of carbon, nitrogen and sulphur.

Air Pollution: Major regions of atmosphere. Chemical and photochemical reactions in atmosphere. Air pollutants: types, sources, particle size and chemical nature; Photochemical smog: its constituents and photochemistry. Environmental effects of ozone, Major sources of air pollution. Pollution by SO_2, CO_2, CO, NO_x, H_2S and other foul smelling gases. Methods of estimation of CO, NO_x, SO_x and control procedures.

Effects of air pollution on living organisms and vegetation. Greenhouse effect and Global warming, Ozone depletion by oxides of nitrogen, chlorofluorocarbons and Halogens, removal of sulphur from coal. Control of particulates.

Water Pollution: Hydrological cycle, water resources, aquatic ecosystems, Sources and nature of water pollutants, Techniques for measuring water pollution, Impacts of water pollution on hydrological and ecosystems. Water purification methods. Effluent treatment plants (primary, secondary and tertiary treatment). Industrial effluents from the following industries and their treatment: electroplating, textile, tannery, dairy, petroleum and petrochemicals, agro, fertilizer, etc. Sludge disposal.

Industrial waste management, incineration of waste. Water treatment and purification (reverse osmosis, electro dialysis, ion exchange). Water quality parameters for waste water, industrial water and domestic water.

Unit-4: ***(10 classes of 60 minutes each)*** **15m**

Energy & Environment:

Sources of energy: Coal, petrol and natural gas. Nuclear Fusion / Fission, Solar energy, Hydrogen, geothermal, Tidal and Hydel, etc.

Nuclear Pollution: Disposal of nuclear waste, nuclear disaster and its management.

Unit-5: ***(5 classes of 60 minutes each)*** **10m**

Biocatalysis:

Introduction to biocatalysis: Importance in "Green Chemistry" and Chemical Industry.

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
3. J. A. Kent: Riegel's *Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
4. S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.
5. K. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.
6. S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi.
7. S.E. Manahan, Environmental Chemistry, CRC Press (2005).
8. G.T. Miller, Environmental Science 11th edition. Brooks/ Cole (2006).
9. A. Mishra, Environmental Studies. Selective and Scientific Books, New Delhi (2005).

CHM-HE 801(P): Industrial Chemistry Laboratory

1. Determination of dissolved oxygen in water.
2. Determination of Chemical Oxygen Demand (COD)
3. Determination of Biological Oxygen Demand (BOD)
4. Percentage of available chlorine in bleaching powder.
5. Measurement of chloride, sulphate and salinity of water samples by simple titration method ($AgNO_3$ and potassium chromate).
6. Estimation of total alkalinity of water samples (CO_3^{2-}, HCO_3^-) using double titration method.
7. Measurement of dissolved CO_2.
8. Study of some of the common bio-indicators of pollution.
9. Estimation of SPM in air samples.
10. Preparation of borax/ boric acid.

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol-I, Ellis Horwood Ltd. UK.
2. R.M. Felder, R.W. Rousseau: *Elementary Principles of Chemical Processes*, Wiley Publishers, New Delhi.
3. J. A. Kent: Riegel's*Handbook of Industrial Chemistry*, CBS Publishers, New Delhi.
4. S. S. Dara: *A Textbook of Engineering Chemistry*, S. Chand & Company Ltd. New Delhi.
5. K. De, *Environmental Chemistry*: New Age International Pvt., Ltd, New Delhi.
6. S. M. Khopkar, *Environmental Pollution Analysis*: Wiley Eastern Ltd, New Delhi.

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CHM-HE 802: DISSERTATION

Students will complete a project work and then prepare a report on that.

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ABILITY ENHANCEMENT COMPULSORY COURSES (AECC)

SEMESTER I

GEN-AE 1 : English Communications (Syllabus will available at Oriental College website.)

SEMESTER II

EVS-AE 2 : Environmental Science (Syllabus will available at Oriental College website.)

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SKILL ENHANCEMENT COURSES

SEMESTER I

Any one from the following:

CHM-SE 501: IT SKILLS FOR CHEMISTS

(Credits: 04 = 3 + 1)

Course Objective: *The objectives of the proposed course are:*

1) *To provide the basic knowledge of mathematics which are needed to pursue chemistry as major subject.*
2) *To provide the necessary training for the basic programming knowledge.*
3) *The course provides information technology literacy and basic skills training for learners with limited experience.*
4) *To familiarize with the Introductory writing activities and Handling numeric data.*

Course Learning Outcome: *Course learning outcomes focus on skill development related to basic computer operations and information technology. After completing the course the incumbent is able to use the computer for basic purposes of preparing his personnel/business letters, viewing information on Internet (the web), sending mails, using internet banking services etc. After opting this course the students are expected to accumulate the skills in writing activities and Handling numeric data.*

IT Skills For Chemists : ***(100 marks : 30 classes of 60 minutes each)***

Mathematics

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

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

Uncertainty in measurement: types of uncertainties, combining uncertainties. Statistical treatment. Mean, standard deviation, relative error. Data reduction and the propagation of errors. Graphical and numerical data reduction. Numerical curve fitting: the method of least squares

(regression). Algebraic operations on real scalar variables (e.g. manipulation of van der Waals equation in different forms).Roots of quadratic equations analytically and iteratively (e.g. pH of a weak acid). Numerical methods of finding roots (Newton-Raphson, binary –bisection, e.g. pH of a weak acid not ignoring the ionization of water, volume of a van der Waals gas, equilibrium constant expressions).
Differential calculus: The tangent line and the derivative of a function, numerical differentiation (e.g., change in pressure for small change in volume of a van der Waals gas, potentiometric titrations). Numerical integration (Trapezoidal and Simpson's rule, e.g. entropy/enthalpy change from heat capacity data).

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

HANDS ON
Introductory writing activities: Introduction to word processor and structure drawing (ChemSketch) software. 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/Latex.
Handling numeric data: Spreadsheet software (Excel), creating a spreadsheet, entering and formatting information, basic functions and formulae, creating charts, tables and graphs. Incorporating tables and graphs into word processing documents. Simple calculations, plotting graphs using a spreadsheet (Planck's distribution law, radial distribution curves for hydrogenic orbitals, gas kinetic theory- Maxwell-Boltzmann distribution curves as function of temperature and molecular weight), spectral data, pressure-volume curves of van der Waals gas (van der Waals isotherms), data from phase equilibria studies. Graphical solution of equations.

Numeric modelling: Simulation of pH metric titration curves. Excel functions LINEST and Least Squares. Numerical curve fitting, linear regression (rate constants from concentration time data, molar extinction coefficients from absorbance data), numerical differentiation (e.g. handling data from potentiometric and pH metric titrations, pK_a of weak acid), integration (e.g. entropy/enthalpy change from heat capacity data).
Statistical analysis: Gaussian distribution and Errors in measurements and their effect on data sets. Descriptive statistics using Excel. Statistical significance testing: The *t* test. The *F* test.
Presentation: Presentation graphics

Recommended Books:
1. McQuarrie, D. A. Mathematics for Physical Chemistry University Science Books (2008).
2. Mortimer, R. Mathematics for Physical Chemistry. 3rd Ed. Elsevier (2005).
3. Steiner, E. The Chemical Maths Book Oxford University Press (1996).
4. Yates, P. Chemical calculations. 2nd Ed. CRC Press (2007).
5. Harris, D. C. *Quantitative Chemical Analysis*. 6th Ed., Freeman (2007) Chapters 3-5.
6. Levie, R. de, *How to use Excel in analytical chemistry and in general scientific data analysis*, Cambridge Univ. Press (2001) 487 pages.
7. Noggle, J. H. *Physical chemistry on a Microcomputer.* Little Brown & Co. (1985).
8. Venit, S.M. *Programming in BASIC: Problem solving with structure and style*. Jaico Publishing House: Delhi (1996).
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(2) CHM-SE 501: BASIC ANALYTICAL CHEMISTRY

(Credits: 04 = 3 + 1)

Course Objective: *To familiarize students with different micro and semimicro analytical techniques and help develop the ability to use modern instrumental methods for chemical analysis of food, soil, air and water.*

Course Learning Outcome: *Upon completion of this course, students shall be able to explain the basic principles of chemical analysis, design/implement microscale and semimicro experiments, record, interpret and analyze data following scientific methodology.*

Basic Analytical Chemistry : ***(100 marks : 30 classes of 60 minutes each)***

Introduction: Introduction to Analytical Chemistry and its interdisciplinary nature. Concept of sampling. Importance of accuracy, precision and sources of error in analytical measurements. Presentation of experimental data and results, from the point of view of significant figures.

Analysis of soil: Composition of soil, Concept of pH and pH measurement, Complexometric titrations, Chelation, Chelating agents, use of indicators

a. Determination of pH of soil samples.

b. Estimation of Calcium and Magnesium ions as Calcium carbonate by complexometric titration.

Analysis of water: Definition of pure water, sources responsible for contaminating water, water sampling methods, water purification methods.

a. Determination of pH, acidity and alkalinity of a water sample.

b. Determination of dissolved oxygen (DO) of a water sample.

Analysis of food products: Nutritional value of foods, idea about food processing and food preservations and adulteration.

a. Identification of adulterants in some common food items like coffee powder, asafoetida, chilli powder, turmeric powder, coriander powder and pulses, etc.

b. Analysis of preservatives and colouring matter.

Chromatography: Definition, general introduction on principles of chromatography, paper chromatography, TLC etc.

a. Paper chromatographic separation of mixture of metal ion (Fe^{3+} and Al^{3+}).

b. To compare paint samples by TLC method.

Ion-exchange: Column, ion-exchange chromatography etc.
Determination of ion exchange capacity of anion / cation exchange resin (using batch procedure if use of column is not feasible).

Analysis of cosmetics: Major and minor constituents and their function

a. Analysis of deodorants and antiperspirants, Al, Zn, boric acid, chloride, sulphate.

b. Determination of constituents of talcum powder: Magnesium oxide, Calcium oxide, Zinc oxide and Calcium carbonate by complexometric titration.

Suggested Applications (Any one):

a. To study the use of phenolphthalein in trap cases.

b. To analyze arson accelerants.

c. To carry out analysis of gasoline.

Suggested Instrumental demonstrations:

a. Estimation of macro nutrients: Potassium, Calcium, Magnesium in soil samples by flame photometry.

b. Spectrophotometric determination of Iron in Vitamin / Dietary Tablets.

c. Spectrophotometric Identification and Determination of Caffeine and Benzoic Acid in Soft Drink.

Recommended Books:

1. Willard, H. H. *Instrumental Methods of Analysis*, CBS Publishers.
2. Skoog &Lerry. *Instrumental Methods of Analysis*, Saunders College Publications, New York.
3. Skoog, D.A.; West, D.M. & Holler, F.J. *Fundamentals of Analytical Chemistry 6th Ed.*, Saunders College Publishing, Fort Worth (1992).
4. Harris, D. C. *Quantitative Chemical Analysis*, W. H. Freeman.
5. Dean, J. A. *Analytical Chemistry Notebook*, McGraw Hill.
6. Day, R. A. & Underwood, A. L. *Quantitative Analysis*, Prentice Hall of India.
7. Freifelder, D. Physical Biochemistry *2nd Ed.*, W.H. Freeman and Co., N.Y. USA(1982).
8. Cooper, T.G. *The Tools of Biochemistry*, John Wiley and Sons, N.Y. USA. 16(1977).
9. Vogel, A. I. *Vogel's Qualitative Inorganic Analysis 7th Ed.*, Prentice Hall.
10. Vogel, A. I. Vogel's *Quantitative Chemical Analysis 6th Ed.*, Prentice Hall.
11. Robinson, J.W. *Undergraduate Instrumental Analysis 5th Ed.*, Marcel Dekker, Inc., New York (1995).

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(3) CHM-SE 501: CHEMICAL TECHNOLOGY & SOCIETY

(Credits: 04 = 3 + 1)

Course Objective: *The objective of the course is to enable students to have a firsthand understanding of different types of equipments needed in chemical technology and offer them concepts regarding some important parameters. The syllabus also emphasizes the dynamic nature of the relations between society on one hand and technological achievement from chemical industries on the other hand. In other words, it tries to explore societal and technological issues from a chemical perspective.*

Course Learning Outcome: *Students shall be familiarized with processes and terminologies in chemical industry, like mass balance, energy balance etc… Learners will be able to use chemical and scientific literacy as a means to better understand the topics related to the society.*

Chemical Technology & Society : (100 marks)

Chemical Technology ***(15 classes of 60 minutes each)***

Different types of equipments needed in chemical technology, including reactors, distillation columns, extruders, pumps, mills, emulgators. Scaling up operations in chemical industry. Introduction to clean technology. Concept of relative humidity, molal humidity, dew point, partial saturation.

Material Balance: Recycle, bypass in batch, stage wise and continuous operations in systems with and without chemical reactions.

Energy balance: Energy balance of systems with and without chemical reactions.

Society ***(15 classes of 60 minutes each)***

Social issues related to soil, air and water pollution. Energy crisis of modern society and search for alternatives such as energy from natural sources (i.e. solar and renewable forms), and from nuclear fission, biofuel etc. Pros and cons of use of materials like plastics and polymers and their

natural analogues, Genetic engineering and the manufacture of drugs (proteins and nucleic acids, and molecular reactivity and inter conversions).

Recommended Book:

1. John W. Hill, Terry W. McCreary & Doris K. Kolb, *Chemistry for changing times* 13th Ed.
2. E.J. Hackett, O. Amsterdamska, M. Lynch and J. Wajcman (eds.), The Handbook of Science and Technology Studies, The MIT Press, 2008.
3. D. MacKenzie and J. Wajcman (eds.), The Social Shaping of Technology, The Open University Press, 1999.

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(4) CHM-SE 501: CHEMOINFORMATICS

(Credits: 04 = 3 + 1)

Course Objectives: *The primary objective of this course is to familiarize the students with the use of various computer software and information technology. The students are expected to learn different chemical search engines and utilize them for molecular modelling and structure elucidation with a final goal to compute NMR, IR, mass and other spectra that can be later compared with the experimental data. The course also provides sufficient information and hands on exercises on the use of cheminformatics, with a special emphasis on its application in modern drug discovery.*

Course Learning Outcomes: *On the successful completion of the course, the students should be able to explain, interpret and critically examine the utility of computers and software tools to solving chemistry related problems. Recognize, apply, compare and predict chemical structures, properties, and reactivity and; solve chemistry related problems. Employ critical thinking and scientific reasoning to design and safely implement laboratory experiments and keep the records of the same. Compile, interpret and analyze the qualitative/quantitative data and communicate the same in a scientific literatur.*

Chemoinformatics: ***(100 marks : 30 classes of 60 minutes each)***

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

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

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

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

Hands-on Exercises

Recommended Books:

1. Andrew R. Leach & Valerie, J. Gillet (2007) *An introduction to Chemoinformatics.* Springer: The Netherlands.
2. Gasteiger, J. & Engel, T. (2003) *Chemoinformatics: A text-book.* Wiley-VCH.
3. Gupta, S. P. (2011) *QSAR & Molecular Modeling.* Anamaya Pub.: New Delhi

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(5) CHM-SE 501: BUSINESS SKILLS FOR CHEMISTS

(Credits: 04 = 3 + 1)

Course Objective: *To familiarize students with important concepts of business operations and intellectual rights as applied to chemical industry.*

Course Learning outcome: *students shall be able to explain and/or analyze the important steps of business operations, finance and intellectual property as applied to chemical industry.*

Business Skills For Chemists: ***(100 marks : 30 classes of 60 minutes each)***

Chemistry in Industry

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

Basics of Business and Management

Key business concepts: Business plans, market need, project management and routes to market. Management Functions and skills, principles of motivation, forms of business organization including partnerships and companies.

Marketing Skills

Understanding basics of marketing and marketing mix strategies with cases.

Human Resource Management (HRM) Skills

Managerial HRM functions viz. recruitment, training and development and compensation.

Financial Management Skills

An overview of financial and cost accounting with cases, managerial finance functions.

Intellectual Property Rights

Concept of intellectual property rights, patents.

Recommended books

1. http://www.rsc.org/learn-chemistry/resources/business-skills-forchemists/ OnlineCourse/
2. Philip Kotler, Keven Lane Keller Marketing Management 15th Ed., Pearson Education; Fifteenth edition (10 August 2017)

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(6) CHM-SE 501: INTELLECTUAL PROPERTY RIGHTS (IPR)

(Credits: 04 = 3 + 1)

Course Objective: *In this era of liberalization and globalization, the perception about science and its practices has undergone dramatic change. The importance of protecting the scientific discoveries, with commercial potential or the intellectual property rights is being discussed at all levels – statutory, administrative, and judicial. With India ratifying the WTO agreement, it has become obligatory on its part to follow a minimum acceptable standard for protection and enforcement of intellectual property rights. The purpose of this course is to apprise the students about the multifaceted dimensions of this issue.*

Course Learning Outcome: *After completing this course, students will have in-depth understanding about the importance and types of IPR. This course will also provide the clarity on the legal and economic aspects of the IP system.*

Intellectual Property Rights* : *(100 marks : 30 classes of 60 minutes each)

Introduction to Intellectual Property: Historical Perspective, Different Types of IP, Importance of protecting IP.

Copyrights

Introduction, How to obtain, Differences from Patents.

Trade Marks

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

Patents

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

Geographical Indications

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

Industrial Designs

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

Layout design of integrated circuits

Circuit Boards, Integrated Chips, Importance for electronic industry.

Trade Secrets

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

Different International agreements

(a) Word Trade Organization (WTO):

(i) General Agreement on Tariffs & Trade (GATT), Trade Related Intellectual Property Rights (TRIPS) agreement

(ii) General Agreement on Trade related Services (GATS)

(iii) Madrid Protocol

(iv) Berne Convention

(v) Budapest Treaty.

(b) Paris Convention
WIPO and **TRIPS, IPR** and Plant Breeders Rights, IPR and Biodiversity
IP Infringement issue and enforcement – Role of Judiciary, Role of law enforcement agencies – Police, Customs etc. Economic Value of Intellectual Property – Intangible assets and their valuation, Intellectual Property in the Indian Context – Various laws in India Licensing and technology transfer.

Recommended Books:

1. N.K. Acharya: *Textbook on intellectual property rights*, Asia Law House (2001).
2. Manjula Guru &*M.B.* Rao, *Understanding Trips: Managing Knowledge in Developing Countries*, Sage Publications (2003).
3. P. Ganguli, Intellectual Property Rights: *Unleashing the Knowledge Economy*, Tata McGraw-Hill (2001).
4. Arthur Raphael Miller, MichealH.Davis; *Intellectual Property: Patents, Trademarks and Copyright in a Nutshell*, West Group Publishers (2000).
5. JayashreeWatal, *Intellectual property rights in the WTO and developing countries*, Oxford University Press, Oxford.

SEMESTER II

Any one from the following:

(1) CHM-SE 502: ANALYTICAL CLINICAL BIOCHEMISTRY
(Credits: 04 = 3 + 1)

Course objective: *This course is intended to apprise students with various clinically relevant biomolecules, their structures and physiological roles. Students are also expected to learn the basics of analysis of pathological samples (blood and urine).*

Course Learning outcome: *Students will be able to identify various molecules relevant to a particular pathological condition and their estimation protocols.*

Analytical Clinical Biochemistry : ***(75 marks)***

Basic understanding of the structures, properties and functions of carbohydrates, lipids and proteins: ***(20 classes of 60 minutes each)***

Review of concepts studied in the core course.

Carbohydrates: Biological importance of carbohydrates, metabolism, cellular currency of energy (ATP), glycolysis, alcoholic and lactic acid fermentations, Krebs cycle, Isolation and characterization of polysachharides.

Proteins: Classification, biological importance, primary and secondary, tertiary and quaternary structures of proteins: α-helix and β- pleated sheets, isolation, characterization, denaturation of proteins.

Enzymes: Nomenclature, characteristics, classification, active site, mechanism of enzyme action, stereospecificity of enzymes, effect of pH, temperature on enzyme activity, , enzyme inhibitors, coenzymes and cofactors introduction to biocatalysis: importance in "Green Chemistry" and chemical industry.

Lipids: Classification, biological importance of triglycerides and phosphoglycerides and cholesterol, lipid membrane, liposomes and their biological functions and underlying applications. Lipoproteins. Properties, functions and biochemical functions of steroid hormones. Biochemistry of peptide hormones.*Structure of DNA* (Watson-Crick model) and RNA, genetic code, biological roles of DNAand RNA: replication, transcription and translation, introduction to gene therapy.

Biochemistry of disease: A diagnostic approach by blood/ urine analysis: ***(10 classes of 60 minutes each)***

Blood: Composition and functions of blood, blood coagulation, blood collection and preservation of samples, anemia, regulation, estimation and interpretation of data for blood sugar, urea, creatinine, cholesterol and bilirubin.

Urine: Collection and preservation of samples, formation of urine, composition and estimation of constituents of normal and pathological urine.

Practicals: (25 marks)

Identification and estimation of the following:

1. Carbohydrates - qualitative and quantitative analysis.
2. Lipids - qualitative and quantitative analysis.
3. Determination of the iodine number of oil.
4. Determination of the saponification number of oil.
5. Detection of cholesterol using Liebermann- Burchard reaction.
6. Isolation of protein.
7. Determination of concentration of protein by the Biuret reaction.
8. Determination of nucleic acid concentration.
9. Separation of nucleic acids.

Recommended Books:

1. David L. Nelson and Michael M. Cox: Lehninger Principles of Biochemistry
2. T.G. Cooper: Tool of Biochemistry.
3. Keith Wilson and John Walker: Practical Biochemistry.
4. Alan H Gowenlock: Varley's Practical Clinical Biochemistry.
5. Thomas M. Devlin: Textbook of Biochemistry.
6. Jeremy M. Berg, John L Tymoczko, LubertStryer: Biochemistry.
7. G. P. Talwar and M Srivastava: Textbook of Biochemistry and Human Biology.
8. O. Mikes, R.A. Chalmers: Laboratory Handbook of Chromatographic Methods

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(2) CHM-SE 502: PHARMACEUTICAL CHEMISTRY

(Credits: 04 = 3 + 1)

Course Objective: *This primary objective of this course is to introduce students to the fundamentals of drug design and development process, drugs for various diseases available in market, their mode of action and side effects. Students are expected to learn the biosynthetic procedures of various bio-relevant small molecules.*

Course Learning Outcome: *Students will be able to appreciate the drug development process, identify various small molecules used for treatments different ailments and other physiological processes.*

Pharmaceutical Chemistry: ***(75 marks)***

Drugs & Pharmaceuticals: ***(20 classes of 60 minutes each)***

Drug discovery, design and development; basic retrosynthetic approach, synthesis of the representative drugs of the following classes: analgesics, antipyretic, anti-inflammatory (aspirin, paracetamol, ibuprofen), antibiotics (chloramphenicol), antibacterial and antifungal (sulphonamides, sulphanethoxazol, sulphacetamide, trimethoprim), antiviral (acyclovir), drugs

effecting central nervous system (phenobarbital, diazepam), cardiovascular (glyceryl trinitrate), antilaprosy (dapsone), HIV-AIDS related drugs (AZT- Zidovudine).

Fermentation: ***(10 classes of 60 minutes each)***
Aerobic and anaerobic fermentation, production of (i) ethanol and citric acid, (ii) antibiotics (penicillin, cephalosporin, chloromycetin and streptomycin), (iii) lysine, glutamic acid, vitamin B2, vitamin B12 and vitamin C.

Practicals: (25 marks)
1. Preparation of Aspirin and its analysis.
2. Preparation of magnesium bisilicate (antacid).

Recommended Books:
1. Graham L. Patrick: *An Introduction to Medicinal Chemistry, Oxford University* Press, UK.
2. Gareth Thomas: *Fundamentals of Medicinal Chemistry*, Wiley.
3. Hakishan, V.K. Kapoor: *Medicinal and Pharmaceutical Chemistry*, Vallabh Prakashan, Pitampura, New Delhi.
4. William O. Foye, Thomas L., Lemke, David A. William: *Principles of Medicinal Chemistry*, B.I. Waverly Pvt. Ltd. New Delhi.

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(3) CHM-SE 502: PESTICIDE CHEMISTRY
(Credits: 04 = 3 + 1)

Course Objective*: This is a brief and introductory course on pesticides, through which the students will be introduced to various classes of pesticides, their synthesis, applications and possible hazards of their uses.*
Course Learning Outcome*: Students will be able to explain or describe and critically examine different types of pesticides, their activity/toxicity and their applications and the need for the search of an alternative based on natural products.*

Pesticide Chemistry : ***(75 marks : 30 classes of 60 minutes each)***

Definition of pesticides, general introduction to pesticides (natural and synthetic), benefits and adverse effects of pesticides. Classification, mode of action, toxicity and methods of pesticides residue analysis. Synthesis and technical manufacture and uses of representative pesticides in the following classes: Organochlorines (DDT, Gammexene); organophosphate (Malathion, Parathion); Carbamates (Carbofuran and carbaryl); Quinones (Chloranil), Anilides (Alachlor and Butachlor)

Practicals: (25 marks)
1. To calculate acidity/alkalinity in given sample of pesticides formulations as per BIS specifications.
2. Preparation of simple organophosphates, phosphonates and thiophosphates.

Recommended Book:
1. R. Cremlyn: Pesticides, Preparation and Mode of Action, John Wiley & Sons, New York, 1978

2. RPBateman, Pesticide Applications, AAB Press, 2004
3. Principles of Pesticide chemistry: S K Handa, Ed. by Agrobios (India), 2008
4. Pesticide Science & Biotechnology: R Greenhalgh and T R Robers, IUPAC, Blackwell Scientific Publications, 1987
5. The Chemical Process Industries: D N Shreve
6. Pesticide Chemistry : G Matolesy, M. Nadasy, V. Andriska, Elsevier Sc. Publisher, USA, 1988

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(4) CHM-SE 502: FUEL CHEMISTRY

(Credits: 04 = 3 + 1)

Course Objectives: *This course discusses about the chemistry of various sources of energy. Students are expected to learn about the composition of coal and petroleum products, their extraction, purification methods and usage. A section also covers classification and applications of natural and synthetic lubricants. Students will also learn about the determination and significance of various industrially relevant physical parameters for different fuels and lubricants.*

Course Learning Outcomes: *At the end of this course students will learn about the classes of renewable and non-renewable energy sources. Students will learn about the composition of coal and crude petroleum, their classification, isolation of coal and petroleum products and their usage in various industries. They will also learn to determine industrially significant physical parameters for fuels and lubricants.*

Fuel Chemistry: ***(100 marks : 30 classes of 60 minutes each)***

Review of energy sources (renewable and non-renewable). Classification of fuels and their calorific value.

Coal: Uses of coal (fuel and nonfuel) in various industries, its composition, carbonization of coal. Coal gas, producer gas and water gas—composition and uses. Fractionation of coal tar, uses of coal tar bases chemicals, requisites of a good metallurgical coke, Coal gasification (Hydro gasification and Catalytic gasification), Coal liquefaction and Solvent Refining.

Petroleum and Petrochemical Industry: Composition of crude petroleum, Refining and different types of petroleum products and their applications. Fractional Distillation (Principle and process), Cracking (Thermal and catalytic cracking), Reforming Petroleum and non-petroleum fuels (LPG, CNG, LNG, bio-gas, fuels derived from biomass), fuel from waste, synthetic fuels (gaseous and liquids), clean fuels.

Petrochemicals: Vinyl acetate, Propylene oxide, Isoprene, Butadiene, Toluene and its derivatives Xylene.

Lubricants: Classification of lubricants, lubricating oils (conducting and non-conducting) Solid and semisolid lubricants, synthetic lubricants. Properties of lubricants (viscosity index, cloud point, pore point) and their determination.

Recommended Books:

1. E. Stocchi: *Industrial Chemistry*, Vol -I, Ellis Horwood Ltd. UK.
2. P.C. Jain, M. Jain: *Engineering Chemistry*, Dhanpat Rai & Sons, Delhi.
3. B.K. Sharma: *Industrial Chemistry*, Goel Publishing House, Meerut.

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(5) CHM-SE 502: Renewable Energies (solar and biogas)

(Credits: 04 = 3 + 1)

Learning outcomes:

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

- Develop their understanding on the concept of renewable energies.
- Identify the different forms of energies and their uses
- Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components.
- Chemical composition of biomass Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation.

Renewable Energies: (100 marks)

UNIT-1: ***(10 classes of 60 minutes each)***

Introduction to renewable energy sources – solar, wind, small hydro, biomass, geothermal and ocean energy, energy flow in ecosystem Solar Energy Resources Solar radiation: Spectrum of EM radiation, sun structure and characteristics, extraterrestrial radiation, solar constant, air mass, beam, diffused and total solar radiation, spectral distribution.

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

UNIT-2: ***(10 classes of 60 minutes each)***

Solar mapping using satellite data, Typical Meteorological Year

Models and methods for estimating solar radiation, estimation of global radiation, estimation of diffused components.

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

Bulk chemical properties Moisture content, proximate and ultimate analyses, calorific value, waste water analysis for solids.

UNIT-3: ***(10 classes of 60 minutes each)***

Chemical composition of biomass Cellulose, hemicelluloses and lignin content in common agricultural residues and their estimation, protein content in biomass, extractable, COD. Structural properties Physical structure, particle size and size distribution, permeability. Physical properties: Bulk density, angle of repose, thermal analysis (thermogravimetric, differential thermal and differential scanning calorimetry). Properties of microbial biomass: Proteine stimation, flocculating ability, relative hydrophobicity of sludge, sludge volume index.

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(6) CHM-SE 502: Biofertilizer

(Credits: 04 = 3 +1)

Course Learning outcomes:

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

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

Biofertilizer: ***(100 marks)***

UNIT-1: ***(9 classes of 60 minutes each)***

General account about the microbes used as biofertilizer – Rhizobium – isolation, identification, mass multiplication, carrier based inoculants, Actinorrhizal symbiosis. *Azospirillum:* isolationand mass multiplication – carrier based inoculant, associative effect of different microorganisms. *Azotobacter*: classification, characteristics–crop response to *Azotobacter* inoculum, maintenance and mass multiplication.

UNIT-2: ***(7 classes of 60 minutes each)***

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

UNIT-3: ***(7 classes of 60 minutes each)***

Mycorrhizal association, types of mycorrhizal association, taxonomy, occurrence and distribution, phosphorus nutrition, growth and yield – colonization of VAM – isolation and inoculum production of VAM, and its influence on growth and yield of crop plants.

UNIT-4: ***(7 classes of 60 minutes each)***

Organic farming–Green manuring and organic fertilizers, Recycling of bio-degradable municipal, agricultural and Industrial wastes – biocompost making methods, types and method of vermin composting– field Application.

Suggested Readings

1. Dubey, R.C.(2005). *A Textbook of Biotechnology* S. Chand & Co, New Delhi.
2. John Jothi Prakash, E. (2004). *Outlines of Plant Biotechnology*. Emkay Publication, NewDelhi.
3. Kumaresan, V. (2005).*Biotechnology*, Saras Publications, NewDelhi.
4. NIIR Board. (2012). *The complete Technology Book on Biofertilizer and organicfarming*.2nd Edition.NIIRProjectConsultancyServices.
5. Sathe, T.V. (2004) *Vermiculture and Organic Farming*. Daya publishers.
6. Subba Rao N.S. (2017). *Biofertilizers in Agriculture and Forestry*. Fourth Edition. Medtech.

B.Sc. With Chemistry
&
Chemistry as Generic Elective

LOCF under Choice based credit System (CBCS)
Course effective from academic year 2022-23

Oriental College (Autonomous), Imphal
Department of Chemistry

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Preamble

In view of the National Education Policy 2020 of Government of India and the University Grants Commission's Guidelines for Learning Outcomes-based Curriculum Framework (LOCF) under Choice Based Credit System (CBCS), the Oriental College, Imphal has decided to introduce the LOCF for four-year undergraduate programme from the session 2022-23. The LOCF syllabus under CBCS for the B.Sc. (Regular) is prepared in the model of syllabus prepared by the UGC.

Chemistry as Generic Elective for other disciplines (Credit: 06 each)

CHM-HG 601: CHEMISTRY-1: Atomic Structure, Bonding, General Organic Chemistry & Aliphatic Hydrocarbonds, (4) + Lab (2)

CHM-HG 602: CHEMISTRY-2: s-and p-Block Elements, Transition Elements & States of Matter (4) + Lab (2)

CHM-HG 701: CHEMISTRY-3: Chemical Energetics, Equilibria & Functional Group Organic Chemistry -I (4) + Lab (2)

CHM-HG 702: CHEMISTRY-4: Solutions, Phase Equilibrium, Conductance & Functional Group Organic Chemistry -II (4) + Lab (2)

CHM-HG 801: CHEMISTRY-5: Coordination Chemistry, Acids and Bases, Noble Gases, Stereochemistry, Amino Acids, Peptides and Proteins (4) + Lab (2)

CHM-HG 802: CHEMISTRY-6: Electrochemistry, Chemical Kinetics, Transition Elements, Lanthanoids and Actinoids (4) + Lab (2)

GENERIC ELECTIVE COURSE

Semester III

CHM-HG 601: CHEMISTRY-1

ATOMIC STRUCTURE,BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONDS

(Credits: Theory-04, Practicals-02)

***Course Objectives**: This course aims at giving students theoretical understanding about the basic constituents of matter – atoms, ions and molecules in terms of their electronic structure and reactivity. Structure and bonding in/of these are to be dealt with basic quantum chemistry treatment. Reactivity of chemical species based on their electron transfer affinity is introduced. Further, The organic chemistry part contains fundamental of Organic Chemistry, and aliphatic hydrocarbon.*

***Course Learning Outcomes:** On successful completion, students would have clear understanding of the concepts related to atomic and molecular structure, chemical bonding, Students are expected to learn basic ideas used in organic Chemistry, functional group ,Alkanes, Alkenes, Alkynes etc.*

SECTION –A: Inorganic Chemistry1

UNIT -1 :Atomic Structure (10 classes of 60 minutes each) 15 Marks

Bohr's theory, its limitations and atomic spectrum of hydrogen atom. Wave mechanics de-Brogle equation, Heisenberg's uncertainty principle and its significance, Schrodinger wave equation, significance of Ψ and $\Psi,^2$quantum numbers and their significances, Pauli's Exclusion Principle , Hunds rule of maximum multiplicity , aufbou's principle and variation of energy of atomic orbitals with atomic number. Radial and angular wave functions, and probability distribution curves, shapes of s, p, and d orbitals.

UNIT-2: Chemical Bonding (12 classes of 60 minutes each) 20 M

Covalent bond – Valence bond theory and its limitations, directional characteristics of covalent bond, various types of hybridization and shapes of simple inorganic molecules and ions. Valence shell electron pair repulsion (VSEPR) theory and shapes of simple molecules and ions containing lone pairs and bond pairs of electrons. Molecular orbital theory, homonuclear and heteronuclear diatomic molecules, bond strength and bond energy. Hydrogen bonding, metallic bonding and van der Waals' interactions.

SECTION-B: Organic Chemistry1

UNIT-3: Fundamentals of Organic Chemistry (11 classes of 60 minutes each) 20M

Physical Effects, Electronic Displacements: Inductive Effect, Electromeric Effect, Resonance and Hyperconjugation. Cleavage of Bonds: Homolysis and Heterolysis.

Structure, shape and reactivity of organic molecules: Nucleophiles and electrophiles. Reactive Intermediates: Carbocations, Carbanions and free radicals.

Aromaticity: Benzenoids and Hückel's rule.

UNIT-4: Aliphatic Hydrocarbons (12 classes of 60 minutes each) 20M

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Alkanes: (Upto 5 Carbons). Preparation: Catalytic hydrogenation, Wurtz reaction, Kolbe's synthesis, from Grignard reagent. Reactions: Free radical Substitution: Halogenation.

Alkenes: (Upto 5 Carbons) Preparation: Elimination reactions: Dehydration of alkenes and dehydrohalogenation of alkyl halides (Saytzeff's rule); cis alkenes (Partial catalytic hydrogenation) and trans alkenes (Birch reduction). Reactions: cis-addition (alk. $KMnO_4$) and trans-addition (bromine), Addition of HX (Markownikoff's and anti-Markownikoff's addition), Hydration, Ozonolysis, oxymecuration-demercuration, Hydroboration-oxidation.

Alkynes: (Upto 5 Carbons) Preparation: Acetylene from CaC_2 and conversion into higher alkynes; by dehalogenation of tetra halides and dehydrohalogenation of vicinal-dihalides.

Reactions: formation of metal acetylides, addition of bromine and alkaline $KMnO_4$, ozonolysis and oxidation with hot alk. $KMnO_4$.

Recommended Books:

1. J. D. Lee: A new Concise Inorganic Chemistry, E L. B. S.
2. F. A. Cotton & G. Wilkinson: Basic Inorganic Chemistry, John Wiley.
3. Douglas, McDaniel and Alexader: Concepts and Models in Inorganic Chemistry, John Wiley.
4. James E. Huheey, Ellen Keiter and Richard Keiter: Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Publication.
5. T. W. Graham Solomon: Organic Chemistry, John Wiley and Sons.
6. Peter Sykes: A Guide Book to Mechanism in Organic Chemistry, Orient Longman.
7. E. L. Eliel: Stereochemistry of Carbon Compounds, Tata McGraw Hill.
8. I. L. Finar: Organic Chemistry (Vol. I & II), E. L. B. S.
9. R. T. Morrison & R. N. Boyd: Organic Chemistry, Prentice Hall.
10. Arun Bahl and B. S. Bahl: Advanced Organic Chemistry, S. Chand

CHM-HG 601(P) LAB: CHEMISTRY-1

ATOMIC STRUCTURE, BONDING, GENERAL ORGANIC CHEMISTRY & ALIPHATIC HYDROCARBONDS

Section A: Inorganic Chemistry-

Volumetric Analysis

1. Estimation of sodium Carbonate and Hydrogen Carbonate present in a mixture

2. Estimation of Oxalic acid by titrating it with $KMnO_4$

3. Estimation of Fe(II) ions by titrating it with $K_2Cr_2O_7$ using internal indicator

4. Estimation of Cu(II) ions iodometrically using $Na_2S_2O_3$

Section-B: Organic Chemistry

1. Detection of extra elements (N, S, Cl, Br, I) in Organic compound containing upto two extra elements.

2. Separation of mixtures by Chromatography: Measure the Rf value in each case (combination of two compounds to be given)

(a) Identify and separate the components of a given mixture of 2 amono acids (glycine aspartic acid glutamic acid, tyrosine or any other amino acid) by paper Chromatography.

(b) Identify and separate the sugars present in the given mixture by paper chromatography.

Recommended books:

1. Vogel's Quanlitative inorganic Analysis AI Vogel Prentic Hall, 7th Edition
2. Vogel's Quanlitative inorganic Analysis AI Vogel Prentic Hall, 6th Edition
3.Texbook of Practical Organic Chemistry A.I. Vogel, Prentic Hall, 5th Edition
4. Practical organic Chemistry F.G. Mann & B.C. Saunders, Orient Longman 1960

Semester IV

CHM-HG 602: CHEMISTRY-2

s-AND p-BLOCK ELEMENTS, TRANSITION ELEMENTS & STATES OF MATTER (Credits: Theory-04, Practicals-02)

Course Objectivse: This course may be divided into two broad parts-inorganic and physical chemistry. Three units-main group elements and transition elements will be taught in the inorganic chemistry part. The physical chemistry part contains states of matter.

Course Learning Outcomse: After completion of this course the students will learn periodic properties in main group elements, transition metals (3d series). In physical chemistry part, the students are expected to learn kinetic theory of gases, ideal gas and real gases, surface tension, viscosity and basic solid state chemistry.

SECTION –A: Inorganic Chemistry2

UNIT-1: s- and p-Block Elements (11 classes of 60 minutes each) 20 M

Periodicity in s- and p-block elements with respect to electronic configuration, atomic and ionic size, ionization enthalpy, electronegativity (Pauling, Mulliken, and Alfred-Rochow scales). Allotropy in C, S, and P. Oxidation states with reference to elements in unusual and rare oxidation states like carbides and nitrides), inert pair effect, diagonal relationship and anomalous behaviour of first member of each group.

UNIT-2: Transition Elements (3d series) (8 classes of 60 minutes each) 15 M

General group trends with special reference to electronic configuration, variable valency, colour, magnetic and catalytic properties, ability to form complexes and stability of various oxidation states (Latimer diagrams) for Mn, Fe and Cu.

Section- B: Physical Chemistry2

UNIT-3: Kinetic Theory of Gases (10 classes of 60 minutes each) 18 M

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-4: Liquids (8 classes of 60 minutes each) 10 M

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).

UNIT-5: Solids (8 classes of 60 minutes each) 12 M

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. Structures of NaCl, KCl and CsCl (qualitative treatment only). Defects in crystals. Glasses and liquid crystals.

Reference Books:

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).

3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
5. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
6. Cotton, F.A. & Wilkinson, G. Basic Inorganic Chemistry, Wiley.
7. Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
8. Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
9. Rodgers, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Ltd., 2008

CHM-HG 602 LAB: CHEMISTRY-2

s- AND p-BLOCK ELEMENTS, TRANSITION ELEMENTS, & STATES OF MATTER

Section- A: Inorganic Chemistry

Semi-micro qualitative analysis using H_2S of mixtures - not more than four ionic species (two anions and two cations and excluding insoluble salts) out of the following: CO_3^{2-} , NO_2^- , S^{2-} , SO_3^{2-}, $S_2O_3^{2-}$, CH_3COO^- , F^- , Cl^- , Br^- , I^- , NO_3^- , BO_3^{3-} , $C_2O_4^{2-}$, PO_4^{3-} , NH_4 + , K+ , Pb^{2+}, Cu^{2+}, Cd^{2+}, Bi^{3+}, Sn^{2+}, Sb^{3+}, Fe^{3+}, Al^{3+}, Cr^{3+}, Zn^{2+}, Mn^{2+}, $Co^{2+,}$ Ni^{2+}, Ba^{2+} , Sr^{2+} , Ca^{2+}, Mg^{2+}

(Spot tests should be carried out wherever feasible)

1. Estimate the amount of nickel present in a given solution as bis(dimethylglyoximato) nickel(II) or aluminium as oximate in a given solution gravimetrically.

2. Draw calibration curve (absorbance at λ_{max} vs. concentration) for various concentrations of a given coloured compound ($KMnO_4$/ $CuSO_4$) and estimate the concentration of the same in a given solution.

3. Determine the composition of the Fe^{3+}-salicylic acid complex solution by Job's method.

4. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.

5. Estimation of total hardness of a given sample of water by complexometric titration.

6. Determination of concentration of Na^+ and K^+ using Flame Photometry.

Section- B: Physical Chemistry

(I)Surface tension measurement (use of organic solvents excluded).

a) Determination of the surface tension of a liquid or a dilute solution using a stalagmometer.
b) Study of the variation of surface tension of a detergent solution with concentration.

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

Reference Books:

1. Svehla, G. Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
2. Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
3. Khosla, B. D.; Garg, V. C. & Gulati, A. Senior Practical Physical Chemistry, R. Chand & Co.: New Delhi (2011).

Semester V

CHM-HG 701: CHEMISTRY-3

CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL GROUP ORGANIC CHEMISTRY-I

(Credits: Theory-04, Lab-02)

Course Objectives: This course contains two broad parts- physical and organic chemistry. In physical chemistry part the students will be taught chemical energetics, chemical equilibrium and ionic equilibrium. In organic chemistry part, the students will be introduced to different classes of organic compounds.

Course Learning Outcomes: After completion of this course the students will able to understand the chemical system from thermodynamic points of view. They will also learn two very important topics in chemistry- chemical equilibrium and ionic equilibrium. In organic chemistry part, the students are expected to learn various classes of organic molecules-alkyl halides, aryl halides, alcohols, phenols, ethers, aldehydes and ketones.

Section- A: Physical Chemistry3

UNIT-1: Chemical Energetics (10 classes of 60 minutes each) 18 M

Review of thermodynamics and the Laws of Thermodynamics.

Important principles and definitions of thermochemistry. Concept of standard state and standard enthalpies of formations, integral and differential enthalpies of solution and dilution. Calculation of bond energy, bond dissociation energy and resonance energy from thermochemical data. Variation of enthalpy of a reaction with temperature – Kirchhoff's equation. Statement of Third Law of thermodynamics and calculation of absolute entropies of substances.

UNIT-2: Chemical Equilibrium (10 classes of 60 minutes each) 20 M

Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between ΔG and ΔGo, Le Chatelier's principle. Relationships between Kp, Kc and Kx for reactions involving ideal gases.

Ionic Equilibria: Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, ionization constant and ionic product of water. Ionization of weak acids and bases, pH scale, common ion effect. Salt hydrolysis-calculation of hydrolysis constant, degree of hydrolysis and pH for different salts. Buffer solutions. Solubility and solubility product of sparingly soluble salts – applications of solubility product principle.

Section- B: Organic Chemistry3

UNIT-3: (10 classes of 60 minutes each) 20 M

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Aromatic hydrocarbons

Preparation (Case benzene): from phenol, by decarboxylation, from acetylene, from benzene sulphonic acid.

Reactions: (Case benzene): Electrophilic substitution: nitration, halogenation and sulphonation. Friedel-Craft's reaction (alkylation and acylation) (upto 4 carbons on benzene). Side chain oxidation of alkyl benzenes (upto 4 carbons on benzene).

Alkyl and Aryl Halides

Alkyl Halides (Upto 5 Carbons) Types of Nucleophilic Substitution (SN1, SN2 and SNi) reactions.

Preparation: from alkenes and alcohols.

Reactions: hydrolysis, nitrite & nitro formation, nitrile & isonitrile formation. Williamson's ether synthesis: Elimination vs substitution.

Aryl Halides *Preparation*: (Chloro, bromo and iodo-benzene case): from phenol, Sandmeyer & Gattermann reactions.

Reactions (*Chlorobenzene)*: Aromatic nucleophilic substitution (replacement by –OH group) and effect of nitro substituent. Benzyne Mechanism: KNH_2/NH_3 (or $NaNH_2/NH_3$). Reactivity and Relative strength of C-Halogen bond in alkyl, allyl, benzyl, vinyl and aryl halides.

UNIT-4: (10 classes of 60 minutes each) 17M

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Alcohols, Phenols and Ethers (Upto 5 Carbons)

Alcohols: Preparation: Preparation of 1^0, 2^0 and 3^0 alcohols: using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters.

Reactions: With sodium, HX (Lucas test), esterification, oxidation (with PCC, alk. $KMnO_4$, acidic dichromate, conc. HNO_3). Oppeneauer oxidation Diols: (Upto 6 Carbons) oxidation of diols. Pinacol-Pinacolone rearrangement.

Phenols: (Phenol case) Preparation: Cumene hydroperoxide method, from diazonium salts. Reactions: Electrophilic substitution: Nitration, halogenation and sulphonation. Reimer Tiemann Reaction, Gattermann-Koch Reaction, Houben–Hoesch Condensation, Schotten – Baumann Reaction.

Ethers (aliphatic and aromatic): Cleavage of ethers with HI.

Aldehydes and ketones (aliphatic and aromatic):(Formaldehye, acetaldehyde, acetone and benzaldehyde)

Preparation: from acid chlorides and from nitriles.

Reactions – Reaction with HCN, ROH, $NaHSO_3$, NH_2-G derivatives. Iodoform test. Aldol Condensation, Cannizzaro's reaction, Wittig reaction, Benzoin condensation. Clemensen reduction and Wolff Kishner reduction. Meerwein-Pondorff Verley reduction.

Recommended Books:

1. T. W. Graham Solomons: Organic Chemistry, John Wiley and Sons.
2. Peter Sykes: A Guide Book to Mechanism in Organic Chemistry, Orient Longman.
3. I.L. Finar: Organic Chemistry (Vol. I & II), E. L. B. S.
4. R. T. Morrison & R. N. Boyd: Organic Chemistry, Prentice Hall.
5. Arun Bahl and B. S. Bahl: Advanced Organic Chemistry, S. Chand.
6. G. M. Barrow: Physical Chemistry Tata McGraw---Hill (2007). 15
7. G. W. Castellan: Physical Chemistry 4th Edn. Narosa (2004).
8. J. C. Kotz, P. M. Treichel & J. R. Townsend: General Chemistry Cengage Lening India Pvt. Ltd., New Delhi (2009).
9. B. H. Mahan: University Chemistry 3rd Ed. Narosa (1998).
10. R. H. Petrucci: General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).

CHM-HG 701(P) LAB: CHEMISTRY3

CHEMICAL ENERGETICS, EQUILIBRIA & FUNCTIONAL GROUP ORGANIC CHEMISTRY

***Section A: Physical Chemistry*3**

Thermochemistry

1. Determination of heat capacity of calorimeter for different volumes.
2. Determination of enthalpy of neutralization of hydrochloric acid with sodium hydroxide.
3. Determination of enthalpy of ionization of acetic acid.
4. Determination of integral enthalpy of solution of salts (KNO_3, NH_4Cl).
5. Determination of enthalpy of hydration of coppersulphate.
6. Study of the solubility of benzoic acid in water and determination of ΔH.

Ionic equilibria

pH measurements

a) Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps (use dilute solutions of soaps and shampoos to prevent damage to the glass electrode) using pH-meter.

b) Preparation of buffer solutions:

(i) Sodium acetate-acetic acid

(ii) Ammonium chloride-ammonium hydroxide Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

***Section B: Organic Chemistry* 3**

1. Purification of organic compounds by crystallization (from water and alcohol) and distillation.

2. Criteria of Purity: Determination of melting and boiling points.

3. Preparations: Mechanism of various reactions involved to be discussed. Recrystallisation, determination of melting point and calculation of quantitative yields to be done.

(a) Bromination of Phenol/Aniline

(b) Benzoylation of amines/phenols

(c) Oxime and 2,4 dinitrophenylhydrazone of aldehyde/ketone

Recommended Books

1. A.I. Vogel: Textbook of Practical Organic Chemistry, 5th edition, Prentice-Hall.
2. F. G. Mann & B. C. Saunders, Practical Organic Chemistry, Orient Longman (1960).
3. B.D. Khosla, Senior Practical Physical Chemistry, R. Chand & Co.

Semester VI

CHM-HG 702: CHEMISTRY-4

SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE & FUNCTIONAL GROUP ORGANIC CHEMISTRY -II
(Credits: Theory-04, Lab-02)

Course Objectives: This course may be divided into two broad parts-physical and organic chemistry. In 1st part of this course students will be introduced to solutions, phase equilibrium and electrochemistry. The 2nd part contains carboxylic acid and derivatives, amines and diazonium salt and biochemistry.
Course Learning Outcomes: After completion of this course the students learn solutions, phase rule and its application in specific cases, basics of conductance and electrochemistry. Students will also learn some important topics of organic and biochemistry- carboxylic acids, amines, amino acids, peptides, proteins and carbohydrates.

Section -A: Physical Chemistry4

UNIT-1: Solutions (9 classes of 60 minutes each) 14M
Thermodynamics of ideal solutions: Ideal solutions and Raoult's law, deviations from Raoult's law– non-ideal solutions. Vapour pressure-composition and temperature composition curves of ideal and non-ideal solutions. Distillation of solutions. Lever rule. Azeotropes. Partial miscibility of liquids: Critical solution temperature; effect of impurity on partial miscibility of liquids. Immiscibility of liquids- Principle of steam distillation. Nernst distribution law and its applications, solvent extraction.

UNIT-2: Phase Equilibrium (7 classes of 60 minutes each) 12M
Phases, components and degrees of freedom of a system, criteria of phase equilibrium. Gibbs Phase Rule and its thermodynamic derivation. Derivation of Clausius – Clapeyron equation and its importance in phase equilibria. Phase diagrams of one-component systems (water and sulphur) and two component systems involving eutectics, congruent and incongruent melting points (lead-silver, $FeCl_3$-H_2O and Na-K only).

UNIT-3: Conductance (7 classes of 60 minutes each) 12M
Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch law of independent migration of ions.

Transference number and its experimental determination using Hittorf and Moving boundary methods. Ionic mobility. Applications of conductance measurements: determination of degree of ionization of weak electrolyte, solubility and solubility products of sparingly soluble salts, 17 ionic product of water, hydrolysis constant of a salt. Conductometric titrations (only acid base).

Section- B: Organic Chemistry4

UNIT-4: (12 classes of 60 minutes each) 20M

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Carboxylic acids and their derivatives

Carboxylic acids (aliphatic and aromatic)

Preparation: Acidic and Alkaline hydrolysis of esters.

Reactions: Hell – Vohlard - Zelinsky Reaction.

Carboxylic acid derivatives (aliphatic): (Upto 5 carbons)

Preparation: Acid chlorides, Anhydrides, Esters and Amides from acids and their inter conversion.

Reactions: Comparative study of nucleophilicity of acyl derivatives. Reformatsky Reaction, Perkin condensation.

UNIT-5: (10 classes of 60 minutes each) 17M

Functional group approach for the following reactions (preparations & reactions) to be studied in context to their structure.

Amines and Diazonium Salts

Amines (Aliphatic and Aromatic): (Upto 5 carbons)

Preparation: from alkyl halides, Gabriel's Phthalimide synthesis, Hofmann Bromamide reaction.

Reactions: Hofmann vs. Saytzeff elimination, Carbylamine test, Hinsberg test, with HNO_2, Schotten – Baumann Reaction. Electrophilic substitution (case aniline): nitration, bromination, sulphonation.

Diazonium salts:

Preparation: from aromatic amines.

Reactions: conversion to benzene, phenol, dyes.

Recommended Books:

1. G. M. Barrow: Physical Chemistry Tata McGraw--Hill (2007).
2. G. W. Castellan: Physical Chemistry 4th Ed. Narosa (2004).
3. J. C. Kotz, P. M. Treichel, J. R. Townsend, General Chemistry, Cengage Learning India Pvt. Ltd.: New Delhi (2009).
4. B. H. Mahan: University Chemistry, 3rd Edn. Narosa (1998).
5. R. H. Petrucci, General Chemistry, 5th Edn., Macmillan Publishing Co.: New York (1985).
6. Morrison, R. T. & Boyd, R. N. Organic Chemistry, Dorling Kindersley (India) Pvt. Ltd. (Pearson Education).
7. Finar, I. L. Organic Chemistry (Volume 1), Dorling Kindersley (India) Pvt. Ltd. (Pearson Education). 8. Finar, I. L. Organic Chemistry (Volume 2), Dorling Kindersley (India) Pvt.

Ltd. (Pearson Education). 9. Nelson, D. L. & Cox, M. M. Lehninger's Principles of Biochemistry 7th Ed., W. H. Freeman.
10. Berg, J. M., Tymoczko, J. L. & Stryer, L. Biochemistry 7th Ed., W. H.

CHM-HG 702(P) LAB: CHEMISTRY4

SOLUTIONS, PHASE EQUILIBRIUM, CONDUCTANCE, ELECTROCHEMISTRY & FUNCTIONAL ORGANIC CHEMISTR

Section- A: Physical Chemistry

Distribution

Study of the equilibrium of one of the following reactions by the distribution method:

$I_{2(aq)} + I^-_{(aq)} \rightleftharpoons I_3^-{}_{(aq)}$

$Cu^{2+}(aq) + xNH_3(aq) \rightleftharpoons [Cu(NH3)x]^{2+}$

Phase equilibria

a) Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.

b) Determination of the critical solution temperature and composition of the phenol water system and study of the effect of impurities on it.

c) Study of the variation of mutual solubility temperature with concentration for the phenol water system and determination of the critical solubility temperature.

Conductance

i. Determination of cell constant

ii. Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

iii. Perform the following conductometric titrations:

a) Strong acid vs. strong base

b) Weak acid vs. strong base

Section -B: Organic Chemistry

Systematic Qualitative Organic Analysis of Organic Compounds possessing mono functional groups (-COOH, phenolic, aldehydic, ketonic, amide, nitro, amines) and preparation of one derivative.

Recommended Books:

1. A.I. Vogel: Textbook of Practical Organic Chemistry, Prentice Hall, 5th Edn.
2. F. G. Mann & B. C. Saunders: Practical Organic Chemistry, Orient Longman, 1960.
3. B.D. Khosla: Senior Practical Physical Chemistry, R. Chand & Co.
4. Ahluwalia, V.K. & Aggarwal, R. Comprehensive Practical Organic Chemistry, Universities Press.

Semester VII

CHM-HG 801 CHEMISTRY-5

COORDINATION CHEMISTRY, ACIDS AND BASES, NOBLE GASES, STEREOCHEMISTRY, AMINO ACIDS, PEPTIDES AND PROTEINS
(Credits: Theory-04, Lab-02)

***Course Objectives**: This course may divide into two broad parts - Inorganic and organic chemistry and aims at giving students theoretical understanding about the coordination chemistry, acids and bases, noble gases in inorganic part. Further, the organic chemistry part contains stereochemistry, Amino Acids, Peptides and Proteins.*

***Course Learning Outcomes:** On successful completion, students would have clear understanding of the concepts coordination chemistry. Students are expected to learn basic ideas used in stereochemistry, Amino Acids, Peptides and Proteins etc.*

Section A - Inorganic Chemistry5

UNIT-1: Coordination Chemistry - (8 classes of 60 minutes each) 14M

Coordination compounds, types of ligands, Werner's theory, IUPAC nomenclature and isomerism in coordination compounds. Stereochemistry of complexes with 4 and 6 coordination numbers.

Drawbacks of VBT. Crystal field effect, octahedral symmetry. Crystal field stabilization energy (CFSE), Crystal field effects for weak and strong fields. Tetrahedral symmetry. Factors affecting the magnitude of D. Comparison of CFSE for Oh and Td complexes, Tetragonal distortion of octahedral geometry. Jahn-Teller distortion, Square planar coordination.

UNIT-2: Acids and Bases (7 classes of 60 minutes each) 12M

Brönsted-Lowry concept of acid-base reactions, solvated proton, relative strength of acids, types of acid-base reactions, levelling solvents, Lewis acid-base concept, Classification of Lewis acids, Hard and Soft Acids and Bases (HSAB) Application of HSAB principle.

UNIT-3: Noble Gases: (8 classes of 60 minutes each) 12M

Occurrence and uses, rationalization of inertness of noble gases, Clathrates; preparation and properties of XeF_2, XeF_4 and XeF_6; Nature of bonding in noble gas compounds (Valence bond treatment and MO treatment for XeF_2). Molecular shapes of noble gas compounds (VSEPR theory).

Section B - Organic Chemistry5

UNIT-4: Stereochemistry (12 classes of 60 minutes each) 20M

Conformations with respect to ethane, butane and cyclohexane. Interconversion of Wedge Formula, Newmann, Sawhorse and Fischer representations. Concept of chirality (upto two carbon atoms). Configuration: 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).

UNIT-5: Amino Acids, Peptides and Proteins (10 classes of 60 minutes each) 17M

Preparation of Amino Acids: Strecker synthesis using Gabriel's phthalimide synthesis. Zwitterion, Isoelectric point and Electrophoresis.

Reactions of Amino acids: ester of –COOH group, acetylation of $–NH_2$ group, complexation with Cu^{2+} ions, ninhydrin test.

Overview of Primary, Secondary, Tertiary and Quaternary Structure of proteins. Determination of Primary structure of Peptides by degradation Edmann degradation (Nterminal) and C–terminal (thiohydantoin and with carboxypeptidase enzyme). Synthesis of simple peptides (upto dipeptides) by N-protection (t-butyloxycarbonyl and phthaloyl) & Cactivating groups and Merrifield solid-phase synthesis.

Carbohydrates: Classification, and General Properties, Glucose and Fructose (open chain and cyclic structure), Determination of configuration of monosaccharides, absolute configuration of Glucose and Fructose, Mutarotation, ascending and descending in monosaccharides. Structure of disacharrides (sucrose, cellobiose, maltose, lactose) and polysacharrides (starch and cellulose) excluding their structure elucidation.

CHM-HG 801(P): LAB

Inorganic Chemistry

(A) Iodo / Iodimetric Titrations

(i) Estimation of Cu(II) and $K_2Cr_2O_7$ using sodium thiosulphate solution (Iodimetrically).

(ii) Estimation of (i) arsenite and (ii) antimony in tartar-emetic iodimetrically

(iii) Estimation of available chlorine in bleaching powder iodometrically.

(B) Inorganic preparations

(i) Cuprous Chloride, CuCl

(ii) Preparation of manganese(III) phosphate, $MnPO_4.H_2O$

(iii) Preparation of aluminium potassium sulphate $KAl(SO_4)_2.12H_2O$ (Potash alum) or Chrome alum.

Organic Chemistry **-**

1. Separation of amino acids by paper chromatography
2. Determination of the concentration of glycine solution by formylation method.
3. Titration curve of glycine
4. Action of salivary amylase on starch

5. Effect of temperature on the action of salivary amylase on starch.
6. Determination of the saponification value of an oil/fat.
7. Determination of the iodine value of an oil/fat
8. Differentiation between a reducing/nonreducing sugar.
9. Extraction of DNA from onion/ cauliflower

Recommended Books:

1. J. D. Lee: A new Concise Inorganic Chemistry, E L. B. S.
2. F. A. Cotton & G. Wilkinson: Basic Inorganic Chemistry, John Wiley.
3. Douglas, McDaniel and Alexader: Concepts and Models in Inorganic Chemistry, John Wiley.
4. James E. Huheey, Ellen Keiter and Richard Keiter: Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Publication.
5. T. W. Graham Solomon: Organic Chemistry, John Wiley and Sons.
6. Peter Sykes: A Guide Book to Mechanism in Organic Chemistry, Orient Longman.
7. E. L. Eliel: Stereochemistry of Carbon Compounds, Tata McGraw Hill.
8. I. L. Finar: Organic Chemistry (Vol. I & II), E. L. B. S.
9. R. T. Morrison & R. N. Boyd: Organic Chemistry, Prentice Hall.
10. Arun Bahl and B. S. Bahl: Advanced Organic Chemistry, S. Chand.

Semester VIII

CHM-HG 802 CHEMISTRY-6

ELECTROCHEMISTRY, CHEMICAL KINETICS, TRANSITION ELEMENTS, LANTHANOIDS AND ACTINOIDS
(Credits: Theory-04, Lab-02)

Course Objectives: This course may be divided into two broad parts-physical and inorganic chemistry. Electrochemistry and chemical kinetics will be taught in the physical chemistry part. The inorganic chemistry part contains transition elements, lanthanoids and actinoids.

Course Learning Outcomes: After completion of this course the students will learn the difference between first, second and third transition series as well as chemistry of first -row transition elements. In physical chemistry part, the students are expected to electrochemistry and chemical kinetics.

Section A - Physical Chemistry6

UNIT-1: Electrochemistry (12 classes of 60 minutes each) 20M

Reversible and irreversible cells. Concept of EMF of a cell. Measurement of EMF of a cell. Nernst equation and its importance. Types of electrodes. Standard electrode potential. Electrochemical series. Thermodynamics of a reversible cell, calculation of thermodynamic properties: ΔG, ΔH and ΔS from EMF data.

Calculation of equilibrium constant from EMF data. Concentration cells with transference and without transference. Liquid junction potential and salt bridge.
pH determination using hydrogen electrode and quinhydrone electrode.
Potentiometric titrations -qualitative treatment (acid-base and oxidation-reduction only).

UNIT-2: Chemical Kinetics (11 classes of 60 minutes each) 18M

The concept of reaction rates. Effect of temperature, pressure, catalyst and other factors on reaction rates. Order and molecularity of a reaction. Derivation of integrated rate equations for zero, first and second order reactions (both for equal and unequal concentrations of reactants). Half–life of a reaction. General methods for determination of order of a reaction. concept of activation energy and its calculation from Arrhenius equation. Theories of reaction rates: Collision theory and Activated Complex theory of bimolecular reactions. Comparison of the two theories (qualitative treatment only).

Section B - Inorganic Chemistry6

UNIT-3:Transition Elements (12 classes of 60 minutes each) 20M

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

UNIT-4: Lanthanoids and Actinoids (10 classes of 60 minutes each) 17M

Electronic configuration, oxidation states, colour, spectral and magnetic properties, lanthanide contraction, separation of lanthanides (ion-exchange method only).

CHM-HG 802(P) LAB: CHEMISTRY-6

A - Physical Chemistry

Potentiometry

Perform the following potentiometric titrations:

i. Strong acid vs. strong base
ii. Weak acid vs. strong base
iii. Potassium dichromate vs. Mohr's salt

iv) **Chemical Kinetics** Study the kinetics of the following reactions. 1. Initial rate method: Iodide-persulphate reaction 2. Integrated rate method: a. Acid hydrolysis of methyl acetate with hydrochloric acid. b. Saponification of ethyl acetate. c. Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methyl acetate

B - Inorganic Chemistry

Inorganic Preparations:

i. Tetraamminecopper(II) sulphate, $[Cu(NH_3)_4]SO_4.H_2O$
ii. *Cis* and *trans* $K[Cr(C_2O_4)_2.(H_2O)_2]$ Potassium dioxalatodiaquachromate (III)

iii. Tetraamminecarbonatocobalt (III) ion
iv. Potassium tris(oxalato)ferrate(III)

Chromatography of metal ions

Principles involved in chromatographic separations. Paper chromatographic separation of following metal ions:

i. Ni(II) and Co(II)
ii. Fe(III) and Al(III)

Reference Books:

1. Barrow, G.M. Physical Chemistry Tata McGraw-Hill (2007).
2. Castellan, G.W. Physical Chemistry 4th Ed. Narosa (2004).
3. Kotz, J.C., Treichel, P.M. & Townsend, J.R. General Chemistry Cengage Learning India Pvt. Ltd., New Delhi (2009).
4. Mahan, B.H. University Chemistry 3rd Ed. Narosa (1998).
5. Petrucci, R.H. General Chemistry 5th Ed. Macmillan Publishing Co.: New York (1985).
6. Cotton, F.A. & Wilkinson, G. Basic Inorganic Chemistry, Wiley.
7. Shriver, D.F. & Atkins, P.W. Inorganic Chemistry, Oxford University Press.
8. Wulfsberg, G. Inorganic Chemistry, Viva Books Pvt. Ltd.
9. Rodgers, G.E. Inorganic & Solid State Chemistry, Cengage Learning India Ltd., 2008