Integrated M.Sc. Chemistry Programme (CBCS) Curriculum

Department of Chemistry
(DST-FIST Sponsored)
School of Basic and Applied Sciences
Central University of Tamil Nadu
Thiruvarur- 610 005
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CENTRAL UNIVERSITY OF TAMIL NADU

VISION

To develop enlightened citizenship of knowledge society for peace and prosperity of individuals, nation and the world, through promotion of innovation, creative endeavors, and scholarly inquiry and to be a global destination of higher education and research.

MISSION

- To serve a beacon of change, through multi-disciplinary learning, for creation of knowledge community, by building a strong character and nurturing a value-based transparent work ethics, promoting creative and critical thinking for holistic development and self-sustenance for the people of India.
- The University seeks to achieve this objective by cultivating an environment of excellence in teaching, research and innovation in pure and applied areas of learning.

OBJECTIVES AND GOALS

- To disseminate and advance knowledge by providing instructional and research facilities in such branches of learning as it may deem fit
- To make special provisions for integrated courses in humanities, social sciences, science and technology in its educational programmes
- To take appropriate measures for promoting innovations in teaching-learning process and inter-disciplinary studies and research
- To educate and train manpower for the development of the country
- To establish linkages with industries for the promotion of science and technology
- To pay special attention to the improvement of the social and economic conditions and welfare of the people, their intellectual, academic and cultural development

DEPARTMENT OF CHEMISTRY

The Department of Chemistry started functioning from the year 2010 with five-year integrated M.Sc. Chemistry programme. The Department has the distinction of starting the first two-year PG programme in Science at CUTN. Besides the state-of-the-art PG and research laboratories, the Department is committed to excellence in Chemistry by establishing research programmes for meeting Scientific and Technological challenges faced by the ever changing, science centered world of the 21st century.

The department is presently offering M.Sc., Integrated M.Sc. Post Graduate Diploma in Chemical Lab Technician (PGDCLT) and Ph.D. programmes. The Department provides ample opportunity for the students to accumulate a thorough fundamental knowledge of all fields of Chemistry. Meticulous lecture courses in the general areas of inorganic, organic and physical chemistry are conducted regularly in addition to the state-of-the-art laboratory courses which provide hands-on experience to the students at all levels.

The focus of the department is to instill the necessary spark and provide the scientific impetus so that the students can virtually experience the jiggling and wiggling of atoms and molecules. To enable students to have a glimpse of contemporary research, both in terms of academia and industry, the final year students in Chemistry will be completely engaged in project works. As a part of the curriculum the students have to undergo Internships at industry, institutes, and Universities. The department aim is to produce highly sought after and knowledgeable graduates for pursuing careers with academia, industry and government.

VISION AND MISSION OF THE DEPARTMENT

VISION

The Department envisions establishing itself as a place of excellence for chemistry education and research programmes globally.

MISSION

- To bridge the gap between academia and industry by regularly updating the curriculum on par with recent developments in science and encourage doing in house projects
- To educate and invoke the students to deliver their maximum outputs in competitive examinations and meet industrial competences.
- To develop chemists with excellent analytical and synthetic skills through the curriculum with more laboratory components and industrial visits/internships.

1. THE PROGRAMME

The five-year Integrated M.Sc. Chemistry programme offered under CBCS by the Department of Chemistry, CUTN has ten semesters, which include73 courses in total with an overall credit of 237. At the end of first the student has the flexibility to slide over to any of the other three majors (Biotechnology, Mathematics or Physics) based on his/her interest and following CUTN norms. Further, an exit option can be availed at the end of first, second, third and fourth year, provided the student has to satisfy the required credits to get certificate, diploma, B.Sc. degree, BSc degree (Hons/Research), respectively. The duration of each semester shall be 90 working days.

2. COURSE FEATURES

The 73 courses embrace Chemistry, Biotechnology, Mathematics and Physics, elective courses, language, ability enhancement, skill enhancement, value added courses apart from research methodology and online MOOCs courses. In addition, internship and research project courses are included in the curriculum.

3. ELIGIBILITY AND ADMISSION

A pass in the Plus two examination or equivalent of any recognized board in India with 60% marks (Chemistry, Physics, Mathematics or Biology/ Botany / Zoology / Biotechnology) for General Category, 55% marks for OBC (NCL) /EWS and 50% marks for SC/ST/PWD candidates. The admission into the programme is done through the Common University Entrance Test (CUET) conducted by NTA.

4. EXAMINATION

The assessment of a student pursuing the Integrated M.Sc. Chemistry programme shall be based on his/her performances in the Continuous Internal Assessment (CIA) and the End Semester Examinations (ESE). For theory courses the distribution of marks for CIA and ESE are 40 % and 60%, respectively. Irrespective of the score obtained by a student in the CIA, he/she must score a minimum of 50% in the ESE for passing a course. The practical courses are evaluated based on continuous assessment.

4.1. CONTINUOUS INTERNAL ASSESSMENT (CIA)

The 40% marks for CIA shall be based on the students' performance in the following

(i) Periodical assessment tests (30 %)

(ii) Assignment and seminar presentations (10 %)

4.2. END SEMESTER EXAMINATION (ESE)

The ESE for theory courses (maximum marks 60 %) will be conducted by the University at the end of each semester (odd and even). The student must register for the semester examination in order to be eligible for registration in the following semester examinations. To attend the examination 75 % attendance is mandatory.

4.3. QUESTION PAPERPATTERN

The end semester examination question paper comprises three sections, with maximum marks of 60 and allowed time of 3 hours.

SECTION A (10 X 1 = 10) Answer ALL the questions

Ten Multiple Choice Questions, two questions from each unit. Four choices of answers in each question.

SECTION B (5 x 3 = 15) Answer ALL questions

Five questions to be answered from the given choice of seven questions.

SECTION C (5 x 7 = 35) Answer ALL the questions

Answer all questions choosing either (a) or (b) from each question. One question from each unit.

5. PRACTICAL COURSE ASSESSMENT

The assessment of practical courses will be done based on the students' performance in the laboratory, regular attendance, the number of experiments performed, on-time submission of observation and record notes, and written/viva-voce examinations.

6. ATTENDANCE

In each semester, the minimum attendance for a student to get eligible for appearing in the end semester examination is 75%. Upon failing the minimum requirement, the student shall abide by the University norms for eligibility.

7. INTERNSHIP

Students shall undergo two summer internships during the third and fifth year (2 credits each) for a period of 1-2 months. They are encouraged to take up internships at industries/research labs/ institutes/universities (including CUTN). The evaluation of the internship would be based on external (60%, host institution) and internal (40%, Departmental) assessment.

8. RESEARCH PROJECT

Students shall undertake a research project with six credits at the end of the sixth semester to get a B.Sc. degree. Students wishing to exit at the end of fourth year have to complete a project with six credits to get a B.Sc degree (with Hons/Research). The student has to inform the department in the beginning of the particular year, if he/she wishes to exit. To acquire the 5-year Integrated MSc Chemistry degree the student shall complete a 12 credit project during the 10^{th} semester in the 5^{th} year. The research guide shall be allotted to the students based on their research interest and academic ranking. The project report shall be submitted in the form of a dissertation at the end of the 10^{th} semester on or before the date notified by the Department. The student shall present the research project work and shall be evaluated by the Department.

9. REVISION OF CURRICULUM

The Department of Chemistry shall revise and amend the regulations in the curriculum based on the feedback received from the stakeholders.

PROGRAMME EDUCATIONAL OBJECTIVES (PEOs)

The Integrated M.Sc. (Int. M.Sc.) Chemistry programme will enable the student to

PEO1: seamlessly integrate knowledge from other disciplines such as Mathematics, Physics and Biotechnology to enable interdisciplinary and multidisciplinary research.

PEO2: have societal, health, safety, and cultural issues relevant to the science practices and provide a strong foundation for acquiring advanced knowledge in chemistry

PEO3: acquire critical thinking supported by advanced analytical skills to address chemistry related problems.

PEO4: demonstrate the ability to perform accurate quantitative measurements with an understanding of the theory and use of sophisticated instruments, analyze and interpret.

PEO5: enhance skills for employability through activities, such as, seminar, communication skills, industrial visit, internship, and research project dissertation.

GRADUATE ATTRIBUTES

Disciplinary Knowledge: Content and pedagogical knowledge synchronized with the curriculum frameworks and policies

Communication Skills: Possess clarity in conveying the ideas

Critical Thinking: Capacity to apply analytical thought in the teaching and learning process

Problem Solving: Participate in the educational problem solving and applying the knowledge in the day-to-day professional endeavours.

Cooperation: Appreciate collaboration and cooperation among stakeholders of education.

ICT Skills: Selecting and integrating appropriate ICT skills for professional development.

Ethics: Doing what is right to society

Self-Directed Learning: Developing autonomy and self-regulation in teaching learning and professional development.

Reasoning: Ability to interpret and draw the conclusion from qualitative/quantitative data with open-mindedness

Creativity: Ability to produce new ideas

Societal and Environmental Concern: Performing an act or solving a problem with respect to societal and environmental concern

Lifelong Learning: Understands the need for learning and practices it throughout life

PROGRAMME OUTCOMES (POs)

On successful completion of integrated M.Sc. programme, the student will be able to

PO1: Think critically and analyze problems.

PO2: Prepare and present scientific and technical information resulting from laboratory outputs.

PO3: Design methodologies, analyze, and evaluate innovative scientific research problems.

PO4: Pursue higher education / become an employee / entrepreneur.

PO5: Work independently as well as in a team.

POs	PEO1	PEO2	PEO3	PEO4	PEO5
PO1	3	3	3	3	3
PO2	3	2	3	3	2
PO3	2	3	3	2	2
PO4	3	3	3	3	3
PO5	3	2	2	3	3

PROGRAMME SPECIFIC OUTCOMES (PSOs)

Upon successful completion of integrated M.Sc. Chemistry programme, the student will be able to

PSO1: Acquire the knowledge of fundamental chemistry concepts and recent advancement in the scientific field.

PSO2: Understand the features of molecules in organic /inorganic/physical domain

PSO3: Develop computational and experimental skills to explore molecular level phenomena.

PSO4: Apply technical skill in a sophisticated laboratory environment and secure challenging positions in industry and academics.

PSO5: Enhance employability through laboratory activities, solving problems and co-curricular activities

COURSE STRUCTURE

CC: Core Course; CCP: Core Course Practical; Minor: Allied Courses; DSE: Department Specific Elective; OE: Open Elective; AECC: Ability Enhancement Compulsory Course; SEC: Skill Enhancement Course; VAC: Value Added Course; EXT: Extension Activity; VOC: Vocational Course; INT: Internship; Research Project/Dissertation

FIRST YEAR

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – I							
1	CHE1011	General Chemistry	CC	4	4	40	60
2	CHE1012	General Chemistry Laboratory	CCP	2	4	100	
3		Biology I	Minor	4	4	40	60
4		Biology Laboratory I	Minor	2	4	100	
5		Open Elective	OE	3	3	40	60
6		English	AECC	3	3	40	60
7		SEC -1	SEC	3	3	40	60
8		VAC- 1	VAC	2	2	40	60
			Total	**23**	**27**		

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – II							
1		Mathematics I	Minor	4	4	40	60
2		Mathematics Laboratory I	Minor	2	4	100	
3		Physics I	Minor	4	4	40	60
4		Physics Laboratory I	Minor	2	4	100	
5		Open Elective	OE	3	3	40	60
6		Tamil / Hindi	AECC	3	3	40	60
7		SEC- 2	SEC	3	3	40	60
8		VAC- 2 (Env Science)	VAC	4	4	40	60
			Total	**25**	**29**		
			Cumulative Total	**48**	**56**		
For students exiting after one year (Certificate)							
		Vocational Course	VOC	**4**	**4**	100	
			Total	**52**	**60**		

SECOND YEAR

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – III							
1	CHE1031	Organic Chemistry I	CC	4	4	40	60
2	CHE1032	Organic Chemistry Laboratory I	CCP	2	4	100	
3		Mathematics II / Biology II	Minor	4	4	40	60
4		Mathematics / Biology Laboratory II	Minor	2	4	100	
5		Physics II	Minor	4	4	40	60
6		Physics Laboratory II	Minor	2	4	100	
7		Open Elective	OE	3	3	40	60
8		Tamil / Hindi	AECC	3	3	40	60
			Total	**24**	**30**		
			Cumulative Total	**72**	**86**		

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – IV							
1	CHE1041	Inorganic Chemistry I	CC	4	4	40	60
2	CHE1042	Inorganic Chemistry Practical I	CCP	2	4	100	
3	CHE1043	Physical Chemistry I	CC	4	4	40	60
4	CHE1044	Physical Chemistry Laboratory I	CCP	2	4	100	
5		Open Elective	OE	3	3	40	60
6		English	AECC	3	3	40	60
7		SEC-3 (Cyber Security)	SEC	4	4	40	60
8	CHEVAXX	VAC- 3	VAC	2	2	40	60
9		NSS / NCC / etc.	EXT	1	--		
			Total	**25**	**28**		
			Cumulative Total	**97**	**114**		
For students exiting after two years (Diploma)							
10		Vocational Course	VOC	**4**	**4**	100	
			Total	**101**	**118**		

THIRD YEAR

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – V							
1	CHE1051	Analytical Methods in Chemistry	CC	4	4	40	60
2	CHE1052	Inorganic Chemistry II	CC	4	4	100	
3	CHE1053	Organic Chemistry II	CC	4	4	40	60
4	CHE1054	Physical Chemistry II	CC	4	4	100	
5	CHE1055	Inorganic Chemistry Laboratory II	CCP	2	4	40	60
6	CHE1056	Organic Chemistry Laboratory II	CCP	2	4	40	60
7	CHE1057	Physical Chemistry Laboratory II	CCP	2	4	40	60
8	CHE1058	Internship-01	INT	2	--	40	60
			Total	**24**	**28**		
			Cumulative Total	**121**	**142**		

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – VI							
1	CHE1061	Inorganic Chemistry III	CC	4	4	40	60
2	CHE1062	Organic Chemistry III	CC	4	4	40	60
3	CHE1063	Physical Chemistry III	CC	4	4	40	60
4	CHE1064	Inorganic Chemistry Lab III	CCP	2	4	100	
5	CHE1065	Organic Chemistry Lab III	CCP	2	4	100	
6	CHE1066	Physical Chemistry Lab III	CCP	2	4	100	
7	CHEEXX	MOOCS / NPTEL / DSE Course	DSE	4	4	40	60
8	CHESEXX	SEC-4	SEC	2	2	40	60
			Total	**24**	**30**		
			Cumulative Total	**145**	**172**		
For students exiting after three years (Bachelor's Degree, B.Sc.)							
9	CHE1067	Research Project / Dissertation	CC	**6**	--	100	
			Total	**151**	**172**		

FOURTH YEAR

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – VII							
1	CHE1071	Inorganic Chemistry IV	CC	4	4	40	60
2	CHE1072	Organic Chemistry IV	CC	4	4	40	60
3	CHE1073	Physical Chemistry IV	CC	4	4	40	60
4	CHE1074	Physical Methods in Chemistry I	CC	4	4	40	60
5	CHE1075	Organic Chemistry Laboratory IV	CCP	4	8	100	
6	CHEEXX	Elective	DSE	4	4	40	60
7	CHEVAXX	VAC- 4	VAC	2	2	40	60
			Total	**26**	**30**		
			Cumulative Total	**171**	**202**		

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – VIII							
1	CHE1081	Inorganic Chemistry V	CC	4	4	40	60
2	CHE1082	Organic Chemistry V	CC	4	4	40	60
3	CHE1083	Physical Chemistry V	CC	4	4	40	60
4	CHE1084	Physical Methods in Chemistry II	CC	4	4	40	60
5	CHE1085	Physical Chemistry Laboratory IV	CCP	4	8	100	
6	CHEEXX	Elective	DSE	2	2	40	60
7	CHEVAXX	VAC- 5	VAC	2 (not included)	--	40	60
			Total	**22**	**26**		
			Cumulative Total	**193**	**228**		
For students exiting after four years (Bachelor's Degree – Honours/Research)							
8	CHE1086	Research Project / Dissertation	CC	**6**	--	100	
			Total	**199**	**228**		

FIFTH YEAR

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – IX							
1	CHE1091	Inorganic Chemistry VI	CC	4	4	40	60
2	CHE1092	Organic Chemistry VI	CC	4	4	40	60
3	CHE1093	Physical Chemistry VI	CC	4	4	40	60
4	CHE1094	Inorganic Chemistry Laboratory IV	CCP	4	8	100	
5	CHEEXX	Elective	DSE	4	4	40	60
6	CHESEXX	SEC-5	SEC	3	3	40	60
7		Open Elective	OE	3	3	40	60
			Total	**26**	**30**		
			Cumulative Total	**219**	**258**		

No	Course Code	Course Title	Type	Credit	Hours / Week	Marks	
						Int	Ext
SEMESTER – X							
1	CHE1101	Research Project	CC	12	24	40	60
2	CHE1102	Internship-02	INT	2	--	100	
3	CHEEXX	Self-Study Course	DSE	4	4	40	60
			Total	**18**	**28**		
			OVERALL TOTAL	**237**	**286**		

CREDIT FRAMEWORK

For students exiting after one year (Certificate)

S. No.	Course Components / Name of the Course	Nos	Credits	Percentage
1	Core Courses (CC)	1	4	
2	Core Courses Practical (CCP)	1	2	
3	Minor	3	12	
4	Minor Practical	3	6	
5	Open Elective (OE)	2	6	
6	Ability Enhancement Compulsory Course (AECC)	2	6	
7	Skill Enhancement Course (SEC)	2	6	
8	Value Added Course (VAC)	2	6	
9	Vocational Course (VOC)	1	4	
	Total	**17**	**52**	

For students exiting after two years (Diploma)

S. No.	Course Components / Name of the Course	Nos	Credits	Percentage
1	Core Courses (CC)	4	16	
2	Core Courses Practical (CCP)	4	8	
3	Minor	5	20	
4	Minor Practical	5	10	
5	Open Elective (OE)	4	12	
6	Ability Enhancement Compulsory Course (AECC)	4	12	
7	Skill Enhancement Course (SEC)	3	10	
8	Value Added Course (VAC)	3	8	
9	Extension Activity (EA)	1	1	
10	Vocational Course (VOC)	1	4	
	Total	**34**	**101**	

For students exiting after three years (Bachelor's Degree)

S. No.	Course Components / Name of the Course	Nos	Credits	Percentage
1	Core Courses (CC)	11	44	
2	Core Courses Practical (CCP)	10	20	
3	Minor	5	20	
4	Minor Practical	5	10	
5	Department Specific Elective (DSE) / MOOCS/ NPTEL	1	4	
6	Open Elective (OE)	4	12	
7	Ability Enhancement Compulsory Course (AECC)	4	12	
8	Skill Enhancement Course (SEC)	4	12	
9	Value Added Course (VAC)	3	8	
10	Internship	1	2	
11	Research Project	1	6	
12	Extension Activity (EA)	1	1	
	Total	**50**	**151**	

For students exiting after four years (Bachelor's Degree – Honours/Research)

S. No.	Course Components / Name of the Course	Nos	Credits	Percentage
1	Core Courses (CC)	19	76	
2	Core Courses Practical (CCP)	12	28	
3	Minor	5	20	
4	Minor Practical	5	10	
5	Department Specific Elective (DSE) / MOOCS/ NPTEL	3	10	
6	Open Elective (OE)	4	12	
7	Ability Enhancement Compulsory Course (AECC)	4	12	
8	Skill Enhancement Course (SEC)	4	12	
9	Value Added Course (VAC)	5	10	
10	Internship	1	2	
11	Research Project	1	6	
12	Extension Activity (EA)	1	1	
	Total	**64**	**199**	

Five years Integrated M.Sc. Degree

S. No.	Course Components / Name of the Course	Nos	Credits	Percentage
1	Core Courses (CC)	22	88	
2	Core Courses Practical (CCP)	13	32	
3	Minor	5	20	
4	Minor Practical	5	10	
5	Department Specific Elective (DSE) / MOOCS/ NPTEL	5	18	
6	Open Elective (OE)	5	15	
7	Ability Enhancement Compulsory Course (AECC)	4	12	
8	Skill Enhancement Course (SEC)	5	15	
9	Value Added Course (VAC)	5	10	
10	Internship	2	4	
11	Research Project	1	12	
12	Extension Activity (EA)	1	1	
	Total	**73**	**237**	

Semester: I **Course Type: Theory** **Course Code: CHE1011**
Credit: 3 **Course Title: General Chemistry**

Course Outcomes		Level
CO-1	Know the basic concepts of atomic structure and stability of orbitals	**Understand**
CO-2	Understand the various types of chemical bonding and to draw MO diagram	**Apply**
CO-3	Learn the nomenclature of organic compounds based on various functional groups	**Apply**
CO-4	Understand the electronic effects, reactive intermediates and their stability	**Understand**
CO-5	Outline the laws of thermodynamics & basic aspects of various processes and to know the fundamentals of ionic equilibria	**Remember**

Unit-I Atomic Structure

Rutherford atomic model, Bohr theory of hydrogen atom, Hydrogen atom spectra, Sommerfield theory, Electromagnetic radiation, descriptions for λ, υ and velocity. Particle and wave character of electrons, review of black body radiation, Planck's quantum theory, photoelectric effect and Compton effect. deBroglie's equation, Davisson-Germer experiment, Heisenberg's uncertainty principle. Need of a new approach to atomic structure. Introduction to Quantum mechanics Schrodinger wave equation (no derivation), Quantum numbers, Pauli's exclusion principle, Orbits and Orbitals. Rules for filling electrons in various orbitals, electronic configurations of the atoms. Stability of half-filled and completely filled orbitals, concept of exchange energy. Relative energies of atomic orbitals, Anomalous electronic configurations.

UNIT-II Periodic properties

Periodic properties – classification of elements as s, p, d and f-block elements – variation of atomic volume – atomic and ionic radii – ionization potential – electron affinity and electronegativity along period and groups – variation of metallic characters - Factors affecting the periodic properties. Periodic table anomalies and variations in atomic radius, ionic radius, electronic configuration, electron affinity and electronegativity, ionization energy and metallic character of elements along the group and periods and their influences on stability, colour, coordination number, geometry, physical and chemical properties.

Unit-III Introduction to Organic Chemistry I

Structure of organic molecules based on hybridization, Physical Effects, Electronic Displacement: Inductive Effect, Electromeric Effect, Mesomeric 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-generation, stability and identification methods. Strength of organic acids and bases: Comparative study with emphasis on factors affecting pK values.

Unit-IV Introduction to Organic Chemistry II

Classification and nomenclature of organic compounds. Introduction to functional groups. Structure, nomenclature and isomerism in alkanes, General methods of preparation and reactions of alkanes, alkenes and alkynes. Sources, nomenclature and preparation of cycloalkanes. Stability of cyclopropane to cyclooctane. Elimination reactions E1 and E2: Hofmann vs. Saytzeff rule. Addition reaction with hydrogen halide (Markovnikov's and Anti-Markovnikov's rule) and ozonolysis. Oxidation and reduction in organic chemistry.

Unit-V Thermodynamics and Ionic Equilibria

Review of thermodynamics and the Laws of Thermodynamics, Important principles and definitions of thermochemistry. Concept of standard state: standard enthalpy of formation, integral enthalpy and differential enthalpy of solution. Work of expansion, work of compression, maximum and minimum quantities of work, reversible and irreversible transformations of energy, isothermal and adiabatic changes. Thermodynamic state functions and Joule Thomson experiment. Variation of enthalpy of a reaction with temperature: Kirchhoff's equation.

Ionic Equilibria: Strong, moderate and weak electrolytes, degree of ionization, factors affecting degree of ionization, pH scale, Henderson's equation, Buffer solutions and their types. Applications of buffer solutions.

Reference Books

1. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
2. F. A. Cotton, G. Wilkinson, P. L. Gaus, Basic Inorganic Chemistry, 3rd Ed, Wiley, 2007
3. Ajai Kumar, Basic Inorganic Chemistry
4. B. R. Puri, L. R. Sharma, M. S. Pathania, Elements of Physical chemistry, Vishal Pub. Co. Jalandhar, 2017.
5. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
6. G. K. Vemulapalli, Physical Chemistry, Prentice-Hall of India Pvt. Ltd. 1997.
7. R. L. Madan, Chemistry for Degree Students, S Chand & Company Limited, 2022
8. Manas, Chand, Atomic Structure and Chemical Bond, IK International Pvt. Ltd. 2019
9. D. D. Ebbing, General Chemistry, 10th Ed, Cengage Learning India Pvt. Ltd., 2013.
10. G. Solomons, T. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
11. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford University Press, 2014.
12. I. Levine, Physical Chemistry, 6th Ed, McGraw Hill, 2011

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	1	1	2	1
2	2	1	2	2	1
3	2	1	1	2	1
4	3	1	2	2	1
5	3	1	2	2	1

Semester: I **Course Type: Practical** **Course Code: CHE1012**
Credit: 2 **Course Title: General Chemistry Laboratory**

Course Outcomes		Level
CO-1	Estimate heat transfer of various reactions and thermodynamic parameters	**Analyze**
CO-2	Use pH measurements for assessing the acidic and basic properties	**Apply**
CO-3	Prepare buffer solutions and standards	**Apply**
CO-4	Estimate the ionic equilibrium in each system	**Analyze**

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 copper sulfate.
6. Study of the solubility of benzoic acid in water and determination of ΔH.

Ionic Equilibria:

1. Measurement of pH of different solutions like aerated drinks, fruit juices, shampoos and soaps using pH-meter.
2. Preparation of buffer solutions:
   (a) Sodium acetate-acetic acid
   (b) Ammonium chloride-ammonium hydroxide
3. Measurement of the pH of buffer solutions and comparison of the values with theoretical values.

Reference books:

1. B. Viswanathan, Practical Physical chemistry, Viva Pub., 2005.
2. Saroj Kumar Naba Kumar, Physical Chemistry Practical, New Central Book Agency, 2012.
3. A.M. James, F.E. Prichard Practical Physical Chemistry Paperback, 1974.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	2	1	3
2	1	3	1	1	3
3	2	3	2	1	3
4	2	3	3	2	3

Semester: III **Course Type: Theory** **Course Code: CHE1031**
Credit: 3 **Course Title: Organic Chemistry-I**

Course Outcomes		Level
CO-1	Identify the type of stereoisomerism existing in organic compounds	**Apply**
CO-2	Describe the structure and chemical properties of aromatic hydrocarbons	**Understand**
CO-3	Predict the mechanism of nucleophilic substitution and elimination reactions of alkyl halides.	**Understand**
CO-4	Demonstrate the mechanism and synthetic applications of some important name reactions of alcohols and phenols	**Remember**
CO-5	Know the chemistry of carbonyl compounds and their interconversions	**Remember**

Unit-I Stereochemistry
Molecular representation and Interconversion - Wedge formula, Newman, Sawhorse and Fischer. Conformations with respect to ethane, butane and cyclohexane. Principles of symmetry – symmetry elements (C_n, C_i and S_n) - Concept of chirality (up to two stereo centers) - asymmetry – isomerism – constitutional isomers – stereoisomers. Configuration: Geometrical and Optical isomerism; Enantiomerism, Diastereomerism and meso compounds. *Threo* and *erythro*; D and L; *cis – trans* nomenclature; CIP Rules: R/ S (for up to 2 chiral carbon atoms) and E / Z Nomenclature (for up to two C=C systems).

Unit-II Aromatic hydrocarbons
Structure of benzene, Aromaticity: Benzenoids and Hückel's rule. Preparation of benzene from acetylene, benzenesulfonic acid and phenol. Reactions: Aromatic Electrophilic substitution: nitration, halogenation and sulfonation. Friedel-Craft's reaction (alkylation and acylation). Side chain oxidation of alkyl benzenes. Polycyclic aromatic hydrocarbons: structure, preparation, and aromaticity of naphthalene, phenanthrene and anthracene.

Unit-III Alkyl and aryl halides
Alkyl halides: Nomenclature of alkyl halides. Preparation: from alkenes and alcohols. Nucleophilic substitution reactions (S_N1, S_N2 and S_Ni), stereochemical aspects. Reactions: hydrolysis, Williamson ether synthesis, nitrite and nitro formation. Aryl halides: Preparation, properties and reactions. Nucleophilic aromatic substitution reaction mechanisms.

Unit-IV Alcohols and Phenols
Alcohols: Preparation using Grignard reagent, Ester hydrolysis, Reduction of aldehydes, ketones, carboxylic acid and esters. Reactions: with sodium, HX (Lucas test), esterification, oxidation reaction.
Phenols: Preparation: from Cumene and diazonium salts. Reactions: Electrophilic substitution: Nitration, halogenation and sulfonation. Reimer-Tiemann reaction, Gattermann-Koch reaction, Houben–Hoesch Condensation, Schotten–Baumann reaction. Di- and Tri-hydric phenols: Preparation of catechol and phloroglucinol.

Unit-V Chemistry of Carbonyl compounds

Aldehydes and Ketones: Preparation from acid chlorides, nitriles. Reactions with HCN, ROH, amine derivatives, iodoform test, Aldol Condensation, Cannizzaro's reaction, Clemmensen reduction, Wolff-Kishner reduction. Oxidation reactions of carbonyl compounds.

Carboxylic acids: Mono, di- and unsaturated carboxylic acids: preparation and reactions. Carboxylic acid derivatives: preparation and reactions of acid chlorides, anhydrides, amides and esters.

Reference Books:

1. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
2. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford Univ. Press, 2014.
3. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
4. Graham Solomons, T. W. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
5. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
6. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
7. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
8. Francis A. Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, 5th Ed. 2007
9. L. G. Wade, Organic Chemistry, 6th Ed. Pearson, 2006
10. Francis A. Carey, Robert M. Giuliano, Organic Chemistry, 8th Ed. 2008
11. Edwin S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Publications, 1959

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	1	1	3	1
2	1	1	3	2	2
3	2	1	2	2	1
4	1	1	3	2	1
5	2	1	2	2	1

Semester: III **Course Type: Practical** **Course Code: CHE1032**
Credit: 2 **Course Title: Organic Chemistry Laboratory-I**

Course Outcomes		Level
CO-1	Understand the chemistry of functionalized organic compounds	**Understand**
CO-2	Explain the procedure for the systematic analysis of oxygen and nitrogen based functional groups	**Apply**
CO-3	Examine qualitative analysis of unknown organic compounds systematically	**Analyze**
CO-4	Analyze and articulate simple methods of preparation of functional group derivatives	**Apply**
CO-5	Determine the chemical nature and the purity of the prepared derivatives by simple testing	**Evaluate**

Qualitative Analysis of Organic Compounds

(a) Identification of acidic, basic, phenolic and neutral organic substances.
(b) Test for saturation and unsaturation.
(c) Test for aliphatic and aromatic nature of substances.
(d) Detection of nitrogen, sulfur and halogens.
(e) Identification of functional groups:
(i) Carboxylic acids (ii) Phenols (iii) Aldehydes (iv) Ketones (v) Esters
(vi) Carbohydrates (vii) Amines (viii) Amides (ix) Nitro (x) Halogen

Preparation and determination of melting or boiling points of derivatives for the functional groups

(a) Nitration of benzene (b) Oxidation of benzaldehyde
(c) Esterification of salicylic acid (d) Hydrolysis of methyl salicylate
(e) Nitration of phenol

Reference Books:

1. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Textbook of Practical Organic Chemistry, Prentice-Hall, 5th Ed, 1996.
2. F. G. Mann, B. C. Saunders, Practical Organic Chemistry, 4th Ed, Pearson Education India, 2009.
3. B. Haynes, Qualitative Organic Analysis, Pearson Education, 2011.
4. P. B. Cranwell, L. M. Harwood, C. J. Moody, Experimental Organic Chemistry, 3rd Ed, Wiley-Blackwell, 2017.
5. V. K. Ahluwalia, R. Aggarwal, Comprehensive Practical Organic Chemistry, Universities Press, 2004.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	3	2	2	3
2	1	3	2	2	3
3	2	3	2	2	3
4	2	3	2	2	3
5	1	3	2	2	3

Semester: IV **Course Type: Theory** **Course Code: CHE1041**
Credit: 3 **Course Title: Inorganic Chemistry-I**

Course Outcomes		Level
CO-1	Understand various bonding theories - VB and MO theories	**Understand**
CO-2	Know about basic metallurgical processes.	**Analyze**
CO-3	Acquire the knowledge of acid, base and redox reactions	**Understand**
CO-4	Understand the chemistry of s - block elements and its complexes	**Understand**
CO-5	Develop the knowledge in the principles of concentration, primary and secondary standards and qualitative analysis of inorganic ions	**Remember**

Unit-I Chemical Bonding and Molecular Structure

Ionic bond - Properties of ionic compounds, factors favoring the ionic compounds ionization potential - electron affinity - electronegativity - Lattice energy - Born-Haber Cycle - Pauling and Mulliken's scales of electronegativity - Polarizing power and Polarizability - Partial ionic character from electronegativity. Transition from ionic to covalent character and vice versa - Covalent character of ionic compounds - Fajan's rules - Covalent bond - structure and bonding of homo and heteronuclear molecules - Hydrogen bonding - Its nature, types, effect on properties - Intermolecular forces - London forces and van der Waals forces - ion dipole-dipole interactions. VSEPR Theory - Principles and hybridization- Shapes of simple inorganic molecules ($BeCl_2$, BF_3, $SiCl_4$, PCl_5, SF_6, IF_7, H_2O, NH_3, XeF_6) - MO theory of homo-nuclear diatomic molecules of 1st and 2nd periods and heteronuclear diatomic molecules such as HF, CO, NO and NO^+. Polyatomic molecules BeH_2, BH_3 and NH_3 - Walsh diagram. Comparison of VB and MO approaches.

Unit-II Acids, Bases, and Redox Reactions

Theory of Acid bases: Bronsted-Lowry theory, Lewis theory, Lux-Flood definition, Usanovich definition, HSAB theory and symbiosis - Gas phase acid-base chemistry – Solvent levelling effects. Chemistry in aqueous and Non-aqueous Solvents - super acids - molten salts. Oxidation and reduction reactions - oxidation number concept, balancing redox equations by oxidation number method and ion-electron method - equivalent weight of oxidizing and reducing agents. Disproportionation and com-proportionating reaction, Redox stability in water: Frost-Ebsworth, Latimer and Pourbaix diagrams, applications of redox reactions to extraction of elements from their ores - Ellingham diagram.

UNIT-III s-Block elements

Position of hydrogen in the periodic table, General characteristics of s-block elements- Compounds of s-block metals - oxides, hydroxides, peroxides, superoxide's - preparation and properties - oxo salts - carbonates - bicarbonates - nitrates - halides and polyhalides. Anomalous behavior of Li and Be - extraction of beryllium - physical and chemical properties of Be - Uses - Extraction of Mg - physical and chemical properties - Uses. Complexes of s-block metals - complexes with crown ethers - biological importance sodium and potassium - Organometallic compounds of Li and Be.

UNIT-IV Metallurgy

Occurrence of metals-basic metallurgical operations and metallurgy process - General methods involved in extraction of metals- concentration of ores - froth floatation, magnetic separation, calcination, roasting, smelting, flux, aluminothermic process. Extraction processes - Chemical

reduction - electrolytic reduction - metal displacement - refining methods - distillation - fractional crystallization - electrolysis. Zone reining - van Arkel de Boer methods - electrolytic refining - ion exchange method - muffle furnace - chemical properties - important compounds and uses of Cr, Mn, Co, Ni and Zn.

UNIT-V Principles of Quantitative and Qualitative Analysis

General principles of inorganic qualitative analysis: Solubility product, ionic product, HSAB concept, common ion effect, complexation, and oxidation-reduction reactions - systematic analysis of anions and cations and separation of groups. Concentration systems: Molarity, molality formality, normality, wt%, ppm, milli-equivalence and millimoles -problems. Types of titrations - primary and secondary standards. Limitation of volumetric analysis, endpoint and equivalence point. Neutralisation-titration curve, theory and types of indicators, use of indicators (phenolphthalein, methyl orange, eriochromeblack T). Complexometric titrations: Stability of complexes, titration involving EDTA. Problems based on titrimetric analysis.

Reference Books:

1. B. H. Mahan, University Chemistry 3rd Ed. Narosa. 1998.
2. R. H. Petrucci, General Chemistry 5th Ed. Macmillan Publishing Co., New York,1985.
3. C. E. Housecraft and A. G. Sharpe, Inorganic Chemistry, 4th edition, Pearson, 2012.
4. D. Shriver, P.W. Atkins, Inorganic Chemistry, W.H. Freeman and Company,5th Ed, 2009
5. J. D. Lee, Concise Inorganic Chemistry, Wiley, 5th edn., 2016.
6. C. N. R. Rao, Understanding Chemistry, University Press (India) Ltd., 2001
7. R. P. Sarkar, General and Inorganic Chemistry Part- I, 3rd revised edition; New Central Book Agency, 2011.
8. B. E. Douglas, D.H. McDaniel, &J.J. Alexander, Concepts and Models in Inorganic Chemistry, John Wiley & Sons. 2010
9. J. E. Huheey, E. A. Keiter, R. L. Keiter, & O. K. Medhi, Inorganic Chemistry: Principles of Structure and Reactivity, Pearson Education India, 2006
10. G. Wulfsberg, Inorganic Chemistry, Viva Books Pvt. Ltd. 2014
11. F. A. Cotton, G. Wilkinson, C. A. Murillo and, M. Bochmann, Advanced Inorganic Chemistry, 6th Edition, John Wiley & Sons, 2008.
12. N. N. Greenwood and A. Earnshaw, Chemistry of the Elements, 2nd Ed, Elsevier, 2005.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	3
2	1	1	1	1	3
3	3	2	3	1	3
4	2	1	2	1	3
5	2	1	3	1	2

Semester: IV **Course Type: Practical** **Course Code: CHE1042 Credit: 2** **Course Title: Inorganic Chemistry Laboratory-I**

Course Outcomes		Level
CO-1	Quantitatively estimate the amount of metal ions from the given samples	**Analyze**
CO-2	Obtain expertise in preparing stock solutions and volumetric methods	**Understand**
CO-3	Identify cationic/anionic species with specific group separation procedures	**Apply**
CO-4	Develop semi-micro qualitative analytical skills	**Skill**
CO-5	Analyze and articulate simple methods of Qualitative Analysis	**Skill**

Volumetric Analysis:

1. Estimation of sodium carbonate and sodium hydrogen carbonate present in a mixture.
2. Estimation of oxalic acid by titrating it with $KMnO_4$.
3. Estimation of water of crystallization in Mohr's salt by titrating with $KMnO_4$.
4. Estimation of Fe(II) ions by titrating it with $K_2Cr_2O_7$ using an internal indicator.
5. Estimation of Cu(II) ions iodometrically using $Na_2S_2O_3$.
6. Estimation of (i) Mg^{2+} or (ii) Zn^{2+} by complexometric titrations using EDTA.
7. Estimation of total hardness of a given sample of water by complexometric titration.

Qualitative Analysis:

Semi-micro qualitative analysis - not more than four ionic species (a mixture containing two cations and two anions of which one will be an interfering ion) out of the following (excluding insoluble salts):

Cations: NH_4^+, Pb^{2+}, Ag^+, Bi^{3+}, Cu^{2+}, Cd^{2+}, Sn^{2+}, Fe^{3+}, Al^{3+}, Co^{2+}, Cr^{3+}, Ni^{2+}, Mn^{2+}, Zn^{2+}, Ba^{2+}, Sr^{2+}, Ca^{2+}, K^+

Anions: CO_3^{2-}, S^{2-}, SO_3^{2-}, $S_2O_3^{2-}$, NO_3^-, CH_3COO^-, Cl^-, Br^-, I^-, NO_3^-, SO_4^{2-}, PO_4^{3-}, BO_3^{3-}, $C_2O_4^{2-}$, F^- (Spot tests should be carried out wherever feasible)

Reference Books

1. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012. Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
2. G. H. Jeffery, J. Bassett, J. Mendham, and R. C. Denney, Vogel's quantitative chemical analysis, 5th edition, Longman Scientific and Technical, 1989.
3. J. Mendham, J. C. Denney, J. D. Barnesand, M. J. K. Thomas: Vogel's Prescribed book of qualitative chemical analysis, 6th Edition, Prentice Hall, 2000.
4. M. Hein, J. N. Peisen and R. L. Miner, Foundations of College Chemistry in the Laboratory, John Wiley and Sons, 2011.
5. J. D. Woollins, Inorganic experiments, 3rd Edition, Wiley-VCH Verlag GmbH Co., 2012.
6. In-house manual prepared by Department of Chemistry, CUTN, Thiruvarur.
7. Ghoshal, Mahapatra and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	3
2	1	1	1	1	3
3	3	2	3	1	2
4	2	1	2	1	3
5	2	1	2	1	2

Semester: IV **Course Type: Theory** **Course Code: CHE1043**
Credit: 3 **Course Title: Physical Chemistry-I**

Course Outcomes		Level
CO-1	Acquire basic knowledge of chemical equilibrium and chemical kinetics	**Remember**
CO-2	Classify types of solutions and colligative properties	**Apply**
CO-3	Understand the chemical reactions in the batteries and corrosion	**Understand**
CO-4	Explore the surface phenomena and electrochemical cells	**Analyze**

Unit-I Chemical Equilibrium and Kinetics

Chemical Equilibrium: Free energy change in a chemical reaction. Thermodynamic derivation of the law of chemical equilibrium. Distinction between ΔG and ΔG^0, Le Chatelier's principle. Relationships between Kp, Kc and Kx for reactions involving ideal gases.

Kinetics: The concept of reaction rates, Order and Molecularity. Factors affecting reaction rates. Integrated rate equations for zero, first and second order reactions. Half–life of a reaction. Experimental determination of order of a reaction. Concept of activation energy and Arrhenius equation. Collision theory and Activated Complex theory of bimolecular reactions.

Unit-II 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. Lever rule. Azeotropes. Critical solution temperature (CST); effect of impurity on partial miscibility of liquids. Immiscibility of liquids- Principle of steam distillation. Nernst distribution law and its applications, solvent extraction. Colligative properties- relative lowering of vapour pressure, osmosis, law of osmotic pressure, derivation of elevation of boiling point and depression in freezing point. Determination of molecular masses using colligative properties. Abnormal molecular masses, molecular dissociation- degree of dissociation- molecular association.

Unit-III Phase Equilibrium

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-IV Surface Chemistry

Surface Chemistry: Adsorption-types-chemical and physical; characteristics of adsorption. Theories of catalysis- intermediate compound formation theory and adsorption theory. Fruendlich and Langmuir adsorption isotherms – BET theory multilayer adsorption – BET equation (derivation not required) – determination of surface using BET theory –Ion-exchange adsorption, water softening, applications of adsorption.

Unit-V Electrochemistry-I

Conductivity, equivalent and molar conductivity and their variation with dilution for weak and strong electrolytes. Kohlrausch's law of independent migration of ions. Ionic mobility.

Transference number and its experimental determination using Hittorf and Moving boundary methods. hydrolysis constant of a salt.
EMF of a cell, Types of electrodes. Standard electrode potential. Electrochemical series. Nernst equation and its importance. Thermodynamics of a reversible cell, calculation of thermodynamic properties: ΔG, ΔH and ΔS from EMF data. Calculation of equilibrium constant from EMF data. Liquid junction potential and salt bridge. Concentration cells with transference and without transference (qualitative). Corrosion of metals – forms of corrosion, corrosion monitoring and prevention methods.

Reference Books:

1. G. M. Barrow, Physical Chemistry Tata McGraw Hill 2007.
2. G. W. Castellan, Physical Chemistry 4th Edn. Narosa 2004.
3. J. C. Kotz, P.M. Treichel and J.R. Townsend, General Chemistry Cengage Learning India Pvt. Ltd., New Delhi 2009.
4. R. P. Rastogi, R. R. Mishra, An Introduction to Chemical Thermodynamics, 6thEdn., Vikas Pub. Pvt. Ltd. 2003.
5. B. H. Mahan, University Chemistry 3rd Edn. Narosa 1998.
6. R. H. Petrucci, General Chemistry 5th Edn. Macmillan Publishing Co.: New York 1985.
7. B. S. Bahl, G. D. Tuli and A. Bahl, Essentials of Physical Chemistry, S. Chand & Company Ltd, New Delhi, 12th Edn.,2011.
8. B. R. Puri, L.R. Sharma and M. S. Pathania, Principles of Physical Chemistry, 48th Edn. Vishal Publishing Co, 2019.
9. K. L. Kapoor, A Textbook of Physical chemistry, Volumes 1, 6thEdn. Macmillan India Ltd, 2020.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	1
2	3	1	2	1	1
3	2	1	2	1	1
4	3	1	3	1	1

Semester: IV **Course Type: Practical** **Course Code: CHE1044**
Credit: 2 **Course Title: Physical Chemistry Laboratory-I**

Course Outcomes		Level
CO-1	Expertise with the basic skills required for wet lab chemistry	**Analyze**
CO-2	Apply or correlate the physical chemistry concepts with the experiments	**Apply**
CO-3	Identify or perform the appropriate experiments for the measurements of concentration	**Understand**
CO-4	Execute solvent extraction process and eutectic experiments	**Apply**

Partition Coefficient:

1. Determine the distribution of a solute in two immiscible liquids.
2. Study of the equilibrium of the following reactions by the distribution method:
   $I_2(aq) + I^-(aq) \rightarrow I_3^-(aq)$

Phase equilibria:

1. Construction of the phase diagram of a binary system (simple eutectic) using cooling curves.
2. Determination of the critical solution temperature and composition of the phenol water system and study of the effect of impurities on it.

Potentiometry: Perform the following potentiometric titrations:

1. Strong acid vs. strong base
2. Weak acid vs. strong base

Conductometry: Perform the following conductometric titrations:

1. Strong acid vs. strong base
2. Weak acid vs. strong base

Reference Books

1. J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2001.
2. G. W. Garland, J. W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8th Edn. McGraw Hill, 2009.
3. A. M. James and F.E. Prichard Practical Physical Chemistry Paperback, 1974.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	3	2	1	3
2	2	3	1	1	3
3	2	3	3	1	3
4	1	3	2	1	3

Semester: V **Course Type: Theory** **Course Code: CHE1051**
Credit: 4 **Course Title: Analytical Methods in Chemistry**

Course Outcomes		Level
CO-1	Analyze the accuracy and precision of statistical data	**Apply**
CO-2	Introduce various thermal and electroanalytical methods	**Knowledge**
CO-3	Understand the methodologies of analytical spectroscopy and separation techniques	**Understand**
CO-4	Elucidate the analytical applicability of chromatography and spectroscopy in real samples (water quality, wastewater treatment, etc.)	**Skill**

Unit-1 Error Analysis
Errors, accuracy and precision, methods of their expression, normal law of distribution if indeterminate errors, statistical test of data; F, Q and t test, rejection of data, and confidence intervals, Correlation & regression, correlation coefficient and linear regression.

Unit-II Gravimetric and Electroanalytical Methods
Gravimetric Analysis–Principles, methods–requirements, Precipitation-theories of precipitation. Types of precipitation – co precipitation, post precipitation and precipitation from homogeneous solution-digestion, filtration and washing, drying and ignition. Inorganic and organic precipitating agents. 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-III Spectrophotometry
Optical methods of analysis: Origin of EMR 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 instruments. Applications: Estimation of metal ions from aqueous solution, geometrical isomers, keto-enol tautomers. Woodward–Fieser Rules (enones only), Determination of composition of metal complexes using Job's method of continuous variation and mole ratio method. Infrared Spectrometry: Basic principles & sampling techniques. Factors influencing vibrational frequencies. Structural illustration through interpretation of data, Effect and importance of isotope substitution.

Unit-IV Flame and Thermal Analysis
Flame Atomic Absorption and Emission Spectrometry: Basic principles 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. Thermal methods of analysis: Theory of thermogravimetry (TG), Differential Thermal Analysis (DTA), Differential Scanning Calorimeter (DSC) -Basic principle of instrumentation. Techniques for quantitative estimation of Ca and Mg from their mixture.

Unit-V 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 non-aqueous 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.

Reference Books:

1. G.H. Jeffery, J. Bassett, J. Mendham, & R.C. Denney, Vogel's Textbook of Quantitative Chemical Analysis, 5thEd., John Wiley & Sons, 1989.
2. H.H. Willard, L.L. Merritt, J. Dean, & F.A. Settoe, Instrumental Methods of Analysis, 7th Edn. Wadsworth Publishing Company Ltd., Belmont, California, USA, 1988.
3. G. D. Christian, P. K. Dasgupta, K. A. Schug, Analytical Chemistry, 7th Ed., John Wiley& Sons, New York, 2004.
4. D. C. Harris, Exploring Chemical Analysis, Ed. New York, W.H. Freeman, 2004.
5. S.M. Khopkar, Basic Concepts of Analytical Chemistry,3rd Edn., New Age, International Publisher, 2017.
6. D.A. Skoog, F.J. Holler & T.A. Nieman, Principles of Instrumental Analysis, 6thEdn, Cengage Learning India Ed.1998.
7. O. Mikes, Laboratory Hand Book of Chromatographic & Allied Methods, Elles Harwood Series on Analytical Chemistry, John Wiley & Sons, 1979.
8. R.V. Ditts, Analytical Chemistry; Methods of Separation, New York van Nostrand, 1974

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	3	1	2	1	3
2	2	1	2	1	3
3	3	2	3	1	3
4	2	1	3	1	3

Semester: V **Course Type: Theory** **Course Code: CHE1052**
Credit: 4 **Course Title: Inorganic Chemistry-II**

Course Outcomes		Level
CO-1	Understand the basics of p block elements	**Understand**
CO-2	Acquire knowledge of crystal structures and crystal defects	**Remember**
CO-3	Know about the composition and stability of the nucleus and types of nuclear reactions	**Understand**
CO-4	Grasp chemistry of p-block elements (B, C, N, O and halogen groups) & noble gases	**Remember**
CO-5	Predict the reaction and balancing the reaction of p-block elements	**Understand**

UNIT-I p-Block elements - Boron and Carbon family

General characteristics of elements of Group III A - Extraction of Boron - Physical and chemical properties of Boron - compounds of boron - Borax, Boric acid, Diborane, Boron nitride - Extraction of Al - Physical and Chemical properties - uses - compounds of aluminum - Al_2O_3, $AlCl_3$, alums - Alloys of aluminum. General characteristics of elements of Group IV A - Allotropic forms of carbon - Chemistry of charcoal - chemistry of oxides of carbon- preparation of Silicon - Physical and chemical properties of Si - Uses - Oxides of silicon - structures of silicates. Chemistry of silicones - Manufacture of glass - types of glasses - ceramics - extraction of lead - physical and chemical properties - Uses - lead pigments.

UNIT-II p-Block elements - Nitrogen and Oxygen family

General characteristics of elements of V A Group - Preparation of nitrogen - Physical and chemical properties of nitrogen - uses - Chemistry of some compounds of nitrogen - hydrazine, hydroxylamine, hydrazoic acid, nitric acid - nitrogen cycle. Preparation of phosphorus - Physical and chemical properties of phosphorus - uses - chemistry of PH_3, PCl_3, PCl_5, $POCl_3$, P_2O_5 and oxyacids of phosphorus - fertilizers - Oxides of nitrogen and Phosphorus - oxoacids of nitrogen and phosphorus. Anomalous behavior of oxygen - Structure and allotropy of elements, ozone, oxides - peroxides, suboxides, basic oxides, amphoteric oxides, acidic oxides, neutral oxides - Oxides of Sulphur - oxoacids of sulfur - sulfuryl compounds - Chemistry of selenium and tellurium.

UNIT-III Halogen family and Noble gases

General characteristics of halogen with reference of electronegativity, electron affinity, oxidation states, and oxidizing power - peculiarities of fluorine, Hydrides, oxides and oxo acids of halogens Interhalogen compounds - polyhalide ions - pseudohalogens - preparation, properties and structure of interhalogen compounds Inert gases - position in the periodic table - isolation from atmosphere - General characteristics - Structure and shape of xenon compounds - XeF_2, XeF_4, XeF_6, $XeOF_2$, $XeOF_4$ - uses of noble gasses.

Unit-IV Basic Solid State Chemistry

Introduction – Structure of ionic solids - crystal structures - Sodium chloride, Zinc blende, wurtzite, rutile, Cesium chloride, fluorite - antifluorite - Solid state reactions - Fick's law of diffusion and its derivation, types of diffusion mechanisms, thermal decomposition of solids - Type I and Type II reactions. Solid state synthesis: Nucleation, crystal growth, epitaxy and its types, topotaxy, Conventional heat and beat methods, Coprecipitation method, Sol-gel methods, Hydrothermal method, Flux method, Slow evaporation at room temperature method, Reaction at high pressure.

Unit-V Basic Nuclear Chemistry

Introduction - composition of nucleus and nuclear forces - nuclear stability - mass defect - binding energy - packing fraction - N/P ratio - magic numbers - nuclear models - liquid drop - Shell and collective model. Isotopes - detection and separation - deviation of atomic weights from whole numbers - isobars, isotones and isomers - Radioactive decay and equilibrium - nuclear isomerism - internal conversion. Nuclear Q-value - threshold energy - cross sections, types of reactions - fission and fusion - modes of radioactive decay - half-life period - Average life period - radioactive displacement law - radioactive series

Reference Books

1. J. E. Huheey, E. A. Keiter, R. L. Keiterand, O. K. Medhi, Inorganic Chemistry - Principles of Structure and Reactivity, 4thedition, Pearson Education, 2006.
2. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5th edition, Oxford University Press, 2010.
3. J.D. Lee, Concise Inorganic Chemistry, Wiley, 5th edn., 2016.
4. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3rdedition, Pearson, 2004.
5. N. N. Greenwood, and A. Earnshaw, Chemistry of the Elements, 2nd Ed, Elsevier, 2005.
6. R. M. Felder and R. W. Rousseau, Elementary Principles of Chemical Processes, Wiley Publishers, New Delhi.
7. C. E. Housecraft and A. G. Sharpe, Inorganic Chemistry, 4th edition, Pearson, 2012.
8. A. G. Massey, Main Group Chemistry, 2ndedition, John and Wiley & Sons, LTD, 2000.
9. J. Arnikar, Essentials of Nuclear Chemistry, 4th edition, New Age International Publishers Ltd., New Delhi, 1995.
10. W. D. Lovel, D. J. Morrissey and G. T. Seaborg, Modern Nuclear Chemistry, Wiley-VCH Verlag GmbH Co. KGaA, 2006.
11. Glasstone, Source Book on Atomic Energy, 3rd edition, Affiliated East West Press, 1979.
12. B. E. Douglas, D.H. McDaniel, &J.J. Alexander, Concepts and Models in Inorganic Chemistry, John Wiley & Sons. 2010.
13. G. Wulfsberg, Inorganic Chemistry, Viva Books Pvt. Ltd. 2014.
14. F. A. Cotton, G. Wilkinson, C. A. Murilloand, M. Bochmann, Advanced Inorganic Chemistry, 6thEdition, John Wiley & Sons, 2008.
15. N. N. Greenwood and A. Earnshaw, Chemistry of the Elements, 2nd Ed, Elsevier, 2005.
16. A. F. Wells, Structural Inorganic Chemistry, Oxford University Press, OUP UK; Reprint edition 2013

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	3
2	1	1	1	1	3
3	3	2	3	1	3
4	2	1	2	1	3
5	2	1	2	1	2

Semester: V **Course Type: Theory** **Course Code: CHE1053**
Credit: 4 **Course Title: Organic Chemistry-II**

Course Outcomes		Level
CO-1	Describe the physical and chemical properties amines and their derivatives	**Understand**
CO-2	Learn about the structure, preparation and properties of heterocyclic compounds	**Remember**
CO-3	Deduce the mechanistic and reaction pathways of nucleophilic addition reactions	**Understand**
CO-4	Predict the mechanism, orientation and factors influencing elimination reactions.	**Apply**
CO-5	Demonstrate the mechanism of organic transformations based on carbanion intermediates	**Analyze**

Unit-I Amines and Diazonium Salts

Amino compounds – nomenclature and classification. comparison basicity of aliphatic and aromatic amines - Preparation from alkyl halides, Gabriel's phthalimide synthesis. Reactions: Carbylamine reaction, Hofmann Bromamide reaction, diazotization – Reductive amination of aldehydes and ketones. Amidine, azide, azo, diazoalkanes, cyanates, nitrile, nitrite, oxime, carbamate ester, nitro compounds and diazonium salts – preparation and reactions.

Unit-II Heterocyclic Compounds-I

Nomenclature of heterocyclic compounds with one and two heteroatoms (O, N and S). Structure and aromatic characteristics of pyrrole, furan, thiophene and pyridine; comparison of basicity of pyridine, piperidine and pyrrole Synthetic protocols and reactivity with particular focus on electrophilic substitution. Nucleophilic substitution of pyridine; Skraup synthesis of quinoline, Napieralski synthesis of isoquinoline. Heterocyclic dyes: preparation and uses of – fluorescein, Indigo and sulfur black dyes.

Unit-III Addition Reactions

Hydrogenation of alkene: *syn* and *anti*-addition. Electrophilic addition to alkenes: Markovnikov's Rule – HX, H_2O, H_2SO_4, halogen, oxymercuration, hydroboration & oxidation, and oxidation of alkenes to diols. Conjugate addition to alkenes. Nucleophilic addition reaction to carbonyl group, reactivity of aldehydes and ketones. Addition of oxygen, nitrogen, sulfur and carbon-based nucleophiles to carbonyls.

Unit-IV Elimination Reactions

E1, E2, E1cB and Ei mechanisms – factors influencing elimination – stereochemical aspects, Zaitsev and Hofmann rule, E2 vs E1, dehydrohalogenation, dehydration, quaternary ammonium salts (Hofmann elimination). Pyrolytic *cis* elimination, Chugaev elimination, Grieco elimination, Cope elimination, Corey-Winter olefin synthesis, Ramberg-Backlund reaction.

Unit-V Organic transformations based on reactive species

Carbanions: Acidity of hydrocarbons – carbanion character of organometallic compounds – carbanions stabilized by functional groups – enols, enamines and protonated imines – carbanions as nucleophiles in S_N2 reactions. Synthetic applications of enamines.

Dicarboxylic acids, dicarbonyls and diesters. Acidity of α-hydrogens, active methylene - alkylation of diethyl malonate and ethyl acetoacetate. Synthesis of substituted dicarboxylic

acids, α, β-unsaturated acids, diketones and α,β-unsaturated ketones using diethyl malonate and ethyl acetoacetate. Claisen condensation, Knoevenagel condensation, Dieckmann condensation

Carbenes and Nitrenes: Generation, classifications, stability and reactivities.

Reference Books

1. Raj K. Bansal, Heterocyclic Chemistry, 4th Ed., Anshan Limited, 2008.
2. Alan R. Katritzky, Christopher A. Ramsden, John A. Joule, Viktor V. Zhdankin Handbook of Heterocyclic Chemistry, Elsevier Publication, 2010.
3. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
4. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford University Press, 2014.
5. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
6. Graham Solomons, T. W. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
7. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
8. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
9. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
10. Francis A. Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, 5th Ed. 2007
11. Robert B. Grossman, The Art of Writing Reasonable Organic Reaction Mechanisms, 2nd Ed, Springer, 2003
12. L. G. Wade, Organic Chemistry, 6th Ed. Pearson, 2006
13. Francis A. Carey, Robert M. Giuliano, Organic Chemistry, 8th Ed. 2008
14. Peter Vollhardt, Neil Schore, Organic Chemistry-Structure and Function, 6th Ed. W. H. Freeman and Company, 2011
15. Edwin S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Publications, 1959

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	3	3	1
2	2	1	3	3	2
3	2	1	3	3	1
4	2	1	3	3	1
5	2	1	3	3	1

Semester: V **Course Type: Theory** **Course Code: CHE1054**
Credit: 4 **Course Title: Physical Chemistry-II**

Course Outcomes		Level
CO-1	Explore and understand the basic concepts/theories of the physical states of matter and Photochemistry	**Understand**
CO-2	Well-verse in the kinetic theory of gas molecules, critical phenomenon, molecular symmetry, light matter interaction etc.	**Evaluate**
CO-3	Identify the point group of molecules using group theory	**Apply**
CO-4	Emphasis the spectrophotometric tools and analytical materials for research interest	**Create**

Unit-I Gaseous State

Postulates of Kinetic Theory of Gases and derivation of the kinetic gas equation. Maxwell Boltzmann distribution laws of molecular velocities and molecular energies (graphic representation – derivation not required) and their importance. Collision diameter, mean free path, Transport properties of gases- determination of thermal conductivity, viscosity and diffusion coefficients- effect of temperature and pressure on coefficients (qualitative treatment only). Real gases: Deviation and causes of real gases from ideal behaviour, compressibility factor, van der Waals equation of state – derivation and application in explaining real gas behaviour. virial form – calculation of Boyle temperature, Isotherms of real Gases-Andrews isotherms of CO_2, continuity of states. Critical phenomena, Critical constants and their calculation from van der Waals equation. Liquefaction of gases (based on Joule-Thomson effect).

Unit-II Liquid State, Liquid Crystals & Colloids

Intermolecular forces in liquids (qualitative idea only), Structure of liquids. Unusual behaviour of water. Surface tension and its determination using a Stalagmometer. surface active agents, the Parachor and chemical constitution (atomic and structural parachor), 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). **Liquid Crystals:** Liquid crystals thermographic behaviour. Classification and structure of nematic and cholesteric phases. Applications of liquid crystals. **Colloids:** Colloids - types, preparation, Purification (dialysis, electrodialysis and ultrafilteration) and stability of colloids, gold number. Properties of colloids- kinetic, optical and electrical properties.

Unit-III Solid State

Forms of solids. 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. Glass-Supercooled liquid. concept of conductor, semiconductor and superconductor- band theory. Polymers: Introduction – Classifications – Molecular weight determination methods.

Unit-IV Symmetry and Point Groups

Symmetry of molecules-symmetry elements and symmetry operations – centre of symmetry, plane of symmetry, proper and improper axes of symmetry, combination of symmetry elements, Group multiplication table, Schoenflies symbols, Determination of point groups of simple molecules like H_2O, NH_3 and BF_3, crystallographic point groups symmetry.

Unit-V Photochemistry

Laws of photochemistry-Grothus-Draper law, Stark-Einstein law. Jablonski diagram qualitative description of fluorescence, phosphorescence, non-radiative processes (internal conversion, intersystem crossing). Quenching of fluorescence. Quantum yield, examples of low and high quantum yields, photochemical reactions (decomposition of HBr, isomerisation of maleic acid to fumaric acid), photosensitised reactions (photosynthesis, isomerisation of 2-butene), chemiluminescence, bioluminescence.

Reference Books

1. K. L. Kapoor, A Textbook of Physical chemistry, Volumes 1, 6thEdn. Macmillan India Ltd, 2020.
2. B.R. Puri, L.R. Sharma and M.S. Pathania, Principles of Physical Chemistry, 48thEdn. Vishal Publishing Co, 2019.
3. P. Atkins and J. Paula, The elements of Physical chemistry, 7thEdn., Oxford University Press, 2016.
4. D. A. McQuarrie, J. D. Simon, Physical Chemistry – A molecular Approach, Viva Books Pvt. Ltd, 1997.
5. K. J. Laidler and J. M. Meiser, Physical Chemistry 3rd Edition, Houghton Mifflin Comp., New York, International Edition, 1999.
6. K. K. Sharma, L R Sharma, A textbook of Physical Chemistry, 6thEdn., Vikas Publishing house, 2016.
7. I. N. Levine, Physical Chemistry, 6th Edn. Tata Mc Graw Hill, 2011.
8. G. Raj, Photochemistry, 6th Edn, Goel Publishing House, 2014.
9. K.K. Rohatgi and K.K. Mukherjee, Fundamentals of Photochemistry, 4thEdn., New Age International (P) Ltd, 2021.
10. V. Ramakrishnan and M. S. Gopinathan, Group Theory in chemistry, Vishal Publication, 1986.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	3	1	2	1	1
2	3	1	2	1	1
3	3	1	2	1	1
4	3	1	3	2	2

Semester: V **Course Type: Practical** **Course Code: CHE1055**
Credit: 2 **Course Title: Inorganic Chemistry Laboratory-II**

Course Outcomes		Level
CO-1	Estimate inorganic compounds from a mixture	**Apply**
CO-2	Value volumetric and gravimetric procedures	**Evaluate**
CO-3	Apply UV-Vis spectroscopy to estimate concentration of an ion in given solution	**Apply**
CO-4	Handle spectrophotometric tools and analytical materials of specific interest	**Skill**
CO-5	Application of Job's method to analyze the complexes	**Analyze**

1. Estimation of inorganic compounds in a mixture by Volumetric and Gravimetric analysis.
   A mixture of solutions should be given for estimation (Any three mixtures)
   (i) Cu (V) and Ni (G)
   (ii) Fe (V) and Zn (G)
   (iii) Fe (V) and Ni (G)
   (iv) Zn (V) and Cu (G)

2. Validation of Beer-Lambert's law by estimating unknown concentration of $KMnO_4$/$CuSO_4$ by spectrophotometry.

3. Determine the composition of the Fe^{3+}-salicylic acid complex solution by Job's method.

Reference Books

1. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
2. Mendham, J. Vogel's Quantitative Chemical Analysis, Pearson, 2009.
3. In-house manual prepared by Department of Chemistry, CUTN, Thiruvarur.
4. M. Ghoshal and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.
5. V. Venkateswaran, R. Veerasamy and A. R. Kulandaivelu, Basic principles of Practical Chemistry, 2nd edition, New Delhi, Sultan Chand & sons, 1997.
6. M. Hein, J. N. Peisen and R. L.Miner, Foundations of College Chemistry in the Laboratory, John Wiley and Sons, 2011.
7. AmitaDua, Navneet Manav, Practical Inorganic Chemistry, Manakin Press, New Delhi, 2017.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	2	2	1	3
2	1	2	1	1	3
3	2	3	3	1	3
4	2	3	2	1	3
5	2	2	3	3	2

Semester: V **Course Type: Practical** **Course Code: CHE1056**
Credit: 2 **Course Title: Organic Chemistry Laboratory-II**

Course Outcomes		Level
CO-1	Develop various analytical skills and techniques necessary for the analysis of biological molecules.	**Analyze**
CO-2	Discuss purification of organic compounds by the Column chromatography	**Apply**
CO-3	Appraise and utilize the analytical knowledge to understand various biological processes	**Analyze**
CO-3	Perform synthesis and characterization of the organic compounds	**Analyze**
CO-4	Explain the mechanism of chemical reactions involved in the preparations of organic compounds	**Evaluate**

Qualitative analysis by separation techniques
Thin Layer Chromatography, Column chromatography, Paper Chromatography
Demonstration of flash column chromatography instrumentation
Tests for carbohydrates and amino acids.

Preparation, purification of organic compounds and discussions on mechanisms
Benzoylation of amine/phenols
Acetylation of amine/phenols
Preparation of *p*-bromoacetanilide from acetanilide
Preparation of *p*-nitroacetanilide from acetanilide
Preparation of picric acid from phenol
Preparation of aromatic acid from an ester/amide

Reference Books

1. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Textbook of Practical Organic Chemistry, Prentice-Hall, 5th Ed, 1996.
2. F. G. Mann, B. C. Saunders, Practical Organic Chemistry, 4th Ed, Pearson Education India, 2009.
3. B. Haynes, Qualitative Organic Analysis, Pearson Education, 2011.
4. P. B. Cranwell, L. M. Harwood, C. J. Moody, Experimental Organic Chemistry, 3rd Ed,
5. Wiley-Blackwell, 2017.V. K. Ahluwalia, R. Aggarwal, Comprehensive Practical Organic Chemistry, Universities Press, 2004.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	3	3	3
2	2	3	3	3	3
3	2	3	3	3	3
4	2	3	3	3	3
5	2	3	3	3	3

Semester: V **Course Type: Practical** **Course Code: CHE1057**
Credit: 2 **Course Title: Physical Chemistry Laboratory-II**

Course Outcomes		Level
CO-1	Well verse with the basic laboratory instruments	**Analyze**
CO-2	Present the experimental data in a scientific manner	**Evaluate**
CO-3	Apply fundamental concepts and evaluate physical parameters of solutions	**Apply**
CO-4	Correlate physical parameters with the chemical properties of analyte	**Remember**

Surface tension measurement

(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.

Viscosity measurement

(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.

Chemical Kinetics

(a) Initial rate method: Iodide-persulphate reaction

(b) Integrated rate method:

(i) Acid hydrolysis of methyl acetate with hydrochloric acid.

(ii) Saponification of ethyl acetate.

(iii) Compare the strengths of HCl and H_2SO_4 by studying kinetics of hydrolysis of methyl acetate.

Phase equilibria

(a) Study of the variation of mutual solubility temperature with concentration for the phenol water system and determination of the critical solubility temperature.

Potentiometry: Potassium dichromate vs Mohr's salt

Conductance

(a) Determination of cell constant

(b) Determination of equivalent conductance, degree of dissociation and dissociation constant of a weak acid.

Reference Books

1. J.B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, **2001.**
2. G.W. Garland, J.W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8th Edn. McGraw Hill, **2009.**
3. B. Viswanathan, Practical Physical chemistry, Viva Pub., **2005.**
4. A.M. James, F.E. Prichard, Practical Physical Chemistry Paperback, **1974.**
5. A. Dau, Practical Physical Chemistry, Manakin press, **2017.**

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	2	2	3
2	2	3	2	2	3
3	2	2	3	2	3
4	2	3	3	2	3

Semester: VI **Course Type: Theory** **Course Code: CHE1061**
Credit: 4 **Course Title: Inorganic Chemistry-III**

Course Outcomes		Level
CO-1	Obtain basic knowledge in the transition and inner transition elements	**Remember**
CO-2	Understand about the various basic concepts of coordination complexes	**Understand**
CO-3	Know the reaction mechanisms in coordination complexes	**Remember**
CO-4	Get the basics in organometallic chemistry and its applications in catalysis	**Remember**
CO-5	Understand the principles in bioinorganic chemistry and its role in biology	**Understand**

UNIT-I d- and f- Block Elements

d-block elements - Electronic configuration - General periodic trend –Atomic and ionic radii, metallic character, melting and boiling points, ionization energy, oxidation state, reactivity, colour and tendency to form complexes- Group study of first row transition metals - Interstitial compounds - nitrides, carbides, hydrides, borides of Ti, V, Cr, W and their industrial uses. Toxicity of Cd and Hg.

f-block elements - Comparative account of lanthanides and actinides - Occurrence, Oxidation states, Magnetic properties, Colour and spectra - Lanthanides and Actinides Separation by ion-Exchange and Solvent extraction methods - Lanthanide contraction-Chemistry of thorium and Uranium-Occurrence, Ores, properties and uses - Preparation, Properties and uses of ceric ammonium sulphate, thorium dioxide and uranyl acetate.

UNIT-II Coordination Chemistry I

Types of ligands, IUPAC Nomenclature, Isomerism - Ionisation, hydrate, linkage, ligand and coordination isomerism. Stereoisomerism-geometrical and optical isomerism in 4 & 6 coordinated complexes. Theories of coordination compounds – Werner's and Sidgwick's EAN concept, Valence Bond theory – hybridisation, geometry and magnetic properties of $[Ni(CN)_4]^{2-}$, $[NiCl_4]^{2-}$, $[Fe(CN)_6]^{4-}$, $[Co(NH_3)_6]^{3+}$ and $[CoF_6]^{3-}$, Crystal field theory – spectrochemical series, splitting of 'd' metal orbitals in octahedral and tetrahedral complexes, low spin & high spin complexes. Jahn – Teller distortion (an elementary idea) - square planar complexes - Explanation of colour and magnetic properties using CFT, comparison of VBT and CFT.

UNIT-III Coordination Chemistry II

Ligand field theory (An elementary treatment) - Molecular orbital theory: Molecular orbital diagram for $[Co(NH_3)_6]^{3+}$. Labile and inert complexes, stability of coordination compounds – thermodynamic and kinetic stability, relationship between stepwise formation constant and overall formation constant, factors affecting the stability of complexes. Unimolecular and biomolecular nucleophilic substitution reactions in octahedral and square planar complexes, trans effect – theories of trans effect and applications.

UNIT-IV: Basic Bioinorganic Chemistry

A brief introduction to bioinorganic chemistry - occurrence and availability of inorganic elements in biological systems – enzyme, cofactor, coenzyme, prosthetic group, holoenzyme,

and apoenzyme - chemistry of hemoglobin and myoglobin – Role of: Na^+ and K^+ ions – Mg^{2+} and Ca^{2+} ions – metal ion transport systems. Biological functions and toxicity of trace elements: Cr, Mn, Co, Ni and Cu – ultra trace elements: As, Se, Mo, I, Fe and Zn – Biological fixation of nitrogen – enzymes containing essential inorganic elements as cofactors and photosynthesis.

UNIT-V Basic Organometallic Chemistry

Origin of organometallic compounds - Introduction - Nomenclature of organometallic compounds- Classification of ligands- 18- electron rule - structures and bonding - metal carbonyls- mono and polynuclear carbonyls of Ni, Fe, Cr, Co and Mn - bridging and terminal carbonyls -synthesis and structure -nitrosyl compounds. Transition metal alkyls, carbenes, carbynes, and metallocenes. Catalysis and industrial applications -Wilkinson's catalyst, hydrogenation, hydroformylation, Monsanto acetic acid process, Ziegler - Natta catalyst and polymerization of olefins.

Reference Books

1. J. E. Huheey, E. A. Keiter, R. L. Keiter, and O. K. Medhi, Inorganic Chemistry - Principles of Structure and Reactivity, 4th edition, Pearson Education, 2006.
2. P. Atkins, T. Overton, J. Rourke, M. Weller and F. Armstrong, Inorganic Chemistry, 5thedition, Oxford University Press, 2010.
3. J. D. Lee, Concise Inorganic Chemistry, 5th edition, Wiley, 2016.
4. S. J. Lippard, J. M. Berg, Principles of Bioinorganic Chemistry, Panima Publishing Company, New Delhi, 1997.
5. W. Kaim and B. Schewederski, Bioinorganic Chemistry: Inorganic Elements in the Chemistry of Life, John Wiley & Sons, New York, USA, 2013.
6. Didier Astruc, Organometallic Chemistry and Catalysis, Springer, 2007.
7. B. D. Gupta and A.J. Elias, Basic Organometallic Chemistry: Concepts, Syntheses, and Applications of Transition Metals, 1st edition, Universities Press, CRC Press, 2010.
8. R. H. Crabtree, Organometallic Chemistry of Transition Metals, Wiley, New York, 1988.
9. C. E. Housecraft and A.G. Sharpe, Inorganic Chemistry, 4thedition, Pearson, 2012.
10. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3rd edition, Pearson, 2004.
11. G. Chatwal, M.S.Yadu, Coordination Chemistry, 1st Ed, Himalaya Publishing House, 1992.
12. M. C. Day Jr, J. Selbin, Theoretical Inorganic Chemistry, Literary Licensing, LLC, 2012.
13. F. A. Cotton, G. Wilkinson, C. A. Murillo and M. Bochmann, Advanced Inorganic Chemistry, 6th edition, John Wiley & Sons, 2008.
14. B. Douglas, D. McDaniel and J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd edition, John Wiley & Sons, 2010.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	3	3
2	1	1	1	3	3
3	3	2	3	3	3
4	2	1	2	2	3
5	2	2	2	3	2

Semester: VI **Course Type: Theory** **Course Code: CHE1062**
Credit: 4 **Course Title: Organic Chemistry-III**

Course Outcomes		Level
CO-1	Target synthesis of various molecules by various types of rearrangements	**Understand**
CO-2	Learn the basic biological concepts of biomolecules and natural products	**Remember**
CO-3	Articulate the functions of proteins and nucleic acids	**Understand**
CO-4	Construct the structure of new alkaloids and terpenoids from different methods	**Apply**
CO-5	Elucidate the structure determination of biomolecules and natural products	**Evaluate**

Unit-I Molecular rearrangements
Introduction, Classification – electrophilic, nucleophilic and free radical rearrangements, Rearrangements to electron deficient carbon - Pinacol-pinacolone, Wagner–Meerwin, Tiffenev-Demjanov, Benzil–Benzilic Acid, Rearrangements to electron deficient nitrogen - Hofmann, Schmidt, Lossen, Curtius, Beckmann, Rearrangements to electron deficient oxygen - Baeyer–Villiger. Wittig, Stevens and Fries rearrangement and Baker-Venkatraman rearrangement.

Unit-II 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, anomerisation, epimerization, ascending and descending in monosaccharides. Structure of disaccharides (sucrose, cellobiose, maltose, lactose) and polysaccharides (starch and cellulose)

Unit-III Amino acids, Proteins and Nucleic acids
Amino acids: Preparation - Strecker synthesis, Gabriel's phthalimide synthesis. Zwitterion & Isoelectric point, Electrophoresis. Reactions: ester of –COOH group, acetylation of $–NH_2$ group, complexation.
Proteins: Primary, Secondary, Tertiary and Quaternary Structure of proteins, Edman Degradation, Sanger's reagent and thiohydantoin method. Peptide linkages – Synthesis of simple dipeptides
Nucleic acids: Introduction, purine and pyrimidine bases, structure of nucleosides, nucleotides and polynucleotides, RNA and DNA (an elementary idea about their structure) RNA -types and functions, genetic code.

Unit-IV Alkaloids and Terpenoids
Alkaloids: Occurrence, importance, classification, Isolation, General methods of determining structures including Hoffmann's exhaustive methylation, Synthesis of coniine, nicotine, quinine andpiperine
Terpenoids: Occurrence, importance, classification, Isolation, Isoprene rule, Synthesis of citral, geraniol, α-terpineol, limonene, menthol and camphor

Unit-V Vitamins and Pigments

Vitamins: Classification, properties, physiological functions, structural elucidation and synthesis of vitamins A (Retinol). Structural features of B1, B2 (Riboflavin), B6, B12, vitamin C (Ascorbic acid) (synthesis not required).

Natural pigments: Occurrence, extraction, classification, chemical characterization and functions of anthocyanins, flavonoids, flavones, flavonols, xanthophylls and porphyrins. Chemistry and structure of cyanins, quercetin. Structure of porphyrin skeleton, haemin and chlorophyll.

Reference books

1. Jie Jack Li, Name Reactions: A Collection of Detailed Mechanisms and Synthetic Applications, 5th Ed, Springer, 2014
2. Christian M. Rojas, Molecular Rearrangements in Organic Synthesis, John Wiley & Sons, Inc, 2015
3. I. L. Finar, Organic Chemistry, Vol II, 6th Ed, Pearson Education, 2002.
4. G.P. Talwar, L.M. Srivatsava and K.D. Moudgil, Textbook of Biochemistry and Human Biology, Prentice-Hall of India Limited, New Delhi 2003
5. J.L. Jain, Biochemistry, S. Chand and Sons, New Delhi 2004.
6. M.K. Jain, S.C. Sharma, Modern Organic Chemistry, Vishal publishing Co. 2014, 4th Ed.
7. A. Lehninger, D. L. Nelson, M. Cox and M. M. Cox, Principles of Biochemistry, MPS Publishers, New York, 2009.
8. A.V.S.S. Rama Rao, Text Book of Biochemistry, U B S Publishers, 2008, 9th Ed.
9. Gurdeep R. Chatwal, Chemistry of Natural products, Himalaya publishing House Pvt. Ltd, Mumbai, 2018, Vol I & II.
10. O.P. Agarwal, Chemistry of Natural products, Goel publishing Co, New Delhi 2001, Vol I & II.
11. U. Satyanarayana and U. Chakrapani, Biochemistry, Elsevier, 2019, 5th Ed.
12. Christian M. Rojas, Molecular Rearrangements in Organic Synthesis, John Wiley & Sons, Inc, 2015
13. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	3	3	1
2	2	1	3	3	1
3	2	1	3	3	1
4	2	1	3	3	1
5	2	1	3	3	1

Semester: VI **Course Type: Theory** **Course Code: CHE1063**
Credit: 4 **Course Title: Physical Chemistry-III**

Course Outcomes		Level
CO-1	Analyze the physical significance of wave function, its application in molecular modeling and fundamentals in spectroscopy	**Analyze**
CO-2	Evaluate the molecular physical phenomena as a function of spectral parameters	**Evaluate**
CO-3	Apply various operators used in quantum mechanics	**Apply**
CO-4	Emphasis different theoretical aspects of spectroscopic techniques	**Understand**

Unit-I Quantum Chemistry-I

The success of quantum theory and failure of the classical mechanics-experimental foundation of quantum mechanics-black body radiation-photoelectric effect and Compton effect. Formulation of quantum mechanics-the wave nature of sub-atomic particles-wave particle dualism-Heisenberg's uncertainty principle- postulates of quantum mechanics, operators - orthogonality and normalization theorem, Schrodinger wave equation derivation (Time dependent), eigen values and eigen functions, the significance of wave function,

Unit-II Application of Schrodinger Equation

Particle-in-a-box (1D, 2D and 3D boxes), Quantum Mechanical tunneling, Simple harmonic oscillator, Particle in a ring. Rigid rotator - model of rotation of diatomic molecule. Schrödinger equation, transformation to spherical polar coordinates. Separation of variables. Spherical harmonics. Discussion of solution. Qualitative treatment of hydrogen atom and hydrogen-like ions: setting up of Schrödinger equation in spherical polar coordinates, radial part, and quantization of energy (only final energy expression). Average and most probable distances of electron from nucleus.

Unit-III Optical Spectroscopy-I

Interaction of electromagnetic radiation with molecules and various types of spectra.
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. Fingerprint region, Fermi resonance.

Unit-IV Optical Spectroscopy-II

Raman spectroscopy: Qualitative treatment of Rotational Raman effect; Effect of nuclear spin, Vibrational Raman spectra, Stokes and anti-Stokes lines; their intensity difference, rule of mutual exclusion.
Electronic spectroscopy: Franck-Condon principle, electronic transitions, singlet and triplet states, fluorescence and phosphorescence, dissociation and predissociation, calculation of electronic transitions of polyenes using free electron model.
Mossbauer spectroscopy- basic principle-isomer shift, quadrupole splitting, magnetic field effect.

Unit-V NMR & ESR Spectroscopy

Nuclear Magnetic Resonance (NMR) spectroscopy: Nuclear magnetic spectroscopy-nuclear spin-nuclear relaxation-magnetic shielding and chemical shift, deshielding, spin-spin interactions (eg. Ethanol), Larmor precession. Introduction to ^{13}C NMR.

Electron Spin Resonance (ESR) spectroscopy: Its principle, hyperfine structure, ESR of simple radicals. Electron spin resonance spectroscopy-basic principles, hyperfine splitting, zero field splitting and Kramer's degeneracy, factors affecting 'g' value.

Reference Books

1. R.K. Prasad, Quantum Chemistry, New Age International, 2001.
2. J. P. Lowe and K. Peterson, Quantum Chemistry,3rd Ed., Academic Press, 2006.
3. Mc Quarrie, J. D. Simon, Physical Chemistry – A molecular Approach, Viva Books1997.
4. I.N. Levine, Physical Chemistry, 7th Ed., Tata McGraw Hill, 2016.
5. G. Raj, Advanced Physical Chemistry, Goel Publishing House, 2002.
6. C. N. Banwell, & E. M. Mc Cash, Fundamentals of Molecular Spectroscopy, 4th Ed. Tata McGraw-Hill, New Delhi,2006.
7. M.C handa, Atomic structure and Chemical bonding in Molecular Spectroscopy, Tata McGraw Hill1972.
8. D. L. Pavia, G. M. Lampman, G. S. Kriz, Introduction to spectroscopy, 3rd edn, Thomson Brooks/Cole, 2001.
9. D. N. Satyanarayana, Electronic absorption spectroscopy and related techniques, Universities Press 2001.
10. D. N. Sathyanarayana, Introduction to Magnetic Resonance Spectroscopy ESR, NMR, NQR, IK International, 2009.
11. A. Dau and C. Singh, Quantum chemistry classical to computational, Manakin press, 2017.
12. B.R. Puri, L.R. Sharma and M.S. Pathania, Principles of Physical Chemistry, 48thEdn. Vishal Publishing Co, 2019.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	3	3	1
2	2	1	3	3	1
3	2	1	2	3	1
4	2	2	3	3	1

Semester: VI **Course Type: Practical** **Course Code: CHE1064**
Credit: 2 **Course Title: Inorganic Chemistry Laboratory III**

Course Outcomes		Level
CO-1	Understand the important aspects of inorganic complex preparations	**Understand**
CO-2	Characterization of inorganic complexes using UV-Visible absorption spectroscopy	**Apply**
CO-3	Correlation of theoretical and experimental aspects of CFSE	**Apply**
CO-4	Synthesis and characterization skills of inorganic compounds	**Skill**
CO-5	Utilization of UV-Vis absorption spectroscopy technique for studying the pH dependence of a reaction	**Skill**

Inorganic Preparations (Any six preparations)

1. Tetramminecopper(II) sulphate.
2. Potassium trioxalatoaluminate (III).
3. Tristhioureacopper(I) chloride.
4. Trisacetylacetanatoiron(III)
5. Prussian blue
6. Mohr salt
7. Silver metal nanoparticles

Spectrophotometric determinations (Any two experiments)

Determination of λ_{max} and CFSE for tetramminecopper(II) sulphate.
Determination of λ_{max} of potassium trioxalatoaluminate(III).
Study pH dependence of UV-Visible spectrum of potassium dichromate.

Reference Books

1. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
2. J. Mendham, Vogel's Quantitative Chemical Analysis, Pearson, 2009.
3. Ghoshal, Mahapatra and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.
4. V. Venkateswaran, R. Veerasamy, A. R Kulandaivelu, Basic principles of Practical Chemistry, 2nd edition, New Delhi, Sultan Chand & sons, 2016.
5. AmitaDua, Navneet Manav, Practical Inorganic Chemistry, Manakin Press, New Delhi, 2017.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	2	1	2	2
2	1	2	2	1	2
3	2	2	3	3	3
4	2	2	2	2	3
5	3	2	2	2	3

Semester: VI **Course Type: Practical** **Course Code: CHE1065**
Credit: 2 **Course Title: Organic Chemistry Laboratory-III**

Course Outcomes		Level
CO-1	Acquire the knowledge of different mechanisms in chemical and photochemical reactions	**Understand**
CO-2	Organize organic preparations based on the various one or two step reactions	**Analyze**
CO-3	Predict synthetic aspects of organic reactions involving the rearrangement and photochemical reactions.	**Evaluate**
CO-4	Discuss isolation of natural products by the various isolation methods	**Understand**
CO-5	Test the characterization of different natural products by using various analytical and spectroscopic-methods	**Evaluate**

Preparations: Two-step preparations (any three) involving acetylation, methylation, condensation, rearrangements and photochemical reactions.

Isolation and characterization of natural products:
(a) Isolation of caffeine from tea dust (b) Isolation of casein from milk
(c) Isolation of piperine from pepper (d) Isolation of lycopene from tomato

Reference Books

1. I. Vogel, A. R. Tatchell, B. S. Furnis, A. J. Hannaford, P. W. G. Smith, Textbook of Practical Organic Chemistry, Prentice-Hall, 5th Ed, 1996.
2. F. G. Mann, B. C. Saunders, Practical Organic Chemistry, 4th Ed, Pearson Education India, 2009.
3. B. Haynes, Qualitative Organic Analysis, Pearson Education, 2011.
4. P. B. Cranwell, L. M. Harwood, C. J. Moody, Experimental Organic Chemistry, 3rd Ed, Wiley-Blackwell, 2017.
5. V. K. Ahluwalia, R. Aggarwal, Comprehensive Practical Organic Chemistry, Universities Press, 2004.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	3	3	3
2	2	3	3	3	3
3	2	3	3	3	3
4	2	3	3	3	3
5	2	3	3	3	3

Semester: VI **Course Type: Practical** **Course Code: CHE1066**
Credit: 2 **Course Title: Physical Chemistry Laboratory III**

Course Outcomes		Level
CO-1	Recognize various QM software and spectroscopic (UV-VIS) methods	**Understand**
CO-2	Perform geometry optimization and spectroscopic experiments	**Analyze**
CO-3	Predict the energy gap, dipole moments and stability of organic molecules	**Apply**
CO-4	Evaluate and study the energy, concentration, structures and kinetics using various spectroscopic methods	**Evaluate**

Quantum Mechanics:

1. Optimization of Geometry and single point energy calculations of various organic molecules
2. Calculation of the energy gap between HOMO and LUMO in simple molecules and visualization of molecular orbitals.
3. Calculation of dipole moment in polar organic molecules.
4. Prediction of the stability of ortho, meta, para products of nitration of aromatic ring using DFT methods.
5. Calculation of IR stretching frequencies of groups and visualization of normal modes of vibration in organic molecules.

Spectroscopy:

1. Verify Additivity Principle: Determine the concentrations of $KMnO_4$ and $K_2Cr_2O_7$ in a mixture.
2. Study the pH-dependence of the UV-VIS spectrum (200-500 nm) of $K_2Cr_2O_7$.
3. Record the 200-350 nm UV spectra of the given compounds (acetone, acetaldehyde, 2-propanol, acetic acid) in water. Comment on the effect of structure on the UV spectra of organic compounds.
4. Verify Lambert-Beer's law and determine the concentration of $CuSO_4$/$KMnO_4$/ $K_2Cr_2O_7$ in a solution of unknown concentration
5. Study the kinetics of iodination of propanone in acidic medium.
6. Determine the amount of iron present in a sample using 1,10-phenanthroline.
7. Determine the dissociation constant of an indicator (phenolphthalein).
8. Study the kinetics of interaction of crystal violet/ phenolphthalein with sodium hydroxide.
9. Analyze the given vibration-rotation spectrum of HCl(g)

Reference Books

1. J. Foresman & A. Frisch, Exploring Chemistry with Electronic Structure Methods, Gaussian Inc., 2000.
2. D.C. Young, Computational Chemistry, A Practical Guide for Applying Techniques to Real World Problems, John Wiley & Sons, 2001.
3. D. Rogers, Computational Chemistry Using the PC, 3rd Edition, John Wiley & Sons, 2003.
4. A. Leach, Molecular Modelling, Principles and Applications, 2nd Edn, Longman, 2001.
5. J. M. Haile, Molecular Dynamics Simulation: Elementary Methods 2001.
6. J.B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2001.
7. B. Viswanathan and P.S. Raghavan, Practical Physical Chemistry Viva Books Pvt. Ltd., New Delhi, 2008.

8. G.W. Garland, J.W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8thEdn. McGraw Hill, 2009.
9. S. Kumar and N. Kumar, Physical Chemistry Practical, New Central Book Agency, 2012.
10. A. Dau, Practical Physical Chemistry, Manakin press, 2017.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	3	2	3	3
2	1	3	2	3	3
3	1	3	2	3	3
4	1	3	2	3	3

Semester: VII **Course Type: Theory** **Course Code: CHE1071**
Credit: 4 **Course Title: Inorganic Chemistry-IV**

Course Outcomes		Level
CO-1	Gain knowledge in solid state chemistry and its applications	**Knowledge**
CO-2	Understand the chemistry of main group elements - rings, chains and clusters	**Understand**
CO-3	Apply the theories of coordination chemistry to understand the metal-ligand bonding	**Apply**
CO-4	Analyze the stability of complexes in solution	**Analyze**
CO-5	Understand reaction mechanisms in inorganic complexes	**Understand**

Unit-I Synthesis and Reactions of Inorganic Solids

Introduction – Crystalline and amorphous solids, crystal systems, Close packing of atoms and ions HCP and FCC, packing efficiency, types of packing voids, unit cell, density and radius ratio calculations. Structures of ionic crystals – AX and AX_2 type crystal structures (NaCl, CsCl, ZnS, fluorite, antifluorite, TiO_2, SiO_2, CaC_2 etc. including unit cell calculation) – Spinel, perovskite and layer structures. Lattice energy - Born-Lande equation and its derivations and applications, Born-Mayer and Kapustinskii equations –. Stoichiometric and non-stoichiometric defects. Band theory, n- and p- type semiconductors and superconductors. Solid state synthesis and reactions in solid state - Introduction – law of diffusion, diffusion mechanisms, thermal decomposition of solids -Type I and Type II reactions. Different types of solid-state synthetic methods.

Unit-II The Chemistry of the Main Group Elements

Inorganic Rings, chains, and cages- Catenation and Heterocatenation, Heterocyclic ring system- Borazines, Phosphazines- Monomer and Polymer, S-N ring compounds, Homocyclic rings of P, S and Se. Silicate minerals and its classification based on structure. Boranes: Polyhedral skeletal electron pair theory, styx number - boron cage compounds-closo, nido, arachno, carboranes; cage compounds of S and P. Metal cluster: metal-metal bonding and reactivity of di-, tri- and polynuclear clusters, Metal cluster and metal carbonyl structure based on PSEPR theory.

Unit-III Theories and studies of coordination compounds

Crystal field theory – Splitting of d orbitals under various geometries - factors affecting splitting, CFSE, evidences for CFSE (Structural and thermodynamic effects), spectrochemical series, Jorgensen relation, site preferences, Jahn Teller distortion – Dynamic and Static effects. Application of CFT – Magnetic properties, spectral properties and Kinetic properties, Limitations of CFT, Ligand field Theory - nephelauxetic effect - MO theory – sigma – and pi-bonding in complexes and evidences for π-bonding – angular overlap model.

Unit-IV Studies of Coordination Compounds in Solution

Detection of complex formation in solution – Stability constants – stepwise and overall formation constants – simple methods (Potentiometric, pH metric and photometric methods) of determining the formation constants - factors affecting stability – Irving-William series - statistical and chelate effects – forced configurations.

Unit-V Reaction mechanisms in coordination chemistry

Labile and inert complexes -Types of ligand substitution reactions: Dissociative mechanism (D), Associative mechanism (A) interchange mechanism (I) - acid hydrolysis,

factors affecting acid hydrolysis, base hydrolysis, conjugate base mechanism (S_N1-CB), evidences of conjugate mechanism, anation reaction - reactions without metal ligand bond cleavage. Substitution reactions in square planar complexes- mechanism, trans effect-theories and applications, Interconversion between stereoisomers; Redox reactions Redox Reactions-Electron transfer reactions (complementary and non-complementary types, inner sphere and outer sphere processes), Marcus-Hush Theory.

Reference Books

1. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K.Medhi, Inorganic Chemistry - Principles of Structure and Reactivity, 4th edition, Pearson Education, 2006.
2. P. W. Atkins and, J. Paula, Physical Chemistry, Oxford Publications, 8thedition, 2009.
3. B. Douglas, D. McDaniel and J. Alexander, Concepts and Models of Inorganic Chemistry, 3rd edition, John Wiley & Sons, 2010.
4. F. A. Cotton and G. Wilkinson, Advanced Inorganic Chemistry, 3rd ed. Wiley-Eastern Company, New Delhi, 1990.
5. L.V. Azaroff, Introduction to Solids, McGraw hill, New York. 1960.
6. A. R. West, Solid State Chemistry and Its Applications, John Wiley & Sons, 1984.
7. K. Chakrabarty, Solid State Chemistry, New Age Publishers, 1996.
8. H. V. Keer, Principles of the Solid State, Wiley Eastern Limited, 1993.
9. D.M. Adams, Inorganic Solids: An Introduction to Concepts in Solid State Structural Chemistry, Wiley, 1974.
10. C.N.R. Rao and K.J. Rao, Phase Transitions in Solids, McGraw Hill, 2010.
11. M. C. Day, J. Selbin, Theoretical Inorganic Chemistry, East West Press. 2nd Ed, 1985.
12. S. F. A. Kettle, Physical Inorganic Chemistry – A Coordination Chemistry Approach, Spectrum Academic Publishers, Oxford University Press, 1996.
13. G. L. Miessler and D. A. Tarr, Inorganic Chemistry, 3rd edition, Pearson, 2004.
14. C. E. Housecraft and A.G. Sharpe, Inorganic Chemistry, 4th edition, Pearson, 2012.
15. K. F. Purcelland, J. C. Kotz, Inorganic Chemistry, Cengage Learning, 2012.
16. M. C. Day Jr., J. Selbin, Theoretical Inorganic Chemistry, Literary Licensing, LC, 2012.
17. G. Wilkinson, R. D. Gillars and J. A. McCleverty, Comprehensive Co-ordination Chemistry, Pergamon Press, 1987.
18. G. Wulfberg, Inorganic Chemistry, University Science Books, 2000.
19. D.M. Adam, Inorganic Solids: An introduction to concepts in solid-state structural chemistry, John Wiley & Sons, 1974.
20. G.E. Rodger, Inorganic and Solid State Chemistry, Cengage Learning India, Edition, 2002.

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	1	2	2	2	3
2	2	1	3	3	3
3	2	2	3	3	3
4	2	1	2	3	3
5	3	2	1	2	3

Semester: VII **Course Type: Theory** **Course Code: CHE1072**
Credit: 4 **Course Title: Organic Chemistry-IV**

Course Outcomes		Level
CO-1	Relate thermodynamic stability and reaction rates	**Understand**
CO-2	Predict the aromaticity of organic compounds based on applying various rules	**Apply**
CO-3	Demonstrate the detailed mechanism of nucleophilic and electrophilic substitution reactions	**Understand**
CO-4	Sketch the importance of stereochemistry to predict the reactivity based on various stereochemical factors	**Apply**
CO-5	Learn the preparation and properties of various heterocyclic compounds including fused ring compounds	**Remember**

Unit-I Physical Organic Chemistry

Thermodynamic stability – general relationship between thermodynamic stability and reaction rates – electronic substituent effects on reaction intermediates – Principles of microscopic reversibility –substituent effects – solvent effects – methods of determination of reaction mechanism - kinetic methods – primary and secondary kinetic isotopic effect – non kinetic methods – isotope labeling, crossover experiment, trapping of intermediates, stereochemical studies. Linear free energy relationships: Curtin-Hammett, Hammett plot, steric and polar effects – Taft parameters. Solvent effects-Grunwald-Weinstein plots.

Unit-II Aromaticity

Criteria for aromaticity – Huckel's theory of aromaticity- energy, structural and electronic criteria for aromaticity – relationship among them. Craig's rule – non-benzenoid aromatic compounds. Aromatic, antiaromatic and homoaromatic compounds. Five-, six-, seven- and eight-membered rings and other systems. Aromaticity in annulenes, polycyclic compounds, charged rings - aromatic cations and anions, fused rings. Heteroaromatic systems. Aromaticity in sydnones and fullerenes

Unit-III Nucleophilic Substitution

Aliphatic nucleophilic substitution: S_N1, S_N2, borderline, S_Ni mechanisms and their Stereochemical aspects. Factors affecting the rates of S_N1, S_N2 and S_Ni and neighbouring group participation. Mechanisms of Rearrangement of Carbocations, Non-classical Carbocations. Substitution vs elimination reaction.

Aromatic electrophilic and nucleophilic substitutions: Mechanism, factors influencing ipso substitution and directive effect.

Unit-IV Stereochemistry

Configuration, conformation of cycloalkanes: four, five and six-membered rings, Conformational analysis of substituted cyclohexanes. conformation and reactivity. Conformation of fused and bridged ring systems-decalin, norbornane. anomeric effect. Stereochemistry of molecules with N, S, P chiral centers, allenes, spiranes, biphenyls, molecules with chiral planes, helical chirality. Topicity, prostereoisomerism. stereoselective and stereospecific reactions, enantioselective reactions, determination of enantiomeric and diastereomeric excess, double stereo-differentiation, Introduction to asymmetric synthesis – substrate chirality, chiral auxiliaries, chiral reagents and chiral catalysts. Resolution – optical and kinetic. chemo-, regio - and stereo-selective transformations, Sharpless asymmetric epoxidation.

Unit-V Heterocyclic Compounds-II

Preparation, properties and reactions of pyrrole, furan, thiophene and pyridine. Preparation, properties and reactions of imidazole, pyrazole, oxazole, isoxazole, thiazole, isothiozole, pyrimidine, pyrazine, pyridazine. Preparation, properties and reactions of triazole and triazine. Fused or condensed heterocyclic compounds: Preparation, properties and reactions of indole, quinoline, isoquinoline, carbozole.

Reference Books:

1. E. V. Anslyn, D.A. Dougherty, Modern Physical Organic Chemistry, University Sci,2004
2. Raj K. Bansal, Heterocyclic Chemistry, 4th Ed., Anshan Limited, 2008.
3. Alan R. Katritzky, Christopher A. Ramsden, John A. Joule, Viktor V. Zhdankin Handbook of Heterocyclic Chemistry, Elsevier Publication, 2010.
4. I. L. Finar, Organic Chemistry, Vol II, 6th Ed, Pearson Education, 2002.
5. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
6. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford University Press, 2014.
7. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
8. Graham Solomons, T. W. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
9. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
10. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
11. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
12. Francis A. Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, 5th Ed. 2007
13. Daniel E. Levy, Arrow Pushing in Organic Chemistry-An easy approach to understanding reaction mechanisms, Wiley Publications, 2008
14. Robert B. Grossman, The Art of Writing Reasonable Organic Reaction Mechanisms, 2nd Ed, Springer, 2003
15. L. G. Wade, Organic Chemistry, 6th Ed. Pearson, 2006
16. Francis A. Carey, Robert M. Giuliano, Organic Chemistry, 8th Ed. 2008
17. Peter Vollhardt, Neil Schore, Organic Chemistry-Structure and Function, 6th Ed. W. H. Freeman and Company, 2011

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	3	3	2
2	2	1	3	3	2
3	2	1	3	3	1
4	2	1	3	3	1
5	2	1	2	3	1

Semester: VII **Course Type: Theory** **Course Code: CHE1073**
Credit: 4 **Course Title: Physical Chemistry-IV**

Course Outcomes		Level
CO-1	Know the basic concepts involved in chemical kinetics *i.e.* reaction rate, order and different types of reactions	**Knowledge**
CO-2	Understand the rate theory and to derive equations involved in heterogeneous catalysis and enzyme catalysis	**Understand**
CO-3	Analysis the kinetics of fast chemical reactions by different methods	**Analyze**
CO-4	Identify the point group of molecules and apply the concept of group theory to predict the spectroscopic properties	**Apply**

Unit-I Chemical Kinetics and Rate theories

Introduction- Reaction rates and order and molecularity of reaction, Determination of order – differential method and integration method. Theories of reaction Rates-Collision theory, Statistical mechanics, inclusion of steric factor and Conventional Transition State theory (CTST). Determination of rate constants with various methods in CTST, Comparison of collision theory with CTST, Arrhenius equation- characteristics, Significance of energy of activation, Temperature coefficient and its evaluation. Thermodynamic formulation of CTST and limitations.

Unit-II Chemical Dynamics

Potential energy surfaces, Dynamics of Unimolecular reactions – Lindemann-Hinshelwood – Rice Ramsperger Kassel (RRK) theory and Rice Ramsperger Kassel - Marcus (RRKM) theory. Kinetics of chain reactions (H_2-Cl_2 and H_2-Br_2 reactions) using steady-state treatment.
Experimental methods for the study of fast reactions-flow and Shock methods-chemical relaxation methods, T-jump and P-jump methods, Molecular beam methods, Flash photolysis, Introduction to femto-chemistry.

Unit-III Chemical Kinetics and Catalysis

Heterogeneous catalysis: Unimolecular and bimolecular surface reactions, Inhibition effect, determination of activation energy, Bi-molecular surface Reaction-Langmuir-Hinshelwood and Langmuir-Rideal mechanism. Enzyme catalysis - Michelis-Menten equation, Effect of pH and temperature on enzyme catalysis.

Unit-IV Group Theory - Point Group and GOT

Point Group: Fundamentals Concept of Symmetry, Matrix representation of symmetry operations. Concepts of groups, molecular point groups, representation of groups, matrix representation of symmetry operations, reducible and irreducible representations, symmetry criterion of optical activity, symmetry restrictions on dipole moment.
Great Orthogonality Theorem: Interpretation of character tables, determination of symmetry species for translations and rotations. Transition moment integral, vanishing of integrals, symmetry aspects of molecular vibrations, vibrations of polyatomic molecules.

Unit-V Applications of Group theory in Chemistry

Applications in spectroscopy: IR spectra- Selection rules for vibrational absorption - Symmetry of normal modes of H_2O, C_2H_4, trans-N_2F_2, $CHCl_3$and NH_3 using Cartesian coordinates and internal coordinates, IR activity. Raman Spectra: Complementary of IR and Raman spectra-

determination of the Raman active vibrational modes. Electronic spectra: Selection rules for electronic transition, electronic transitions of simple molecules.
Applications in chemical bonding: Transformation of atomic orbitals: Symmetry adapted linear combinations (SALC), Construction of hybrid orbitals for AB_3(planar), AB_4(Td), AB_5(D_3h) and AB_6(Oh) type of molecules. Ligand field theory: splitting of d orbitals in different environments using group theoretical considerations. MO diagram for water and ammonia, method of descending symmetry

Reference Books

1. W. J. Moore and R. G. Pearson, Kinetics and Mechanism, Wiley, New York, 1988.
2. F. Daniels and R. A. Alberty, Physical Chemistry, 8h Edition, Wiley, New York, 1994.
3. P. W. Atkins, Physical Chemistry 8th Edn., Wiley, New York, 2006.
4. J. Rajaram, J.C. Kuriakose, Kinetics and Mechanisms of Chemical Transformations, Macmillan India, 2000.
5. K. J. Laidler, Chemical kinetics, 3rd Edn. Harper & Row, 1987.
6. C. Kalidas, Chemical Kinetic Methods: Principles of Fast Reaction Techniques and Applications, New Age International, 2005.
7. D.A. McQuarrie, J. D. Simon, Physical chemistry: A Molecular Approach, University Science Books,1997.
8. F. A. Cotton: Chemical Applications of Group Theory, Wiley Eastern, 1985.
9. P. K Ghosh and P. K Shukla: Atomic Electronic Structure, Prentice Hall of India,1994.
10. V. Ramakrishnan and M. S. Gopinathan: Group Theory in chemistry, Vishal Publication, 1986.
11. D. M. Bishop, Group theory and Chemistry, Dover, 1989.
12. B. S. Garg, Chemical Applications of Molecular Symmetry and Group Theory, Macmillan Publishers India Ltd, 2012

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	1	1	2	1
2	2	1	3	2	1
3	3	1	3	2	1
4	3	1	3	2	1

Semester: VII **Course Type: Theory** **Course Code: CHE1074**
Credit: 4 **Course Title: Physical Methods in Chemistry-I**

Course Outcomes		Level
CO-1	Demonstrate the utility of UV-visible, IR and fluorescence spectroscopy in structural characterization	**Apply**
CO-2	Elucidate the structure of organic compounds based on ^{1}H and ^{13}C NMR spectroscopy	**Evaluate**
CO-3	Explicate the applications of two-dimensional NMR spectroscopic techniques for structural elucidation	**Understand**
CO-4	Identify the fragmentation patterns of compounds and solve the structure of compounds using mass spectrometry	**Evaluate**
CO-5	Structural elucidation of unknown compounds using UV-vis, IR, Mass and NMR techniques	**Apply**

Unit-I UV-Visible, Fluorescence Spectroscopy and ORD-CD
Basics of UV Spectroscopy, factors governing absorption maximum and intensity. Woodward Fieser and Fieser-Kuhn's rules - calculation of λ_{max} for simple organic molecules. Fluorescence - principles Stokes shift, quantum yield and application.
ORD-CD: Circular bireferegence, optical rotary dispersion, circular dichroism – Cotton effect curves – octant rule –axial haloketone rule - Applications of chiroptical properties in configurational assignments.

Unit-II Infra-Red Spectroscopy
Principle, instrumentation and sampling technique- Hook's law, vibrational frequency, modes of vibrations, and selection rules. Factors influencing vibrational frequency. Fingerprint and functional group region. Interpretation of the IR spectra of alkane, alkenes, alkynes, aromatic compounds, alcohols, ethers, phenol, carbonyl compounds, amines and heterocyclics– related problems

Unit-III NMR Spectroscopy-I
^{1}H NMR, Spectral parameters –chemical shift & factors affecting chemical shift, intensity (integration), multiplicity, types of coupling & coupling constant. Analysis of first order and second – order spectra – shift reagents - structure determination of organic compounds by ^{1}H NMR spectra. Spin-spin coupling involving different nuclei (^{1}H, ^{19}F, ^{31}P, ^{13}C). Examples for different spin systems (AB, AX, AMX, AA'BB', ABX) – Nuclear Overhauser Effect, Effect of quadrupolar nuclei (^{2}H, ^{10}B, ^{11}B) on the ^{1}H NMR spectra, – study of fluxional behavior of molecules.

Unit-IV NMR Spectroscopy-II
^{13}C NMR: chemical shift & factors affecting chemical shift, Proton coupled; off–resonance decoupled; proton decoupled ^{13}C NMR spectra, DEPT techniques. Assignment of chemical shifts, additive effect, characteristic chemical shifts of common organic compounds and functional groups.

NMR of paramagnetic molecules – isotropic shifts, contact and pseudo-contact interactions – An elementary treatment of second order spectra – examples.
2D NMR techniques: H,H-COSY, C,H-COSY, HMBC, NOESY and INADEQUATE.

Unit-V Mass spectrometry

Instrumentation – methods of ionisation - EI, CI, APCI, ESI, MALDI and FAB. HRMS- Mass analyser – magnetic and electrostatic sector, time of flight and quadrupole. Molecular ion, base peak, multicharged ion, metastable ions and isotope ratio. Fragmentation patterns of saturated, unsaturated and aromatic hydrocarbons, alcohols, phenols, aldehydes, ketones, carboxylic acids, esters, amines, nitro, nitrile and halides. McLafferty rearrangement.

Structural elucidation using UV-Visible, IR, Mass, ^{1}H, ^{13}C NMR and 2D-NMR techniques

Reference Books:

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CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	3	1	2	2	2
2	3	1	2	2	2
3	3	1	2	2	2
4	3	1	2	2	2
5	3	1	2	2	2

Semester: VII **Course Type: Practical** **Course Code: CHE1075**
Credit: 4 **Course Title: Organic Chemistry Laboratory-IV**

Course Outcomes		Level
CO-1	Acquire the knowledge of multistep organic synthesis in microwave assisted synthesis and photochemical reactions	**Understand**
CO-2	Organize experiments based on the organic preparations and qualitative analysis	**Analyze**
CO-3	Use knowledge of the purification techniques	**Apply**
CO-4	Report separation of two mixture present in the organic compounds	**Understand**
CO-5	Support on estimation of organic compounds *viz* volumetric methods	**Evaluate**

Multistep organic synthesis (any four) - conventional synthesis - microwave assisted synthesis - photochemical reactions. Purification of the compounds using column chromatography and characterization of the compounds using spectroscopic techniques.
Qualitative Analysis: Separation and analysis of organic mixture containing two components.
Estimation of Organic Compounds

(a) Estimation of phenol and aniline - volumetric method.
(b) Estimation of glucose by Betrands method.
(c) Estimation of methyl ketone – iodimetric method
(d) Determination of iodine and saponification value of an oil sample.

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CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	3	3	3	3
2	2	3	3	3	3
3	2	3	3	3	3
4	2	3	3	3	3
5	2	3	3	3	3

Semester: VIII **Course Type: Theory** **Course Code: CHE1081**
Credit: 4 **Course Title: Inorganic Chemistry-V**

Course Outcomes		Level
CO-1	Gain knowledge on structure and bonding in organometallic compounds	**Knowledge**
CO-2	Apply organometallic chemistry principles in catalysis	**Apply**
CO-3	Gain knowledge in bioinorganic chemistry and role of metals in biology	**Remember**
CO-4	Grasp the basics of metalloenzymes and related assessment	**Remember**
CO-5	Understand mechanistic aspects of organometallic chemistry and bio-inorganic chemistry	**Understand**

Unit-I Structure and bonding in organometallics

Introduction, nomenclature, types of compounds (ionic/covalent), bond energies and stabilities, ligands and classification-σ-donors, π-donors and σ-donors and π-acceptors, reactivity and trends, metal-carbon bonds of main group metals, structure and bonding in organolithium compounds - metal-carbon bonds of transition metals, trends and properties - 16/18-Electron rule – preparation, structure and bonding of metal carbonyls, alkyls, alkenes, alkynes, aryls, hydrides, dihydrogen and dinitrogen complexes – metallocenes: synthesis and properties, ferrocene - structure and bonding, fluxional molecules. σ–bonded ligands:structure, reactivity and bonding of metal phosphines and nitrosyls – bridging, terminal, bent and linear - Fischer carbenes, Schrock carbenes, carbynes, isolobal analogy, metal-metal bonds, transition metal clusters and quintuple bond.

Unit-II Reaction mechanisms and catalysis

Important types of reactions of organometallic compounds: substitution, electrophilic and nucleophilic attack on ligands, carbonylation and decarbonylation, oxidative addition, reductive elimination, insertion, hydride elimination, abstraction, transmetallation. Catalytic applications: hydrogenation of olefins, hydroformylation, Reppe reaction, Wacker process, Monsanto acetic acid synthesis, hydrosilylation, Ziegler-Natta polymerisation, cyclo-oligomerisation, isomerization, olefin metathesis, Fischer-Tropsch process, and CH functionalization reactions.

Unit-III Transport and storage of Metal ions in Biology

A brief introduction to bioinorganic chemistry - Transport and storage of metals: Mechanism – Fe, Cu, Zn and V storage and transport – metallothioeins. Basics of Biomineralization. Sodium and potassium ion pumps - mechanisms of ion-transport across cell membranes – bleomycin - siderophores (e.g.enterobactin and desferrioxamine) -transport of iron by transferring - storage of iron by ferritin - biochemistry of calcium as hormonal messenger - Role of Ca^{2+} in blood clotting.

Unit-IV Metalloproteins and Metalloenzymes-I

Introduction and classification of metalloproteins and metalloenzymes - enzyme, cofactor, coenzyme, prosthetic group, holoenzyme, and apoenzyme. Dioxygen transport and storage – structure and functions of hemoglobin and myoglobin - Bohr Effect, importance of 2,3-diphosphoglycerate, CO poisoning, hematin formation, sickle cell anemia, and blue baby syndrome - hemerythrin and hemocyanine.– Electron transfer proteins: – Cytochrome a, b, c, cytochrome c oxidase - Iron-sulphur proteins (Ferredoxins, Rubredoxin and Rieske‟s protein) - Classification of copper proteins and examples: blue copper proteins (azurin and plastocyanin). Vitamin B_{12} and B_{12} co-enzyme.

Unit-V Metalloproteins and Metalloenzymes-II

Dioxygen activating enzymes: cytochrome P-450, methane monooxygenases (sMMO, pMMO), catechol dioxygenases, tyrosinase, and galactose oxidase. Protective Metalloenzymes: superoxide dismutase (Fe-SOD, Mn-SOD, Cu-Zn couple SOD and Ni-SOD), catalase, and peroxidases. Non-redox metalloenzyme: carboxypeptidase, carbonic anhydrase, and alcohol dehydrogenase. Bioenergetics and ATP Cycle: Glycolysis (glucose to pyruvate conversion) and glucose storage, oxidative oxidative phosphorylation, cyanide poisoning, chlorophylls, photosystems I and II in cleavage of water, involvement of oxygen evolving complex in oxidation of water to O_2. Nickel and Molybdenum containing Enzymes: Xanthine oxidase, aldehyde oxidase, urease, hydrogenases, biological nitrogen fixation using molybdenum nitrogenase.

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CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	1	2	1	2
2	1	2	1	2	1
3	3	3	3	3	3
4	2	4	2	4	2
5	2	5	2	5	2

Semester: VIII **Course Type: Theory** **Course Code: CHE1082**
Credit: 4 **Course Title: Organic Chemistry-V**

Course Outcomes		Level
CO-1	Synthesize organic compounds based on light mediated route	**Understand**
CO-2	Compare the concepts of pericyclic reaction mechanism for thermal and photochemical reactions	**Remember**
CO-3	Demonstrate the detailed mechanism of various name reactions deals with C-C, C-N and C-O bond formation	**Apply**
CO-4	Make a reaction chart on oxidizing reagents and how to apply in the chemical world and research aspects	**Apply**
CO-4	Demonstrate the use of reducing reagents in the synthetic organic chemistry	**Understand**

Unit-I Organic photochemistry

Thermal vs photochemical reactions. Photochemistry of alkenes, dienes, polyenes and carbonyl compounds. Norrish type I and type II, and Patterno–Buchi reactions. Intramolecular reactions of carbonyl compounds, saturated cyclic and acyclic compounds, α,β and β,γ- unsaturated compounds, cyclohexanone and cyclohexadienones Photochemical rearrangement: di- □-methane, oxa/aza di-□-methane, Photo-Fries, Lumiketone and Barton rearrangement. Intermolecular cycloaddition reactions and dimerisation. Photochemistry of aromatic compounds - isomerizations, additions, substitutions oxidation and reduction.

Unit-II Pericyclic Reactions

Molecular orbitals and symmetry of polyenes- Frontier orbitals of ethylene, 1,3-butadiene, 1,3,5-hexatriene and allyl systems. Classification of pericyclic reactions. Electrocyclic reactions: Conrotation and disrotation in 4n, 4n+2, allyl systems. Cycloaddition reactions: Effect of stereochemistry (cis and endo rules) and substituents on the rate of cycloadditions. analysis of electrocyclic and cycloaddition reactions: FMO and Woodward-Hoffmann correlation diagrams methods. 1,3-Dipolar cycloadditions and cheleotropic reactions. Sigmatropic rearrangements - [1,2]-sigmatropic shifts involving carbon moieties. [m,n] and [m,m] sigmatropic rearrangements. Claisen, Cope and Sommelet Hauser reactions.

Unit-III C-C, C-N, and C-O/S bond formation

C-C bond formation: Aldol, Arndt-Eistert, Bardhan-Sengupta, Barbier, Baylis-Hillman, Benzoin, Michael, Perkin, Robinson annulations, Vilsmeier, and Ullmann Reactions. C-N bond formation: Mannich, Mitsunobu, Ritter, Ugi, Doebner, Buchwald-Hartwig, and Stork enamine reactions. Formation of azides and hydrazines. C-O and C-S bond formation –Fischer esterification, Williamson's ether synthesis, Prins, Darzen, and Mitsunobu reactions.

Unit-IV Oxidation

Alkenes to diols: $KMnO_4$, OsO_4, Prevost oxidation and Woodward modifications. Oxidative cleavage of 1,2-diols - periodic acid, LTA. Alkenes to epoxides: using hydroperoxides and peroxyacids, Sharpless asymmetric epoxidation and dihydroxylation. Oxidation of allylic and benzylic compounds: DDQ, chloranil, SeO_2, NBS. Alkenes to carbonyl compounds: ozonolysis.

Alcohols to carbonyl compounds: chromium reagents ($K_2Cr_2O_7$, Jones, Sarrett's, Collins, PCC, PDC), MnO_2 and $Al(iPrO)_3$. Non-metal based reagents: dimethyl sulfoxide and its variants - Swern oxidation, Moffatt's oxidation (DCC) and Corey-Kim oxidations, hypervalent iodine oxidants (IBX, DMP)

Unit-V Reduction

Nucleophilic metal hydrides: LAH, Red-Al, DIBAL-H, NaBH4, Sodium cyanoborohydride, metal trialkylborohydrides. Electrophilic metal hydrides: BH_3 and AlH_3. Electron transfer reducing reagents: Li/Na in liquid NH3 or alcohol, tri-n-butyl tin hydride. Non-metallic reducing reagents: diimides, Hantzsch ester, Wolf-Kishner reduction. Radical based reductions: tri-n-butyl tin hydride. Catalytic hydrogenation: heterogeneous - Pd/C, homogeneous - Wilinsons hydrogenation, Knowels asymmetric hydrogenation.

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CO	Program Outcomes				
	1	2	3	4	5
1	3	1	3	3	2
2	3	1	3	3	2
3	3	1	3	3	1
4	3	1	3	3	1
5	3	1	3	3	1

Semester: VIII **Course Type: Theory** **Course Code: CHE1083**
Credit: 4 **Course Title: Physical Chemistry-V**

Course Outcomes		Level
CO-1	Apply the advanced quantum chemical methods for solving many-electron systems	**Apply**
CO-2	Solve Schrodinger equation for the simple molecules using perturbation, variation and HF methods	**Create**
CO-3	Demonstrate the applications of LCAO theory and direct bonding in polyatomic molecules	**Apply**
CO-4	Understand pulse sequences in magnetic resonance spectroscopy and apply advanced spectroscopy techniques in the experiments	**Understand**

Unit-I Quantum Chemistry-II

Potential energy of hydrogen-like systems: Wave functions and energy of hydrogen like atoms. angular-radial functions - and their plots. The postulate of spin by Uhlenbeck and Goudsmith-Spin orbitals- Construction of spin orbitals from spin functions. Quantization of angular momentum, quantum mechanical operators corresponding to angular momenta (Lx, Ly, Lz and L^2), commutation relations between these operators. Spherical harmonics as Eigen functions of angular momentum operators Lz and L^2. Ladder operator method for angular momentum. Space quantization. Schrödinger equation for many electron atoms: Helium and Lithium atoms.

Unit-II Approximation Methods

Born-Oppenheimer approximation, Perturbation theory, Variational methods, Hartree-Fock equations, Self-consistent field method for solving Hartree-Fock equations, Anti-symmetric wave function, Slater determinant wave function, Molecular Hamiltonian operators.

Valence bond treatment for chemical bonding in molecules - molecular orbitals, Molecular orbital theory for different diatomic molecular systems, photoelectron spectra, SCF-LCAO-MO wave function. Electronic states of diatomic molecules -sp, sp^2 and sp^3 hybrid orbitals. Molecular term symbols, Hückel molecular orbitals, bonding in polyatomic molecules.

Unit-III EMR and Origin of spectra

Nature of EMR, Interaction of EMR with matter, Natural line width and intensity of spectral lines, Classical and quantum chemical approach to absorption of radiation by molecules. Energy levels in molecules. Born Oppenheimer approximation, Population of energy levels. LASER – three & four level

Unit-IV Optical Spectroscopy-III

Microwave spectroscopy: Molecular classification and Rotation spectra, Diatomic and polyatomic molecules. Application of Rotation spectra (Bond length, Isotopic mass, dipole moment, isotopic abundance), Non-rigidity of rotor.

Vibrational spectroscopy: Vibrational spectra of diatomics & SHO; anharmonicity & Morse potential; Vibration-rotational spectra of diatomics, polyatomic Molecules-P, Q&R branches, Dispersive IR & FTIR, Vibration spectra of polyatomic molecules. Normal modes of vibrations of polyatomic molecules, Coupling of rotation and vibration, Parallel and perpendicular bands, Breakdown of Born-Oppenheimer Approximation,

Unit-V Optical Spectroscopy-IV

Raman Spectroscopy: Polarizability and classical theory of Raman spectrum, Rotational Raman spectra. Vibrational Raman spectra, mutual exclusion principle, Surface enhanced Raman spectra, Resonance Raman,

Electronic Spectroscopy: Electronic energy states of molecules. Vibrational structure of electronic bands, Electronic transitions and absorption bands, Selection rules. Electron spectroscopy for chemical analysis (ESCA)-UPS, X-ray photoelectron spectroscopy (XPS), Auger electron spectroscopy (AES), Inductively coupled plasma mass spectrometry (ICP-MS)

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CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	2	3	2	2
2	3	2	3	2	2
3	3	2	3	2	2
4	2	2	3	2	2

Semester: VIII **Course Type: Theory** **Course Code: CHE1084**
Credit: 4 **Course Title: Physical Methods in Chemistry-II**

Course Outcomes		Level
CO-1	Acquire knowledge on advanced concepts in spectroscopy thereby being able to interpret the spectra and solve the structure of metal complexes	**Remember**
CO-2	Discuss the application of electronic spectroscopy to simple coordination compounds and f-block elements	**Understand**
CO-3	Elucidate the structure of simple organometallic complexes by IR and Raman spectroscopic tools	**Apply**
CO-4	Determine the geometry of inorganic complexes using EPR spectroscopy	**Analyze**
CO-5	Depict the advanced spectroscopic tools like NMR, Mossbauer and NQR and its exploitation to express the structure of inorganic complexes	**Evaluate**

Unit-I Electronic Spectroscopy

Microstates, - terms and energy levels for d^1 - d^9 ions in cubic and square fields – Intensity of bands – group theoretical approach to selection rules - Effect of distortion and spin-orbit coupling on spectra- Orgel and Tanabe-Sugano diagrams – Evaluation of 10Dq and β for octahedral complexes of cobalt and nickel – applications to simple coordination compounds – charge transfer spectra – electronic spectra of $[Ru(bipy)_3]^{2+}$. Electronic Spectra of f-block elements.

Optical rotatory dispersion, circular dichroism and Magnetic circular dichroism – applications to metal complexes.

Unit-II Infrared and Raman Spectroscopy

IR spectroscopy- Introduction, selection rules, stretching frequency of some inorganic ions- effect of coordination on the stretching frequency- sulphato, carbonato, sulphito, aqua, nitro, thiocyanato, cyano, thiourea, DMSO complexes. Effect of isotopic substitution on the vibrational spectra of molecules – vibrational spectra of metal carbonyls with reference to the nature of bonding, geometry and number of C-O stretching vibrations, Raman spectroscopy – Introduction, combined applications of IR and Raman spectroscopy in the structural elucidation of N_2O, ClF_3, NO^{3-}, ClO_4, metal carbonyls.

Unit-III NMR spectroscopy

Introduction to hetero-nuclear NMR, Factors influencing coupling constant (gyromagnetic ratio, periodicity, hybridisation, s-character, electronegativity, coordination number, trans influence, inter-bond angles, lone-pair and oxidation state) - structural assessment of simple inorganic compounds using ^{1}H, ^{13}C, ^{15}N, ^{19}F, ^{31}P-NMR spectroscopic techniques – Studies on fluxional molecules, quadrupolar nuclei-effect in NMR spectroscopy, shift reagents and applications. Overview of ^{13}C NMR of metal carbonyls, ^{119}Sn, ^{195}Pt, and other nuclei NMR and satellite spectra.

Unit-IV EPR spectroscopy

Theory of EPR spectroscopy - Spin densities and McConnell relationship – Factors affecting the magnitude of g and A tensor in metal species - Zero-field splitting and Kramers degeneracy – Spectra of VO(II), Mn(II), Fe(II), Co(II), Ni(II) and Cu(II) complexes – Applications of EPR to a few biological molecules containing Cu(II) and Fe(III) ions.

Unit V NQR and Mössbauer Spectroscopies NQR spectroscopy - Characteristics of quadrupolar nucleus – effects of field gradient and magnetic field upon quadrupolar energy levels – NQR transitions – applications of NQR spectroscopy. Mössbauer spectroscopy - Isomer shifts – Magnetic interactions – Mossbauer emission spectroscopy – applications to iron and tin compounds.

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CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	2	2	2	1
2	2	2	2	2	2
3	3	2	3	2	2
4	3	2	3	2	2
5	2	1	3	1	2

Semester: VIII **Course Type: Practical** **Course Code: CHE1085**
Credit: 4 **Course Title: Physical Chemistry Laboratory-IV**

Course Outcomes		Level
CO-1	Understand the instrumentation methods involved in the experiments	**Understand**
CO-2	Perform or develop working models	**Create**
CO-3	Gain the required experimental skills for career development	**Create**
CO-4	Apply QM methods for modeling simple organic/inorganic compounds for structural optimization and reaction modeling	**Apply**

Part A: List of Wet Lab Chemistry (Any 10-12 Experiments)

1. *Surface Chemistry*
   (a) Verification of adsorption isotherms (Freundlich and Langmuir): charcoal-acetic acid or charcoal-oxalic acid system.
   (b) Kinetics & Determination of surface area by adsorption of acetic acid on Charcoal.
2. *Phase Diagram*
   (a) Determination of the concentration of the electrolyte using CST of phenol-water system.
   (b) Three Component Liquid Systems: Acetic Acid – Chloroform – Water
3. *Partition Coefficient*
   (a) Partition coefficient of benzoic acid between benzene and water.
   (b) Molecular formula of copper-ammonia complex by the partition coefficient method.
4. *Spectroscopy*
   (a) Formation kinetics of Chromium-EDTA complex (Spectrometry).
   (b) Simultaneous Estimation of Manganese and Chromium in a Solution of Dichromate and Permanganate Mixture.
   (c) Photocalorimetric determination of Bimolecular rate constant.
5. *Surface Tension*
   (a) Determine the surface excess of amyl alcohol.
6. *Potentiometry*
   (a) Titration of a strong and weak Acid Mixture with a Strong Base-Potentiometry.
   (b) Determination of stability constant of silver diammine complex by potentiometric titrations.
   (c) Dissociation of a weak acid by potentiometric titration.
7. *Conductometry*
   (a) Verification of Ostwald's dilution law and determination of dissociation constant of weak acid.
   (b) Conductometric titrations of a mixture of acids Vs strong base.
   (c) Van't Hoff's factor of benzoic acid between benzene and water.
   (d) Critical Micelle concentration of surfactant by conductivity measurements.
   (e) Verification of Onsager's Equation and Determination of Equivalent Conductance at Infinite Dilution of Strong Electrolytes.
   (f) Conductometric determination of Nickel using DMG.

8. *Kinetics*
   (a) Second order rate constant for the alkaline hydrolysis of ethyl acetate by conductivity measurements.
   (b) Arrhenius parameters for the Acid–Catalysed Hydrolysis of Methyl acetate.
9. *Viscometry*

(a) Determination of molecular weight of a polymer by viscosity measurements.

10. *Additional*

(a) Specific and molar refraction of a liquid by Refractometry.

(b) Reversibility of a redox process and determination of concentration of a given solution by cyclic voltammetry.

(c) Inversion of Sucrose-Polarimeter.

Part B: List of Computational Chemistry Experiments (Any 3-4 Experiments)

1. Calculation of electrostatic charges of atoms in organic molecules using population analysis.
2. Calculation of Resonance energy of aromatic compounds.
3. Calculation of dimerization energy of carboxylic acids.
4. Perform the conformational analysis of butane using potential energy scan.
5. Find the transition state of simple organic reactions and plot the reaction profile.
6. Determination of heat of hydration of organic molecules.
7. Find the Gibbs free energy of simple gaseous phase reactions and calculate equilibrium constant.
8. Calculation of pKa of simple organic molecules and compare it with experimental values.
9. Docking studies involving protein ligand interactions.
10. Calculation of electrophilicity index in hard-soft acids and bases.

Reference Books:

1. J. B. Yadav, Advanced Practical Physical Chemistry, Goel Publishing House, 2001.
2. G.W. Garland, J. W. Nibler, D.P. Shoemaker, Experiments in Physical Chemistry, 8thEdn. McGraw Hill, 2009.
3. B. Viswanathan, Practical Physical chemistry, Viva Pub., 2005.
4. S. Kumar and N. Kumar, Physical Chemistry Practical, New Central Book Agency,2012.
5. A.M. James, F.E. Prichard, Practical Physical Chemistry Paperback, 1974.
6. J. Foresman and A. Frisch, Exploring Chemistry with Electronic Structure Methods, Gaussian Inc., 2000.
7. D.C. Young, Computational Chemistry: A Practical Guide for Applying Techniques to Real World Problems, John Wiley & Sons, 2001.
8. D. Rogers Computational Chemistry Using the PC, 3rdEdn, John Wiley & Sons,2003.
9. A.R. Leach, Molecular Modelling: Principles and Applications, 2ndEdn, Longman, 2001.
10. J. M. Haile, Molecular Dynamics Simulation: Elementary Methods, 2001.

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	2	2	2	3	3
2	3	3	3	3	3
3	3	3	3	3	3
4	3	3	3	3	3

Semester: IX **Course Type: Theory** **Course Code: CHE1091**
Credit: 4 **Course Title: Inorganic Chemistry-VI**

Course Outcomes		Level
CO-1	Gain knowledge on magnetic materials and its properties	**Knowledge**
CO-2	Understand the photochemistry of inorganic complexes	**Understand**
CO-3	Apply nuclear chemistry principles in various fields	**Apply**
CO-4	Grasp the importance of metals in medicine	**Remember**
CO-5	Gain knowledge on frontier areas of inorganic chemistry	**Knowledge**

UNIT – I Magnetic material and its properties

Types of magnetism – Dia –para – ferro and antiferro magnetism. Magnetic properties of free ions –Zeeman effect. Determination of Magnetic moments and their applications to the elucidation of structures of inorganic compounds – quenching of orbital momentum in transition metal complexes - temperature dependent and temperature independent paramagnetism - Spin crossover in coordination compounds. Magnetic properties of lanthanides and actinides.

UNIT–II Inorganic Photochemistry

Elementary ideas on the photosystems I and II - Photochemistry of Cr(III), Co(III), Ru(II), Pt(II) and Pt(IV) complexes – photoaquation – photoanation – photoisomerisation – photo redox reactions – charge transfer photochemistry – photosensitisation – solar energy conversion – photogalvanic cell – water splitting.

Unit-III Nuclear chemistry and its Applications

Natural radioactivity – Detection and measurement of radioactivity: Geiger Muller and ionization counters. Radioactive series including neptunium series – group displacement law – Rate of disintegration and half-life period – Average life period. Artificial radioactivity – induced radioactivity – uses of radioisotopes – hazards of radiations – nuclear energy – nuclear reactors – nuclear fission and fusion – product yields – Spallation – photonuclear and thermo nuclear reactions – energy source of the sun and stars – carbon dating – rock dating. radioactive waste disposal – applications of nuclear science in agriculture – Atomic power projects in India. Nuclear medicine- Single Proton Emission Tomography (SPECT) and Positron Emission Tomography (PET).

Unit-IV Metals in Medicine

Bioinorganic Chemistry of quintessentially toxic metals. Lead, Cadmium, Mercury, Aluminum, Chromium, Iron, Copper, Plutonium. Detoxification by metal chelation. Metals in medicine: Anti-arthritis drugs – Au in rheumatoid arthritis – Li in psychiatry. Metal based anti-cancer agents: Introduction to cancer and treatment - conventional drugs-platinum, titanium, ruthenium and other metal based drugs - evolution of cisplatin - mechanism - advantages and disadvantages of Pt based drugs. MRI imaging: Principles of MRI - development of MRI contrasting agents - types of contrasting agents - Gadolinium and other transition complexes.

Unit V Introduction to frontier topics in inorganic chemistry

Energy storage materials –Li ion battery, hydrides and hydrogen storage materials – challenges. d-block metal oxides: transparent conducting oxide and applications: ITO, FTO, DSCs, solid state LEDs, OLEDs. Superconductors: origin, theory, high temperature superconductors,

materials, applications – Molecular materials - fullerides– one-dimensional metals, molecular magnets, spintronic, inorganic liquid crystals – materials and applications. Inorganic fibers: boron, carbon and silicon fibers and applications. Nanomaterials: fundamentals, characterisation methods and fabrication, self-assembled nanostructures. Bio-inorganic nanomaterials: DNA and nanomaterials. Biomimetic – natural and artificial nanomaterials, bio-nanocomposites.

Reference Books

1. A. Earnshaw, Introduction to Magnetochemistry, Academic Press, 1968.
2. R. Dutta, Syamal, Elements of Magnetochemistry East-West Press 2010. (Unit I)
3. P. W. Atkins and J. Paula, Physical Chemistry, Oxford Publications, 8th edition, 2009.
4. J. E. Huheey, E. A. Keiter, R. L. Keiter and O. K.Medhi, Inorganic Chemistry - Principles of Structure and Reactivity, 4th edition, Pearson Education, 2006.
5. K. F. Purcell and, J. C. Kotz, Inorganic Chemistry, Cengage Learning, 2012.
6. A. W. Adamson, P. D. Fleischauer, Concepts of Inorganic Photochemistry, Wiley, 1975.
7. D. Bahnemann, A. O. T. Patrocinio, Springer Handbook of Inorganic Photochemistry, Springer Cham, 2022.
8. V. Ramamurthy, S. S. Kirk, Organic and Inorganic Photochemistry, Vol, 2, Marcel Dekkar Inc., New York, 1998.
9. H. J. Arnikar, Essentials of Nuclear Chemistry, 4th edition, New Age International Publishers Ltd., New Delhi, 1995.
10. W. D. Loveland, D. J. Morrissey and G. T. Seaborg, Modern Nuclear Chemistry, Wiley VCH Verlag GmbH Co. KGaA, 2006.
11. Glasstone, Source Book on Atomic Energy, 3rd edition, Affiliated East West Press, 1979.
12. G. R. Choppin, J-O Liljenzin, J. Rydberg, C. Ekberg, Radio Chemistry and Nuclear Chemistry 2016. (Unit II).
13. A. K. Das, Bioinorganic Chemistry, Books and Allied Ltd. Kolkatta, 2016. (Units I-III).
14. Nicholas P. F. Uses of Inorganic Chemistry in Medicine, The Royal Society of Chemistry 1999.
15. J. C. Dabrowiak, Metals in Medicine, 2nd Edition., John Wiley & Sons Ltd., 2017.
16. C. E. Housecraft and A.G. Sharpe, Inorganic Chemistry, 4th edition, Pearson, 2012.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	2	2	1	3
2	2	2	2	2	2
3	2	2	3	2	2
4	1	2	2	2	2
5	2	1	2	1	2

Semester: IX **Course Type: Theory** **Course Code: CHE1092**
Credit: 4 **Course Title: Organic Chemistry-VI**

Course Outcomes		Level
CO-1	Illustrate the application of organometallic reagents and coupling reactions in the field of synthetic organic chemistry	**Understand**
CO-2	Demonstrate synthetic route for various compounds through functional group interconversion	**Remember**
CO-3	Construct synthetic routes to achieve any given target molecules through retrosynthetic analysis	**Apply**
CO-4	Exemplify the significances of rearrangement transformations in organic synthesis	**Apply**
CO-5	Illustrate the stereochemistry structural features and biological importance of steroids and prostaglandins	**Understand**

Unit-I Organometallic reagents in organic synthesis: Main group organometallic reagents - organolithium, organomagnesium, organoboron, organosilicon, organotin. Organotransition metal reagents - organocobalt, organonickel, organoplatinum, organocopper, organozinc, organocadmium and organomercury in organic synthesis. Coupling Reactions: Tsuji-Trost, Heck, Kumada, Sonagashira, Negishi, Stille, Suzuki, Hiyama, Buchwald-Hartwig and Fukuyama coupling reactions.

Unit-II Synthetic Strategies-I: Functional Group Interconversions
Functional group interconversions, the importance of the order of events in organic synthesis, chemoselectivity, regioselectivity, and Umpolung concept. The concept of protection and deprotection of functional groups in synthesis. Protection of amino, hydroxy, diol, carbonyl and, double and triple bonds.

Unit-III Synthetic Strategies-II: Retrosynthesis
Disconnection Approach - synthons and synthetic equivalents, donor and acceptor synthons, disconnection, alternating polarity disconnection and steps in planning the synthesis. One and two groups C-X and C-C disconnections. disconnection of alcohols, olefins and ketones. Logical and illogical disconnections. Two group disconnection 1,2-, 1,3-, 1,4-, 1,5- and 1,6-dioxygenated skeletons and dicarbonyls. Retro Diels – Alder reactions- Wieland Mischer ketone synthesis- Retrosynthesis of 3, 4, 5, 6 membered carbo and heterocycles. Designing synthesis: Disconnection approach in Epothilone, Juvabione and longifolene.

Unit-IV Rearrangements in Organic Synthesis
Mechanistic aspects, nature of migration, migratory aptitude, stereochemical aspects and memory effects. Rearrangements of highly substituted glycols, substituted halides, alcohols, terpenes, 1,2-ketones, haloketones, diazo compounds, amides, azides, hydoxamic esters, nitrogen/phosphorus/sulfur ylides, oximes, peracids, peroxides, phosphorus ylides, 1,2-diphenylhydrazine, phenolic esters, allylaryl/vinyl ethers

Unit-V Steroids and Prostaglandins
Steroids: Classification of steroids, biological importance- structure, and stereochemistry of cholesterol, Structural features of bile acids – Sex hormones – androsterone, testosterone, estrone, estradiol, progesterone - Structure of ergosterol.

Prostaglandins (PG): Types of PG's prostaglandins. Functions of prostaglandins. Synthesis of prostaglandins E_2, prostacyclin (PGI_2). Structural features of prostaglandin D_2 (PGD_2) and prostaglandin $F_{2\alpha}$ ($PGF_{2\alpha}$).

Reference Books:

1. B. D. Gupta, Basic Organometallic Chemistry: Concepts, Syntheses and Applications, University Press, 2011
2. Robert H. Crabtree, The Organometallic Chemistry of the Transition Metals, Wiley, 2014
3. Norio Miyaura, S.L. Buchwald, Metal Catalyzed Cross-Coupling Reactions and More, 2003.
4. G. Denis Meakis, Functional Groups: Characteristics and Interconversions, Oxford Science Publications, 1996
5. Jie Jack Li, Name Reactions: A Collection of Detailed Mechanisms and Synthetic Applications, 5th Ed, Springer, 2014
6. Christian M. Rojas, Molecular Rearrangements in Organic Synthesis, John Wiley & Sons, Inc, 2015
7. S. Warren, P. Wyatt, Organic Synthesis: The Disconnection Approach, Wiley, 2008
8. P. Wyatt, S. Warren, Organic Synthesis: Strategy and Control, Wiley-Blackwell, 2007
9. R. O. C. Norman, J. M. Coxon, Principles of Organic Synthesis, 3rdedn, 1993
10. W. Carruthers, I. Coldham, Modern Methods of Organic Synthesis, 4thedn, Cambridge University Press, 2015
11. E. J. Corey, X. M. Cheng, The Logic of Chemical Synthesis, Wiley-India Private Ltd, 2011.
12. K. C. Nicolaou, E. J. Sorensen, Classics in Total Synthesis, Wiley-ECH, 1996
13. I. L. Finar, Organic Chemistry, Vol II, 6th Ed, Pearson Education, 2002.
14. R. T. Morrison, R. N. Boyd, Organic Chemistry, 7th Ed, Pearson Education, 2010.
15. J. Clayden, N. Greeves, S. Warren, Organic Chemistry, 2nd Ed, Oxford University Press, 2014.
16. Michael B. Smith, March's Advanced Organic Chemistry: Reactions, Mechanisms, and Structure, 8nd Ed., Wiley Publications, 2019
17. Graham Solomons, T. W. Fryhle, C. B. Snyder, S. A., Organic Chemistry, 12th Ed, Wiley, 2016.
18. J. E. McMurry, Fundamentals of Organic Chemistry, 7th Ed, Cengage Learning India Edition, 2013.
19. I. L. Finar, Organic Chemistry, Vol I, 6th Ed, Pearson Education, 2002.
20. P. Sykes, A Guidebook to Mechanism in Organic Chemistry, 6th Ed., Orient Longman, New Delhi, 1988.
21. Francis A. Carey and Richard J. Sundberg, Advanced Organic Chemistry, Part A: Structure and Mechanisms, Springer, 5th Ed. 2007
22. Daniel E. Levy, Arrow Pushing in Organic Chemistry-An easy approach to understanding reaction mechanisms, Wiley Publications, 2008
23. Robert B. Grossman, The Art of Writing Reasonable Organic Reaction Mechanisms, 2nd Ed, Springer, 2003
24. L. G. Wade, Organic Chemistry, 6th Ed. Pearson, 2006
25. Francis A. Carey, Robert M. Giuliano, Organic Chemistry, 8th Ed. 2008
26. Peter Vollhardt, Neil Schore, Organic Chemistry-Structure and Function, 6th Ed. W. H. Freeman and Company, 2011
27. Thomas H. Lowry, Kathleen Schueller Richardson, Mechanism and Theory in Organic Chemistry, Harper and Row Publishers

28. Edwin S. Gould, Mechanism and Structure in Organic Chemistry, Holt, Rinehart and Winston Publications, 1959

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	1	2	3	1
2	3	1	3	3	1
3	3	1	3	3	1
4	3	1	3	3	1
5	1	1	2	3	1

Semester: IX **Course Type: Theory** **Course Code: CHE1093**
Credit: 4 **Course Title: Physical Chemistry-VI**

Course Outcomes		Level
CO-1	Enrich the knowledge about the fundamental concepts of thermodynamics (classical/statistical) and electrochemistry	**Remember**
CO-2	Recognize the electrochemical ideas at equilibrium and dynamics progress	**Understand**
CO-3	Apply different statistical methods	**Apply**
CO-4	Identify the different types of fuel cells and discuss their merits and demerits	**Create**

Unit-I Classical Thermodynamics

Introduction: Laws of thermodynamics, Entropy- Free Energy-Systems of Variable Compositions - Fugacity and Activity- Fugacity determination (graphical method and van der Waals equation of state) –Variation of Fugacity with respect to Temperature and Pressure - Maxwell's relations – significance, Partial molar properties – Chemical potential. Concept of absolute entropy and residual entropy Thermodynamics of mixing: Thermodynamic functions of mixing, Clausius Inequality, Gibbs-Duhem-Margules equation, Konowaloff's rule, Henry's law, excess thermodynamic functions. Third law of thermodynamics: Nernst heat theorem, development of third law of thermodynamics, determination of absolute entropies using third law, entropy changes in chemical reactions. Thermodynamics of Irreversible Processes: Thermodynamics of irreversible processes with simple examples. phenomenological relations. Onsager reciprocal relations - principle of microscopic reversibility. Electrokinetic phenomena. Thermoelectric phenomena.

Unit-II Statistical Thermodynamics

Classical approach: Scope of statistical thermodynamics-probability theorem- starlings' approximation, phase space, microstate and macrostate, configuration, system, assembly and ensemble-different types of ensembles- permutations and combinations, thermodynamic probability, Maxwell-Boltzmann statistics and its limitations. Concept of partition functions and its relation with thermodynamic properties, evaluation of translational, rotational, vibrational and electronic partition functions. Sackur-Tetrode equation- thermodynamic properties of monoatomic gases. Quantum approach: Bose-Einstein Statistics, Bose-Einstein condensate, difference between first order and higher order phase transitions, liquid helium, supercooled liquids. Fermi-Dirac statistics- Application of Fermi-Dirac statistics to electron gas in metal and thermionic emission, Comparison of statistical models. Heat capacity of solids: Dulong - Petit law, Einstein's theory and its modification, Debye's theory of heat capacity of solids.

Unit-III Electrochemistry-II

Activity and Activity coefficient of electrolytes, Mean ionic activity coefficient. ionic strength, Debye Huckel theory of strong electrolytes, Debye Huckel theory-relaxation and electrophoretic effects, Debye-Huckel-Onsager equation and its derivation. Debye Falkenhagen effect. Wein effect. Ionic activity coefficients of strong electrolytes-Derivation of Debye-Huckel limiting law. Equilibrium Electrochemistry: EMF phenomena, cell potential and its measurement, reference electrodes. Electrochemical cells, concentration cells and activity coefficient determination, liquid junction potential. Determination of solubility. Redox indicators and redox titrations.

Unit-IV Electrochemistry-III

Dynamic Electrochemistry: Electrical double layer, various models of electrical double layer, Electrode polarization. Overpotential, hydrogen and oxygen overvoltage, theories of overvoltage, Butler-Volmer equation for simple electron transfer reactions, Tafel plot and its significance, Corrosion: stability of metals, Porbaus Diagram-Evan diagram-corrosion control and methods for prevention.

Unit-V Storage cells and Electroanalytical Techniques

Storage cells: Lead acid battery, lithium battery, nickel cadmium cell. Fuel Cell. Theory and working of fuel cell. H_2- O_2 fuel cell, methanol fuel cell, solid oxide fuel cells. Electroanalytical Techniques: Polarography – diffusion current, different current, supporting electrolyte, polarographic maxima, three electrode system. Amperometry – principles, types and applications. Cyclic voltammetry – principles, applications. Stripping voltammetry.

Reference Books

1. R.P. Rastogi, R.R. Mishra, An introduction to Chemical Thermodynamics, Vikas Publishing house, 2009.
2. J. Rajaram, J.C. Kuriakose, Chemical Thermodynamics: Classical, Statistical and Irreversible, 1stEdn, S Chand and Co., 1999.
3. M.C. Gupta, Statistical Thermodynamics, New age international, 2007.
4. L.K. Nash, Elements of Classical & Statistical Mechanics, 2ndEd. Addison Wesley, 1972.
5. F.W. Sears, G.L. Salinger, Thermodynamics, Kinetic Theory and Statistical Thermodynamics, Addison Wesley, 1975.
6. J. Kestin, J.R. Dorfman, A Course in Statistical Thermodynamics, Academic Press, 1971.
7. John E. Freund. Modern elementary statistics, 2003, ISBN-13: 978-0131874398 20.
8. S. P. Gupta, Statistical Methods: S. Chand, 2014.
9. J. Bockris and A.K.N. Reddy, Modern Electrochemistry, 2ndEd, Wiley, New York, 1998.
10. D.R. Crow, Principles and Applications of Electrochemistry, Chapman & Hall, 3rdEdn., New York, 1994.
11. S. Glasstone, Introduction to Electrochemistry, Biblio Bazar, 2011.
12. B.K. Sharma, Electrochemistry, Krishna Prakashan, 1985.
13. A.I. Vogel, A Textbook of Quantitative Analysis including Instrumental Analysis, John Wiley & Sons, 1961.
14. H.H. Willard, J.A. Dean, L.L. Merritt, Instrumental Methods of Analysis, 7th Ed., Van Nostrand, 1965.
15. A.J. Bard, L.R Faulkner, Electrochemical Methods-Fundamentals and applications, 2nd Edn., Wiley India Ed.2004

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	1	1	3	2	2
2	3	1	3	2	2
3	2	2	3	2	2
4	3	2	2	2	2

Semester: IX **Course Type: Practical** **Course Code: CHE1094**
Credit: 4 **Course Title: Inorganic Chemistry Laboratory-IV**

Course Outcomes		Level
CO-1	Identify the familiar and less familiar cations by semi-micro qualitative analysis	**Analyze**
CO-2	Ensures the students to acquire knowledge and have hands on experience in multistep inorganic compound synthesis and characterize them using spectroscopic techniques	**Skills**
CO-3	Apply the knowledge for performing experiment scientifically and safely to enrich the understanding about experiments in lab work	**Understand**
CO-4	Perform the preparation of inorganic complexes and purify them	**Apply**
CO-5	Gain knowledge on working principle of cyclic voltammetry and differential pulse voltammetry techniques and determine the electrochemical properties of complexes	**Knowledge**

I: Semi-micro qualitative analysis of a mixture containing two common and two rare – cations (any three salt mixtures)

II: Preparation of the following compounds and their Characterization (any seven experiments)

1. Tetraaminecopper(II) sulphate
2. Potassium trioxalatochromate(III)
3. Cis- and trans-potassium dioxalatediaquachromate(III)
4. Hexaamminenickel(II) chloride complex
5. Synthesis and study of Tris(oxalato)iron(III) potassium salt by Cyclic Voltammetry (CV) and Differential Pulse Voltammetry (DPV), and determination of the following: the formal reduction potential (Eo'); the number of electrons transferred in the redox process (n); electrochemical reversibility.
6. Synthesis and study of Mn^{III}(Salen)Cl by Cyclic Voltammetry and Differential Pulse Voltammetry (DPV), and determination of the following: the formal reduction potential (Eo'); the number of electrons transferred in the redox process (n); electrochemical reversibility.
7. Preparation and determination of the effective magnetic moment and number of unpaired electrons in $Mn(acac)_3$.
8. Preparation and determination of the aquation rate of $[Co(NH_3)_5Cl]Cl_2$.
9. Preparation and resolution of the optically active compound $[Co(en)_3]^{3+}$.
10. Control synthesis of copperoxalate hydrate complex; kinetic vs. thermodynamic factors
11. Bioanalytical techniques – Monitoring the cleavage of DNA and protein by metal complexes using Gel electrophoresis techniques – Agarose and PAGE (Demo only).

Reference Books:

1. J. Elias, A Collection of Interesting General Chemistry Experiments, Universities Press, Sangam Books Ltd, 2002.
2. J. D. Woollins, Inorganic experiments, 3rd edition, Wiley-VCH Verlag GmbH @ Co. KGaA, 2012.
3. M. Hein, J. N. Peisen and R. L. Miner, Foundations of College Chemistry in the Laboratory, John Wiley and Sons, 2011.
4. G. S. Girolami, T. B. Rauchfuss and R. J. Angelici, Synthesis and Technique in Inorganic Chemistry: A Laboratory Manual, 3rd edition, University Science Books, 1999.

5. W. L. Jolly, The Synthesis and Characterization of Inorganic Compounds, Prentice-Hall, Inc.1970.
6. In-house Laboratory Manual, Department of Chemistry, CUTN.
7. Ghoshal, Mahapatra and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.
8. G. Svehla, Vogel's Qualitative Inorganic Analysis, Pearson Education, 2012.
9. J. Mendham, Vogel's Quantitative Chemical Analysis, Pearson, 2009.
10. Ghoshal, Mahapatra and Nad, An Advanced Course in Practical Chemistry, New Central Book Agency, 2011.
11. V. Venkateswaran, R. Veerasamy A. R Kulandaivelu, Basic principles of Practical Chemistry, 2nd edition, New Delhi, Sultan Chand & sons, 2016.

CO	**Program Outcomes**				
	1	**2**	**3**	**4**	**5**
1	1	2	2	2	3
2	2	3	3	2	3
3	3	3	1	2	3
4	3	2	3	3	3
5	2	1	3	1	2

Semester: X **Course Type: Practical** **Course Code: CHE1101**
Credit: 4 **Course Title: Research Project**

Course Outcomes		Level
CO-1	Understanding the nature of research problems and identifying the related area of knowledge	**Understand**
CO-2	Analyze literature reports in order to identify the methodology to solve the research problem	**Apply**
CO-3	Analyze data and synthesize research findings	**Apply**
CO-4	Demonstrate capacity to lead and manage change through collaboration with others	**Apply**

The student shall pursue a research project for the whole semester under the allotted guide. The project report shall be submitted in the form of dissertation and the evaluation will be based on the performance in the lab and the final presentation of the research work done.

CO	Program Outcomes				
	1	**2**	**3**	**4**	**5**
1	2	2	2	2	2
2	3	3	3	3	3
3	3	3	3	3	3
4	3	3	3	3	3

List of Elective Courses

Course Code	Title of the Course	Credits
CHEE01	Principles of Polymer Science	4
CHEE02	Principles of Fluorescence Spectroscopy	4
CHEE03	Asymmetric Catalysis	4
CHEE04	Essentials of carbohydrate chemistry	4
CHEE05	Organic Electronics	4
CHEE06	Photochemistry in Molecules and Materials	4
CHEE07	Medicinal Inorganic Chemistry	4
CHEE08	Organic Semiconductors	4
CHEE09	Advances in Polymer Science	4
CHEE10	Advances in carbohydrate Research	4
CHEE11	Advanced Organic Materials & Catalysis	4
CHEE12	Chemistry of C-H Activation	4
CHEE13	Advanced Bioinorganic Chemistry	4
CHEE14	Principles of Biochemistry	4
CHEE15	Mathematics for Chemists and Biologists	4
CHEE16	Electrochemical Energy System	4
CHEE17	Fundamentals of Analytical Chemistry	4
CHEE18	Computational Chemistry	4
CHEE19	Supramolecular Chemistry	4
CHEE20	Computational Materials Modelling	4
CHEE21	Organometallics, Catalysis and Inorganic Spectroscopy	4
CHEE22	Physical Methods in Chemistry	4
CHEE23	Applications of Computational methods in Chemistry	4
CHEE24	Chemical Lab Safety and Management	4
CHEE25	Advances in Organic Chemistry	4
CHEE26	Green Chemistry	4
CHEE27	Selected Topics in Synthetic Organic Methods	4
CHEE28	Advanced Topics in Organometallic Chemistry	4
CHEE29	Industrial Chemistry	4
CHEE30	Advanced Organic Nanomaterials	4
CHEE31	Computer Software for Chemists	4
CHEE32	Selected Experiments in Applied Chemistry	4
CHEE33	Luminescence Spectroscopy for Advanced Research	4
CHEE34	Research Methodology	4
CHEE35	Chemistry in Nanoscience and Technology	4
CHEE36	Advanced NMR Techniques	4
CHEE37	Advanced Organic Synthesis	4
CHEE38	Nanoscience and Nanotechnology	4
CHEE39	Medicinal Chemistry	4
CHEE40	Introduction to Biochemistry	3
CHEE41	2D NMR Spectroscopy	2
CHEE42	Separation Techniques	2
CHEE43	Separation Techniques & 2D NMR Spectroscopy	4

*New electives will be appended based on the availability of course instructor.
Electives will be offered based on the individual faculty's availability

List of Skill Enhancement Courses

Course Code	Title of the Course	Credits
CHESE01	Computer software for Chemists	3
CHESE02	Selected Experiments in Applied Chemistry	3
CHESE03	Instrumentation Methods in Chemistry	3
CHESE04	Water & Waste Water Treatment	3
CHESE05	Pharmaceutical Chemistry	3

List of Value-Added Courses

Course Code	Title of the Course	Credits
CHEVA01	Instrumental Techniques for Chemical Analysis -01	2
CHEVA02	Instrumental Techniques for Chemical Analysis -02	2
CHEVA03	Basic Analytical Experiments	2
CHEVA04	Research Methodology and Publication Ethics	2
CHEVA05	Climate Change & Atmospheric Chemistry	2